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RESEARCH ARTICLE

Integrated AHP-TOPSIS framework for fodder pellet evaluation with fibre-digestibility correlation analysis

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Abstract

Pelleted feeds ensure balanced nutrition, improved digestibility, long-term preservation and enhanced palatability, making them vital for livestock during lean seasons. With the growing demand for optimized feed formulations, evaluating complex nutritional data has become crucial. However, ranking feed combinations using Multi-Criteria Decision-Making (MCDM) methods remains a significant challenge. This study, conducted at Tamil Nadu Agricultural University, Coimbatore, during 2024–2025, assessed 27 fodder pellet combinations using a Multi-Criteria Decision Analysis (MCDA) framework that integrated the Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). Pellets comprised Bajra Napier hybrid, Guinea grass, Fodder maize and legumes such as Lucerne, Desmanthus and Agathi, combined with crop residues from rice, maize and groundnut. Nutritional parameters, including crude protein, fibre fractions (ADF, NDF, ADL, cellulose and hemicellulose), crude fat, total ash, palatability and in vitro dry matter digestibility, were studied. AHP assigned weights to each parameter, while TOPSIS ranked combinations by closeness to the ideal solution. The Bajra Napier Hybrid + Agathi + Groundnut haulms combination had the highest TOPSIS score (0.8808), indicating superior nutritional performance. This study validates AHP-TOPSIS as a reliable tool for optimizing fodder pellet formulations. Correlation studies showed a negative relationship among various pellet formulations. Guinea grass + *Desmanthus* + Maize stover exhibited the highest crude fibre content (32 %) with moderate digestibility (66 %), indicating greater fibre accumulation. Conversely, Fodder Maize + Agathi + Groundnut haulms had a lower crude fibre content (28%) but achieved a digestibility of 64%, making it a favourable choice for improved nutrient bioavailability. The findings from this study can guide feed industries and farmers in selecting nutritionally balanced, cost-effective pellet combinations that contribute to local fodder availability and support sustainable livestock nutrition strategies.

Keywords: AHP; digestibility; fibre fraction; fodder pellets; MCDM; TOPSIS

Introduction

Livestock contributes to food security, nutrition, income and crop production through manure and draft power. As of the *20th Livestock Census*, India is home to over 536.76 million livestock, with small and marginal farmers owning more than 70% of these animals, highlighting their crucial role in income generation and poverty alleviation (1). Livestock contributes 30.19 % to agricultural gross value added (GVA) and 5.73 % to the national GVA, showing its importance in the Indian agrarian economy (2). Animal source foods (ASF), derived from livestock such as milk, meat and eggs, are rich in high-quality proteins and essential micronutrients, including iron, zinc and vitamins A and B_{12} (3). These are especially vital for vulnerable groups and during critical life stages such as pregnancy, early childhood and adolescence. Beyond nutrition, livestock is a valuable economic asset for rural households, providing steady income, employment and social security. It also supports crop production by providing manure (an organic fertiliser) and draft power. Even households without livestock benefit through value chains that involve processing, trade and services (4). Feed deficits remain a persistent challenge, with projected shortfalls of 12% in dry fodder and 25 % in green fodder by 2030 (5,6), which can lead to nutritional deficiencies, diseases and reduced output. Overfeeding can be equally harmful. Providing high-quality feed ensures better performance and economic returns in livestock farming (7).

Nutritive and balanced feed is essential for livestock health, growth and productivity. Animals require specific nutrients based on their age, sex and physiological stage. The nutritional quality of feed significantly impacts animal performance. The nutritional value of feed is assessed based on its energy components, such as carbohydrates, fats and proteins and their digestibility, along with protein quality (including non-protein nitrogen and its degradability), the presence of vitamins and minerals and the dry matter content (8). Other factors, such as palatability, storage, safety, effects on product quality (meat, milk, eggs) and cost, also influence the overall feed value.

Livestock production systems are increasingly dependent on processed and nutritionally balanced feeds, with fodder pellets emerging as a significant component due to their ease of handling, storage and reduced wastage (9, 10). Selecting an ideal feed combination is challenging due to the need to balance multiple quality parameters, such as nutrient content, cost, availability, the presence of anti-nutritional factors and the impact on product quality. These factors often conflict, making it difficult to achieve a mix that is both effective and economical for livestock production. Traditional evaluation methods often fall short in accounting for the complexity of feed performance metrics. Multi-Criteria Decision-Making (MCDM) tools, such as the Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), are well-suited for such complex evaluations (11). AHP facilitates the systematic assignment of weights to decision criteria based on expert judgments while in its final stage, TOPSIS ranks alternatives by measuring their closeness to the positive ideal solution (PIS) and their farthest geometric distance from the negative ideal solution (NIS) (12).

While the TOPSIS method has been widely applied in various domains of agriculture and livestock decision-making, including breed selection and resource prioritisation (13-15), its application in evaluating and ranking cattle feed or fodder pellet formulations remains largely unexplored. This study addresses this research gap by employing a modified TOPSIS approach to systematically assess multiple feed formulations based on nutritional and economic parameters. This study integrates AHP and modified TOPSIS to evaluate and rank 27 fodder pellet combinations derived from three primary fodder sources. The objective of this study is to identify the most nutritionally suitable formulations for enhancing livestock productivity. Dietary fibre plays a crucial role in digestion and nutrient bioavailability, affecting feed efficiency in ruminants. Studies indicate that fibre composition influences digestibility, with higher lignin content reducing nutrient absorption (16). The structure of fibre-rich diets modulates carbohydrate digestion, altering microbial activity in the rumen and impacting energy metabolism (17). Additionally, the physical form and particle size of fibre significantly affect rumen degradation rates and dry matter intake (DMI) (18). Finer fibre particles enhance microbial fermentation, whereas coarse, lignin-rich fibres lower digestion efficiency. These findings are particularly relevant in evaluating fodder pellet formulations, as balancing fibre composition and particle size can optimise digestibility and enhance feed utilisation in livestock nutrition. This study examines the correlation between crude fibre and digestibility in various pellet combinations to improve feed efficiency.

Materials and Methods

The experimental study was conducted during the year 2024-2025 at Tamil Nadu Agricultural University, Coimbatore, India. The objective of the study was to standardise fodder combinations and develop balanced nutritive fodder pellets for milch animals and to evaluate and rank the different pellet combinations based on various quality parameters.

Pellet treatments

A total of 27 fodder pellet treatments were formulated by combining three primary fodder bases, Bajra Napier (*Pennisetum purpureum* × *Pennisetum glaucum*), Guinea Grass (*Panicum maximum*) and Fodder Maize (*Zea mays*) with legume sources including Lucerne (*Medicago sativa*), *Desmanthus* (*Desmanthus virgatus*) and Agathi (*Sesbania grandiflora*), along with dry crop residues such as rice straw, maize stover and groundnut haulms. Each fodder base was used to create nine distinct treatment combinations (Table 1) in a ratio of 60:30:10 of grass/cereal fodders, legume/tree fodders and crop residues, respectively, with three replications. The fodder crops were harvested, dried under a solar dryer and pulverised to make pellets using a pellet die mill.

Quality parameters

Crude protein content was determined by the Kjeldahl method as outlined by (19). A 0.5 g ground sample was digested with concentrated sulfuric acid, assisted by a catalyst mixture (potassium sulfate and copper sulfate), until a clear solution was achieved. The digested sample was then distilled using 40 % sodium hydroxide and the ammonia released was absorbed using boric acid solution with mixed indicators. The ammonia

Table 1. Fodder pellet treatment details

	Bajra napier hybrid-based pellet combinations
T_1	Bajra Napier hybrid grass+ Lucerne+ Rice straw
T_2	Bajra Napier hybrid grass+ Lucerne + Groundnut haulms
T_3	Bajra Napier hybrid grass + Lucerne + Maize stover
T_4	Bajra Napier hybrid grass + *Desmanthus* + Rice straw
T_5	Bajra Napier hybrid grass + *Desmanthus* + Groundnut haulms
T_6	Bajra Napier hybrid grass + *Desmanthus* + Maize stover
T_7	Bajra Napier hybrid grass + Agathi + Rice straw
T_8	Bajra Napier hybrid grass + Agathi + Groundnut haulms
T_9	Bajra Napier hybrid grass + Agathi + Maize stover
	Guinea grass-based pellet combinations
T_{10}	Guinea grass + Lucerne+ Rice straw
T_{11}	Guinea grass + Lucerne + Groundnut haulms
T_{12}	Guinea grass + Lucerne + Maize stover
T_{13}	Guinea grass + *Desmanthus* + Rice straw
T_{14}	Guinea grass + *Desmanthus* + Groundnut haulms
T_{15}	Guinea grass + *Desmanthus* + Maize stover
T_{16}	Guinea grass + Agathi + Rice straw
T_{17}	Guinea grass + Agathi + Groundnut haulms
T_{18}	Guinea grass + Agathi + Maize stover
	Fodder maize -based pellet combinations
T_{19}	Fodder maize + Lucerne+ Rice straw
T_{20}	Fodder maize + Lucerne + Groundnut haulms
T_{21}	Fodder maize + Lucerne + Maize stover
T_{22}	Fodder maize + *Desmanthus* + Rice straw
T_{23}	Fodder maize + *Desmanthus* + Groundnut haulms
T_{24}	Fodder maize + *Desmanthus* + Maize stover
T_{25}	Fodder maize + Agathi + Rice straw
T_{26}	Fodder maize + Agathi + Groundnut haulms
T_{27}	Fodder maize + Agathi + Maize stover

trapped was then titrated using standard 0.1 N hydrochloric acid and nitrogen content was calculated. Crude protein (%) was obtained by multiplying the value of nitrogen by conversion factor 6.25.

Crude fibre was analyzed by a gravimetric procedure using sequential digestion of 1 g sample with 1.25 % sulfuric acid and 1.25 % sodium hydroxide. The residue was filtered, dried, weighed and then ashed in a muffle furnace at 550°C. Difference in weight before and after ashing was taken as crude fibre. Fibre fractions such as Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF) and Acid Detergent Lignin (ADL) were analyzed using the Van Soest sequential fibre analysis technique (20). For NDF, the sample was refluxed for 1 hour with neutral detergent solution (sodium lauryl sulfate and EDTA). The residue was filtered, dried and weighed. For ADF, an identical procedure was adopted employing acid detergent solution (sulfuric acid containing Cetyl Trimethyl Ammonium Bromide). ADL was assessed after treating the residue of ADF with 72% sulfuric acid for 3 hours, then filtering and weighing. Cellulose content was calculated as the difference between ADF and ADL. Hemicellulose content was derived by subtracting ADF (%) from NDF (%).

Cellulose (%) = Residue from ADF- Acid fraction (Eqn. 1)

Hemicellulose (%) = NDF (%) - ADF (%) (Eqn. 2)

These values were included as nutritional parameters for the multi-criteria ranking of the pellet formulations. In vitro dry matter digestibility was assessed using the rumen simulation technique (TANUVAS - RUSITECH) (21). Palatability evaluation was conducted by conducting a feed preference trial. After a 10 -day adaptation period, 1 kg of each treatment pellet was offered to the animals in the morning for 10 min. The quantity consumed was measured and palatability was expressed as a percentage of intake.

Modified TOPSIS Method

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was employed, using AHP-derived weights, to rank the 27 treatments (22). Fig. 1 illustrates the steps involved in the analysis.

The Analytic Hierarchy Process was employed to assign weights to nine evaluation criteria through expert-based pairwise comparisons using the Saaty scale, ranging from 1 to 9 (23).

Methodology overview: AHP-TOPSIS-based ranking of fodder pellet treatments

A total of 27 fodder pellet formulations were evaluated using a Multi-Criteria Decision-Making (MCDM) approach combining the Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). This integrated approach enabled objective ranking based on multiple quality, nutritional and economic parameters.

Step 1: Development of the decision matrix

A decision matrix was constructed, incorporating the 27 treatments as alternatives and the selected evaluation parameters (palatability, nutrient content, digestibility) as criteria.

Step 2: Normalization of the decision matrix

To eliminate scale disparities among criteria, the matrix was normalised using the vector normalisation technique. This transformation ensures comparability of all parameter values across treatments.

Step 3: Weight determination using AHp

Criteria weights were determined through the AHP method, involving pairwise comparison matrices and consistency ratio checks. The final normalized weights reflected the relative importance of each criterion, derived from expert judgement.

Step 4: Construction of the weighted normalized decision matrix

The normalized matrix was multiplied by the AHP-derived weights to obtain the weighted normalized decision matrix. This step integrates both performance and importance of each criterion.

Step 5: Identification of ideal and negative-ideal solutions

The positive ideal solution (PIS) and negative ideal solution (NIS) were identified by selecting the maximum and minimum values for each criterion from the weighted matrix, respectively. PIS represents the best achievable performance, while NIS represents the least desirable. Beneficial attributes includes (crude protein, digestibility, palatability) where higher values are preferred and non-beneficial attributes (crude fibre, ADF, NDF, ADL, cellulose and hemicellulose), where lower values are preferred.

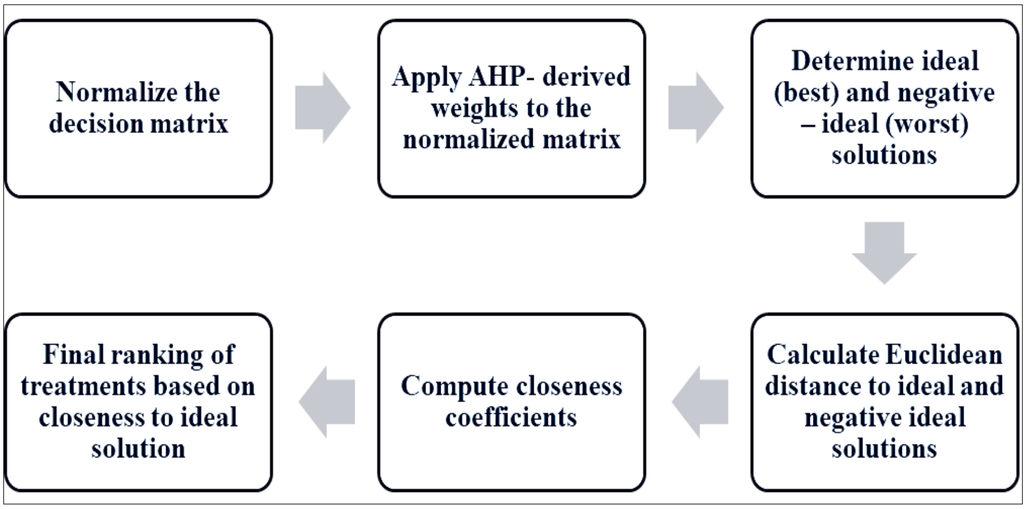

Fig. 1. Steps in modified TOPSIS analysis

For beneficial criteria: $r_{ij} = x_{ij} / \sqrt{(\sum x_{ij}^2)}$ (Eqn. 3)

For non- beneficial criteria: $r_{ij} = (1 / x_{ij}) / \sqrt{(\sum (1 / x_{ij})^2)}$ (Eqn. 4)

Step 6: Calculation of euclidean distances

The Euclidean distances of each alternative from the PIS and NIS were computed. These distances represent how close or far a treatment is from the optimal and least optimal scenarios.

Step 7: Calculation of closeness coefficients

Closeness coefficients (CC_i) were computed for each treatment using the formula:

$CC_i = D_{i-} / (D_{i+} + D_i^-)$ (Eqn. 5)

Where D_i^+ and D_i^- denotes distances from the positive and negative ideal solutions, respectively.

Step 8: Ranking of treatments

Treatments were ranked based on their closeness coefficients, with higher CC_i values indicating better overall performance in meeting the desired criteria.

Sensitivity analysis

A sensitivity analysis was conducted by varying the AHP weights of individual units by ± 10 % in several scenarios, while maintaining the total sum of weights equal to 1. The changes in the rankings of treatments were subtle, with top-ranked combinations being identical in all cases, validating the robustness and stability of the new TOPSIS-AHP model.

Statistical analysis

Experimental data were analysed using R software (version 4.4.3) and the agricolae package (24). This yielded least squares means (LS Means) for each treatment, which were then used in the TOPSIS (version 1.0) package to rank alternatives based on their closeness to an ideal solution using multiple criteria. In this study, several R packages were utilized to support data processing and visualization. The package ahpsurvey (v.0.4.1) calculates weights and checks consistency from AHP pairwise comparisons. dplyr (v. 1.1.4) simplifies data manipulation with functions for filtering, selecting and summarizing data. tidyr (v.1.3.1) helps reshape and clean data by tidying it into a consistent format. The readxl (v.1.4.5) package was employed to import data from Excel files, while tibble (v.3.2.1) facilitated efficient and user-friendly data manipulation. For the graphical representation of results, ggplot2 (version 3.5.2) was used to create clear and customizable plots. Additionally, the ggcorrel (v.0.1.4.1) package was used to explore and visualize the correlation structure among variables.

Results and Discussion

The ranking of 27 different fodder pellet formulations was carried out using a modified Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) analysis, incorporating weights derived from the Analytical Hierarchy Process (AHP). This approach provided a robust multi-criteria evaluation based on key nutritional parameters, with the TOPSIS score representing the closeness of each treatment to an ideal solution (Fig. 2).

Among all 27 treatments, the Bajra Napier hybrid grass + Agathi + Groundnut haulms formulation recorded the highest TOPSIS score of 0.8808, making it the top-ranked treatment. It was closely followed by Guinea grass + Agathi + Groundnut haulms and Fodder Maize + *Desmanthus* + Maize stover with scores of 0.8558 and 0.8026, respectively. On the other hand, Guinea grass + Lucerne + Rice straw and Bajra Napier hybrid grass + Lucerne + Rice straw) recorded the lowest scores of 0.0886 and 0.1701, ranking 27th and 26th, respectively. A clear trend was observed wherein treatments containing Groundnut haulms and Agathi consistently ranked higher, whereas those with Rice straw tended to rank lower.

The positive performance of Agathi and Groundnut haulms can be attributed to their high protein content, digestibility and overall nutritional richness, as supported by earlier findings (25-27). In contrast, the inclusion of Rice straw,

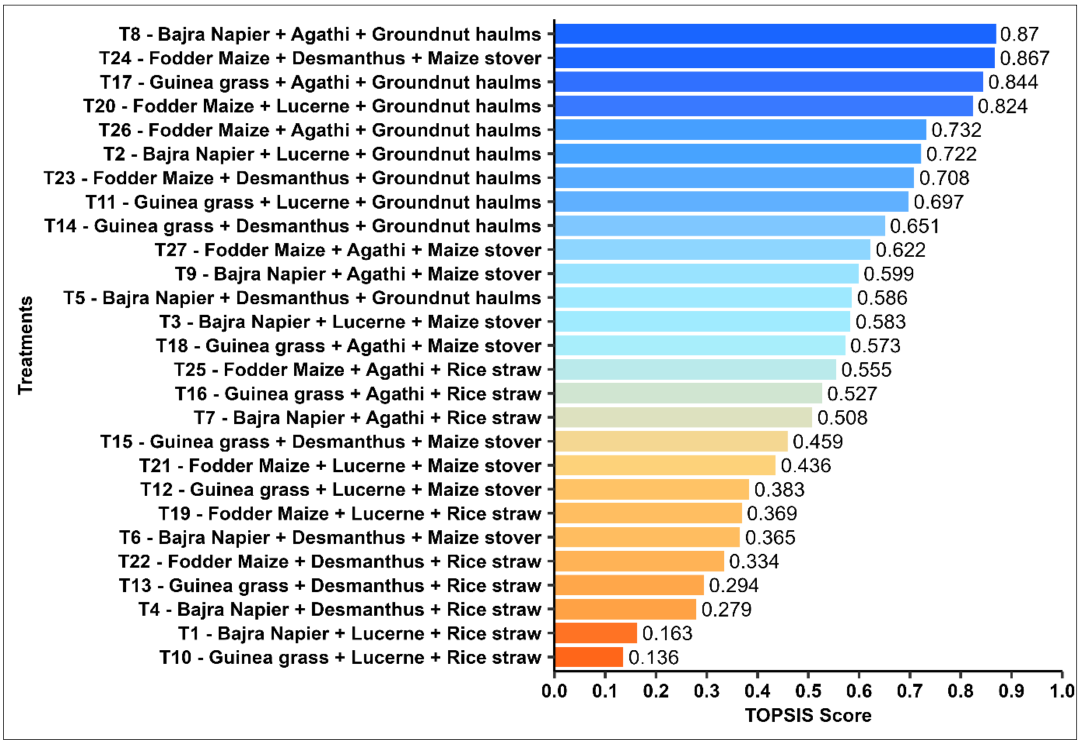

Fig. 2. TOPSIS scores and ranking of fodder pellet combinations

which is high in lignin, silica and oxalic acid, appears to detract from nutritional value and palatability (28-31). The analysis also highlighted the influence of the primary grass component. While the Bajra Napier hybrid performed well in combinations with nutrient-rich supplements (32), Fodder Maize-based pellets, such as T_{24} and T_{20} (Fodder Maize + Lucerne + Groundnut haulms), also ranked highly, emphasising its utility as a versatile and effective base fodder (33).

The use of a modified TOPSIS method, supported by AHP -derived weights, allowed for an objective and structured assessment of each formulation. By integrating expert judgment into the evaluation process, the model offers a practical decision-support tool for selecting nutritionally superior fodder pellets. Fig. 2 provides a visual representation of the ranking, aiding in intuitive comparison and selection.

The AHP-TOPSIS hybrid model efficiently ranked fodder pellet treatments based on multiple quality parameters by integrating AHP-derived criteria weights with TOPSIS ranking. The model enabled objective evaluation through a structured 9 × 9 comparison matrix and closeness coefficient scores (CC_i), clearly distinguishing high-performing formulations. Its ability to handle complex data makes it a reliable tool for optimising fodder pellet quality in both research and practical applications and also guides future feed development strategies for livestock nutritional needs, resource availability and production efficiency.

Correlation analysis of crude fibre and digestibility in different fodder pellet combinations

A correlation study was conducted to analyse the relationship between crude fibre (%) and digestibility (%) across 27 different fodders combinations (Table 2), using R software. The calculated correlation coefficient (r) was -0.43, indicating a moderate negative correlation. This is visually represented in the scatter plot (Fig. 3), which includes a fitted regression line and 95 % confidence band. The scatter plot with a trend line demonstrated a negative correlation between crude fibre and digestibility, indicating that higher crude fibre content is generally associated with lower digestibility.

Guinea grass + *Desmanthus* + Rice straw exhibited elevated crude fibre (32.85 %) but showed a lower digestibility (49.32 %), implying that this pellet combination increases fibre content, it does not enhance digestibility. Similarly, Guinea grass + *Desmanthus* + Maize stover recorded the highest crude fibre content (33.32 %) while maintaining moderate digestibility (55.46 %), suggesting that this combination supports higher fibre accumulation. Fodder Maize + Agathi + Groundnut haulms demonstrated lower crude fibre (28.55 %) while achieving a digestibility of approximately 66.71 %, making it a promising option for enhancing nutrient bioavailability. Treatments containing Lucerne (T_1, T_2, T_3) and Agathi (T_7, T_8, T_9) generally exhibited a balance between fibre and digestibility, supporting moderate digestion rates.

Table 2. Effect of different fodder pellet combinations on the digestibility and crude fibre

Treatments	Digestibility (%)	Crude fibre
T1	60.32	30.95
T2	65.73	30.80
T3	66.12	31.40
T4	56.40	31.20
T5	66.54	31.05
T6	62.47	31.65
T7	56.78	30.90
T8	67.45	30.75
T9	62.15	31.35
T10	52.50	32.58
T11	60.18	32.40
T12	58.56	33.05
T13	49.32	32.85
T14	58.66	32.67
T15	55.46	33.32
T16	57.45	32.50
T17	62.44	32.33
T18	60.34	32.98
T19	55.83	28.75
120	63.45	28.60
121	61.76	29.20
T22	52.13	28.95
T23	60.21	28.80
T24	58.22	29.40
T25	57.46	28.70
T26	66.71	28.55
T27	64.74	29.15
SEd	3.307	1.812
CD (P=0.05)	**NS**	**NS**

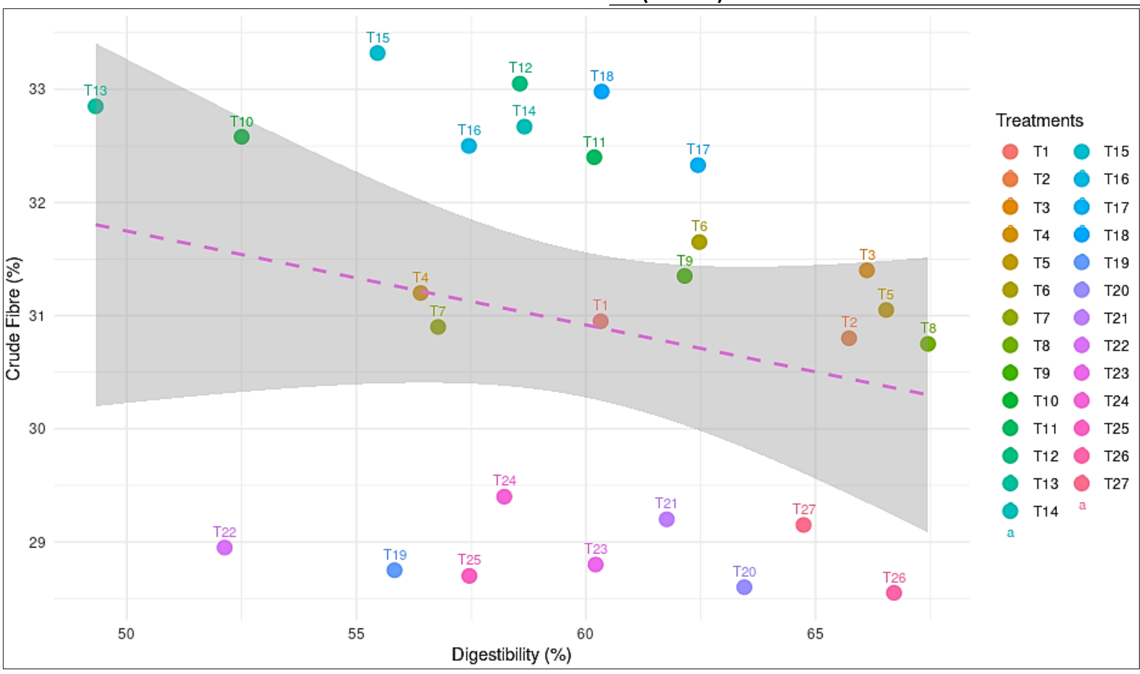

Fig. 3. Correlation analysis between digestibility and crude fibre

Maize stover is known to contain high levels of neutral detergent fibre (NDF) and acid detergent fibre (ADF), which contribute to its crude fibre content. However, it has a relatively lower lignin content compared to rice straw, making it more digestible (34). Research indicates that maize stover has better rumen microbial utilization due to its cellulose-to-lignin ratio, allowing for higher digestibility (35). Rice straw typically contains higher levels of lignin and silica, which significantly reduce its digestibility. This explains why T_{13} showed significantly lower digestibility (63 %) despite having similar crude fibre content (36). Rice straw has lower crude protein and energy content (37), making it less efficient for livestock nutrition compared to maize stover. Due to its high lignin and silica content, rice straw is less fermentable, leading to reduced nutrient absorption (38).

Conclusion

This research employed a modified AHP-TOPSIS framework to rank 27 combinations of fodder pellets. The integrated MCDM approach provides a powerful tool for feed scientists and livestock producers in identifying optimal feed formulations. These findings suggest that the strategic inclusion of nutrient-rich and digestible components, such as Groundnut haulms and Agathi, significantly enhances the overall quality and ranking of fodder pellets, making them more suitable for sustainable livestock feeding systems. The correlation studies in fodder combinations incorporating Guinea grass + *Desmanthus* + Rice straw favour increased crude fibre content, whereas Fodder Maize + Agathi + Groundnut haulms enhance digestibility. This correlation highlights the importance of selecting optimal fodder combinations to achieve a balance between fibre content and digestibility in livestock nutrition. Future research may incorporate the value addition of fodder pellets with additives such as concentrates, yeast sludge, or molasses and evaluate the quality and mineral nutrients in pelleted feeds. Animal trials can then be conducted to validate the nutritional efficacy and digestibility of the formulated fodder under practical feeding conditions.

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Authors' contributions

SM carried out the methodology, data curation, formal analysis and drafted the original manuscript. SS conceived the study, conducted the investigation and provided resources. TR validated the data and manuscript, reviewing. PR contributed to supervision and resource provision. SA performed validation and participated in reviewing and editing the manuscript. VB contributed to formal analysis, supervision and visualization. All authors read and approved the final manuscript.

Compliance with ethical standards

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

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process : During the preparation of the manuscript, the authors utilised the Chat-GPT AI tool to improve the language and readability. Following its use, the authors thoroughly reviewed and revised the content as necessary, taking full responsibility for the final version of the manuscript.

References

1. Bardhan D. Rapporteur's report on sustaining livelihoods: the role of livestock, poultry and fisheries in rural economy. *Indian J Agric Econ.* 2024;79(3):874–87. https://doi.org/10.63040/25827510.2024.03.036
2. Department of Animal Husbandry and Dairying (DAHD). Updated Compendium of Animal Husbandry Statistics 2022-23 [Internet]. New Delhi: Ministry of Fisheries, Animal Husbandry and Dairying, Government of India; 2023 [cited 2025 Jul 25]. Available from: https://dahd.gov.in/sites/default/files/2024-10/UpdatedCompendium2022-23.pdf
3. Adesogan AT, Havelaar AH, McKune SL, Eilitta M, Dahl GE. Animal source foods: sustainability problem or malnutrition and sustainability solution? Perspective matters. Glob Food Secur. 2020; 25:100325. https://doi.org/ 10.1016/j.gfs.2019.100325
4. FAO. Nutrition and livestock - Technical guidance to harness the potential of livestock for improved nutrition of vulnerable populations in programme planning. Rome: FAO; 2020. https://doi.org/10.4060/ca7348en
5. Indian Grassland and Fodder Research Institute (IGFRI). Vision 2050: Fodder and Feed Resources in India. Jhansi: ICAR–IGFRI; 2015.
6. Birthal PS, Jha AK. Economic losses due to various constraints in dairy production in India. Indian J Anim Sci. 2005;75(12): 1371–76.
7. Kırkpınar F, Acıkgoz Z. Feeding. In: Animal Husbandry and Nutrition. IntechOpen; 2018. https://doi.org/10.5772/intechopen.78618
8. Coleman SW, Moore JE. Feed quality and animal performance. Field Crops Res. 2003; 84:17–29. https://doi.org/10.1016/S0378-4290(03)00138-2
9. Katoch R. Conservation and processing of forages. In: Techniques in Forage Quality Analysis. Singapore: Springer Nature Singapore; 2022a. p.187–97. https://doi.org/10.1007/978-981-19-6020-8_15
10. Vinodhini SM, Sivakumar SD, Ramesh T, Pushpam R, Surendrakumar A, Raghavendran VB, et al. Pelletization as a forage conservation technique: enhancing feed efficiency and sustainability in livestock. Plant Sci Today. 2025;12(2):1–10. https://doi.org/10.14719/pst.7123
11. Chaube S, Pant S, Kumar A, Uniyal S, Singh MK, Kotecha K, et al. An overview of multi-criteria decision analysis and the applications of AHP and TOPSIS methods. Int J Math Eng Manag Sci. 2024;9(3):581. https://doi.org/10.33889/ijmems.2024.9.3.030
12. Assari A, Mahesh T, Assari E. Role of public participation in sustainability of historical city: usage of TOPSIS method. Indian J Sci Technol. 2012;5(3):228994.
13. Sumaryanti L, Nurcholis N. Analysis of multiple criteria decision-making method for selection the superior cattle. Intensif J Ilm Penelit Penerap Teknol Sist Inform. 2020;4(1):131–141. https://doi.org/10.1016/j.indic.2024.100362
14. Amenu K, McIntyre KM, Moje N, Knight-Jones T, Rushton J, Grace D. Approaches for disease prioritization and decision-making in animal health, 2000–2021: a structured scoping review. Front. Vet. Sci. 2023; 10:1231711. https://doi.org/10.3389/fvets.2023.1231711

15. Shahrabi-Farahani S, Hafezalkotob A, Mohammaditabar D, Khalili-Damghani K. Selection of sustainable industrial livestock site using the R-Number GIS-MCDM method: a case study of Iran. Environ. Sustain. Indic. 2024; 22:100362. https://doi.org/10.29407/intensif.v4i1.13863

16. Grundy MML, Edwards CH, Mackie AR, Gidley MJ, Butterworth PJ, Ellis PR. Re-evaluation of the mechanisms of dietary fibre and implications for macronutrient bioaccessibility, digestion and postprandial metabolism. Br J Nutr. 2016;116(5):816–33. https://doi.org/10.1017/S0007114516002610

17. Deusch S, Camarinha-Silva A, Conrad J, Beifuss U, Rodehutscord M, Seifert J. A structural and functional elucidation of the rumen microbiome influenced by various diets and microenvironments. Front Microbiol. 2017;8:1605. https://doi.org/10.3389/fmicb.2017.01605

18. Grant R, Smith W, Miller M. Relationships between fibre digestibility and particle size for lactating dairy cows. WCDS Adv Dairy Technol. 2020;32:47–57.

19. Humphries EC. Mineral components and ash analysis. In: Paech K, Tracey MV, editors. Modern Methods of Plant Analysis: Erster Band/ Volume I. Berlin, Heidelberg: Springer Berlin Heidelberg; 1956. p. 468-502.

20. Van Soest PV, Robertson JB, Lewis BA. Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. J Dairy Sci. 1991; 74:3583–97.

21. Czerkawski JW, Breckenridge G. Design and development of a long-term rumen simulation technique (RUSITEC). Br J Nutr. 1977;38 (3):371–84.

22. Hwang CL, Yoon K. Multiple attribute decision making methods and applications. New York: Springer; 1981.

23. Saaty TL. The analytic hierarchy process. New York: McGraw Hill; 1980.

24. R Core Team. R: A language and environment for statistical computing [Internet]. Vienna, Austria: R Foundation for Statistical Computing; 2024 [cited 2025 Jul 25]. Available from: https://www.R-project.org/

25. Prasad JR, Rao ZP, Rao DS. Evaluation of complete rations containing groundnut haulms at different levels in sheep. Indian J Anim Nutr. 2000;17(2):147–52.

26. Vijayakumar P, Singaravadivelan A, Senthilkumar D, Vasanthakumar T, Ramachandran M. Effect of *Sesbania grandiflora* (Agati) supplementation on weight gain of crossbred Jersey heifer calves. Int. J. Econ. Plants. 2021; 8:162–64. https://doi.org/10.23910/2/2021.0415g

27. Mubeena P, Thomas UC, Surendran D. Nutritional evaluation of predominant tree fodders and shrubs of Southern Kerala as a quality livestock feed. Agric Sci Digest. 2022;42(4):454–58. https://doi.org/10.18805/ag. D-5388

28. Rosado MJ, Rencoret J, Marques G, Gutierrez A, Del Río JC. Structural characteristics of the guaiacyl-rich lignins from rice (*Oryza sativa* L.) husks and straw. Front Plant Sci. 2021; 12:640475. https://doi.org/10.3389/fpls.2021.640475

29. Sufyan A, Ahmad N, Shahzad F, Embaby MG, AbuGhazaleh A, Khan NA. Improving the nutritional value and digestibility of wheat straw, rice straw and corn cob through solid state fermentation using different *Pleurotus* species. J Sci Food Agric. 2022; 102:2445–53. https://doi.org/10.1002/jsfa.11584

30. Singh S, Sharma RK, Rastogi A, Khan N. Variability in the nutritional value of paddy straw (*Oryza sativa*) varieties. J Livest Sci. 2022; 13:213–220. https://doi.org/10.33259/JLivestSci.2022.213-220

31. Praveen BR, Sannagoudar MS, Babu RC, Rajanna GA, Singh M, Kumar S, et al. Sustainable use of paddy straw as livestock feed: a climate resilient approach to crop residue burning. In: Singhal RK, Ahmed S, Pandey S, Chand S, editors. Molecular Interventions for Developing Climate-Smart Crops: A Forage Perspective. Singapore: Springer Nature Singapore; 2023. p. 197–214.

32. BR, Sannagoudar MS, Babu RC, Rajanna GA, Singh M, Kumar S, et al. Sustainable use of paddy straw as livestock feed: a climate resilient approach to crop residue burning. In: Molecular Interventions for Developing Climate-Smart Crops: A Forage Perspective. Singapore: Springer Nature Singapore; 2023. p.197–214. https://doi.org/10.1007/978-981-99-1858-4_11

33. Krishna CR, Babu AS, Raju S, Kumar BS. Comparative evaluation of various hybrid Napier Bajra and multicut sorghum green fodders for proximate composition, fodder quality and digestibility parameters. J Pharmacogn Phytochem. 2025;9(2Sa):3683. https://doi.org/10.33545/26174693. 2025.v9. i2Sa.3683

34. Wadhwa M, Kaur K, Kumar B, Bakshi MPS. Comparative evaluation of non-leguminous forages as livestock feed IJAN. 2010;27(1):44–49.

35. Alikwe PCN, Ohimain EI, Aina ABJ. Comparative digestibility of maize stover, rice straw, malted sorghum sprouts in West African Dwarf (WAD) sheep. IOSR -JAVS. 2014;7(7):10–14.

36. Katoch R, Apoorva TA, Sood SURBHI. Improving nutritive value and digestibility of maize stover-A review. Forage Res. 2017;43(3): 174–80.

37. Katoch R. Quality and digestibility of crop residues. In: Katoch R, editor. Nutritional Quality Management of Forages in the Himalayan Region. Singapore: Springer; 2022b. p.399–463. https://doi.org/10.1007/978-981-16-5437-4_14

38. Oladosu Y, Rafii MY, Abdullah N, Magaji U, Hussin G, Ramli A, et al. Fermentation quality and additives: a case of rice straw silage. BioMed Res Int. 2016; 2016:7985167. https://doi.org/10.1155/2016/7985167

39. Hu Y, He Y, Gao S, Liao Z, Lai T, Zhou H, et al. The effect of a diet based on rice straw co-fermented with probiotics and enzymes versus a fresh corn stover-based diet on the rumen bacterial community and metabolites of beef cattle. Sci Rep. 2020;10 (1):10721. https://doi.org/10.1038/s41598-020-67716-w

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