Journal of Animal Environment

(E-ISSN 2717-1396, ISSN 2717-1388)

Original Research Paper

Agricultural Waste to Milk Productivity: A Circular Bioeconomy Approach to Fodder Production, Dairy Productivity and Farmer Livelihoods

Ajay Kushwah, Research Scholar, Department of Management, Dayalbagh Educational Institute, Agra- ajaykushwah.kush@gmail.com
Dr. Rashmi Rajput, Lecturer, Department of Agriculture, Dayalbagh Educational Institute, Agra
Vikas Verma, Guest Faculty, Department of Agriculture, Dayalbagh Educational Institute, Agra
Krishna Kant, Research Scholar, Department of Botany, Dayalbagh Educational Institute, Agra
Dr. Arvind Kumar, Assistant Professor, Department of Management, Dayalbagh Educational Institute, Agra
Prof. Sanjay Bhushan, Professor, Department of Management, Dayalbagh Educational Institute, Agra

Abstract
Agricultural intensification generates enormous volumes of crop residues and agro-industrial by-products, a large share of which is burned, dumped, or left to decompose, producing air pollution, greenhouse gas emissions and lost nutrient value. At the same time, smallholder and commercial dairy systems across much of the Global South face chronic shortages of good-quality roughage and protein feed. This review develops the argument that agricultural residues should not be treated simply as "waste" but evaluated as context-dependent biological resources whose value for dairy production depends jointly on processing technology, nutrient upgrading, logistics, animal response, farmer economics and soil-residue trade-offs. Drawing on peer-reviewed studies, meta-analyses and international assessments, the review synthesises evidence across four linked domains, (i) the classification and nutritional characteristics of cereal, pulse, sugar, oilseed, fruit, vegetable and agro-industrial residues, (ii) physical, chemical, microbial and enzymatic technologies for upgrading their feeding value, (iii) their measured effects on dry-matter intake, digestibility, rumen fermentation, milk yield and milk composition in dairy cattle and buffaloes and (iv) the economic, environmental and adoption dimensions that determine whether residue valorisation translates into real farm-level benefit. An integrated circular bioeconomy framework is proposed, linking crop production, residue processing, dairy feeding, milk output, manure recycling and soil nutrient return into a single closed loop, together with a conceptual Circular Dairy Feed Value Index for future application. The review concludes that waste-to-feed conversion is beneficial only when nutritional upgrading, processing energy, logistics, food safety, in-field residue retention requirements, animal performance and farmer profitability are considered together, rather than through isolated feeding trials. This reframing shifts the field from a conventional animal-nutrition literature toward a systems-level circular bioeconomy science with direct relevance to food security, rural livelihoods, and climate policy.
Keywords: *circular bioeconomy, agricultural residues, agro-industrial by-products, dairy cattle nutrition, fodder processing, farmer livelihoods, environmental sustainability*

1. Introduction

Modern crop production leaves behind an enormous quantity of biomass that is not consumed as food. Cereal straw, sugarcane trash, oilseed cakes, pulse haulms, and the peels, pomace and trimmings generated by fruit and vegetable processing together constitute one of the largest under-used biomass streams in agriculture. In South Asia alone, deficits in green fodder, dry fodder and concentrate feed are estimated at roughly 36%, 25% and 47% respectively, even as residue generation continues to rise with cropping intensity (Kaur et al., 2026). In India, total crop residue generation has been estimated at several hundred million tonnes annually, of which a substantial share is still burned in the open field rather than recovered as feed, fuel or soil amendment (Dutta et al., 2022).

This biomass surplus coincides with a structural shortage of quality livestock feed in the same regions. Smallholder dairy farmers frequently rely on crop residues and low-quality roughage as the backbone of the ration, supplemented only marginally with purchased concentrate, producing chronic deficits in protein, minerals and vitamins (Sahoo et al., 2020).

***Corresponding Author:**

Received: 15th Jul, 2026 | Revised: 25th Jul, 2026 | Accepted: 5th Aug, 2026 | Available Online: 12th Aug, 2026

(DOI): 10.70102/AEJ.2026.18.3s.110

The result is a paradox worth stating explicitly: the same biomass that is disposed of as an environmental liability in one part of the farming system is simultaneously the limiting resource in another.

The existing literature on residue-to-feed conversion is extensive but fragmented. Most studies examine a single residue, a single processing method, a single animal trial and, at most, a single production outcome such as digestibility or milk yield (Chelkapally et al., 2024). Relatively few studies connect nutritional response to farm-level economics, environmental trade and the behavioural and institutional barriers that determine whether farmers actually adopt a given technology (Teklewold et al., 2021).

2. Review Methodology

This paper follows a systematized literature review approach informed by PRISMA reporting principles, rather than a full systematic review or meta-analysis, given the breadth of disciplines covered. Peer-reviewed articles, systematic reviews, meta-analyses, controlled feeding trials, nutritional characterisation studies, techno-economic assessments and authoritative institutional reports (FAO, ICAR) were retrieved from various sources, using combinations of terms such as "crop residue", "agro-industrial by-product", "dairy cattle", "buffalo", "milk yield", "urea treatment", "silage", "fungal treatment", "circular bioeconomy" and "farmer adoption". Studies without an identifiable feed material, without sufficient methodological detail, or unrelated to ruminant or dairy feed systems were excluded. Because evidence quality varies markedly across the literature from large meta-analyses to single-farm case studies, the review classifies cited evidence using the grading scheme and interprets stronger claims only where evidence level A or B supports them.

3. Agricultural Residues and By-products as Feed Resources

Agricultural biomass suitable for dairy feeding can be organised into three broad categories: crop residues generated directly on the farm, agro-industrial by-products generated during processing (milling, oil extraction, brewing, distilling), and food-processing residues generated at the point of preparing fruit, vegetables and other perishables for the market (Figure 1).

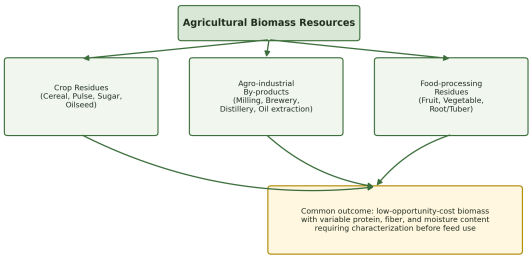


Figure 1. Classification of agricultural residues and agro-industrial by-products as dairy feed resources.

Crop residues across South Asia represent a huge, underused opportunity for dairy feed, but each type needs a different approach: paddy straw is the most abundant and the most problematic low in protein (3.5–4.5% untreated), heavily lignified, and the leading cause of open-field crop burning in the region yet urea treatment alone can nearly double its crude protein to 8% and lift total digestible nutrients from ~40% to 55%, with urea-plus-lime treatment pushing digestibility even higher (Sahoo et al., 2020), wheat straw is already better integrated into fodder markets in North India and Pakistan and responds predictably to urea-molasses treatment, with buffalo calf trials showing digestibility rising steadily as treated straw replaces more of the diet (Sarwar et al., 2011), maize stover, husk, and cob, along with sorghum and millet residues, remain heterogeneous and comparatively understudied, and shouldn't be confused with the much richer whole-crop maize silage; moving beyond cereals, sugarcane tops offer moderate-quality roughage while bagasse is too lignified for use without intensive processing, pulse residues (chickpea, pigeon pea, lentil, mung bean, black gram) provide a modest protein and mineral edge over straw but only seasonally, and oilseed cakes mustard, groundnut, soybean, cottonseed, sesame, sunflower, and rapeseed belong in an entirely different category as true protein concentrates, with groundnut cake reaching 45–50% crude protein (Frontiers in Sustainable Food Systems, 2022), mustard cake plus Azolla meal shown to improve live weight and milk yield in indigenous cattle (Khan et al., 2011), cottonseed meal proven capable of replacing soybean meal without hurting yield when energy is balanced and a meta-analysis across multiple oilseed sources confirming improved milk fatty-acid profiles (more CLA, vaccenic and oleic acid, lower atherogenic index) alongside small drops in milk fat and protein (Ramírez-Bribiesca et al., 2022), fruit and vegetable residues tomato, cabbage, cauliflower, carrot, potato, leafy greens, citrus pulp and peel, mango, banana, pineapple, apple pomace, and grape pomace are rich in soluble carbohydrates and, for citrus and grape by-products, beneficial polyphenols, but their high moisture content causes rapid spoilage and transport headaches (Jalal et al., 2023), making ensiling the standard fix, particularly co-ensiling with drier materials like straw or maize stover to reduce effluent loss and improve fermentation (Dou et al., 2024), with citrus by-products having a long track record as ruminant feed and Kinnow mandarin waste silage specifically shown to match conventional silage in intake and weight gain

for small ruminants (Malla et al., 2015); brewery and distillery by-products are among the most established options, with a meta-analysis of twelve trials spanning 472 cows from 1983–2021 finding that brewers' grains slightly reduce dry-matter intake but improve feed efficiency, best kept under ~20% of the diet for lactating cows (Chelkapally et al., 2024), and these by-products illustrate a broader pattern where such residues cut feed costs per unit of milk more than they raise absolute yield and finally, unconventional and emerging resources bakery waste, retail food loss, root and tuber residues are gaining attention as circular "one-nutrition" feed streams, though recent reviews caution that their real-world value depends on managing safety, processing intensity, logistics, and regulation (Deshmukh et al., 2026), with a systematic review of South Asian dairy systems specifically finding that fragmented supply across households, retail, and hospitality sectors, combined with weak governance and collection infrastructure, remains the main obstacle to scaling these resources up (Kaur et al., 2026).

Table 1. Classification of agricultural residues and agro-industrial by-products for dairy feeding

Feed resource	Major examples	Main limitation	Suitable processing	Potential role	Source(s)
Cereal straw	Paddy, wheat	High NDF / lignin, low CP	Chopping, urea, alkali, microbial	Basal roughage	Sahoo et al. (2020)
Sugarcane residues	Tops, bagasse	High fibre / lignin	Ensiling, chemical /biological	Roughage / energy	Devendra (2012)
Pulse residues	Chickpea, pigeon pea, lentil	Seasonal availability	Drying, grinding	Roughage / protein	Devendra (2012)
Oilseed cakes	Mustard, groundnut, soybean, cottonseed	Anti-nutritional factors (e.g. gossypol)	Decortication, processing	Protein concentrate	Iqbal et al. (2008)
Fruit waste	Citrus, mango, banana, apple, grape	High moisture, spoilage	Drying, ensiling	Energy / bioactive compounds	Jalal et al. (2023)
Vegetable waste	Tomato, cabbage, carrot	High moisture	Ensiling, drying	Energy / fibre	Bakshi et al. (2012)
Brewery by-products	Spent grain, yeast	Moisture, logistics, spoilage	Drying, ensiling	Protein / energy	Chelkapally et al. (2024)
Distillery by-products	DDGS, stillage	Compositional variability	Drying	Protein / energy	Karnjanapratum et al. (2022)

4. Processing and Bioconversion Technologies

Upgrading the feeding value of agricultural residues generally follows a sequence: physical preparation, chemical modification and, increasingly, microbial or enzymatic bioconversion, followed by conservation as hay or silage (Figure 2).

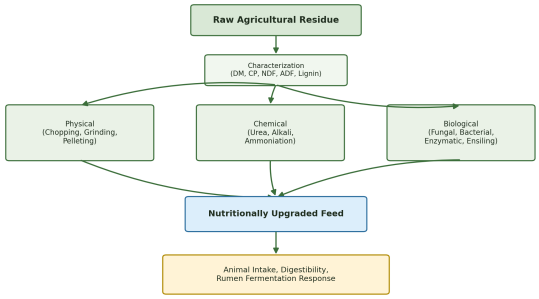


Figure 2. Processing and bioconversion technology map for residue-to-feed upgrading.

4.1 Physical processing

Chopping reduces particle size and improves handling and intake but has limited direct effect on lignin content. Grinding increases surface area and digestibility at the cost of additional energy input, while pelleting and briquetting improve transport density, storage and dust control, which matters disproportionately for high-moisture or bulky residues moving through smallholder supply chains.

4.2 Chemical treatment

Urea treatment remains the most widely adopted chemical upgrading technology for cereal straw because urea hydrolyses to ammonia, which disrupts lignocellulosic bonds and simultaneously enriches the substrate with non-protein nitrogen. On-farm and controlled trials consistently report increased crude protein, improved digestibility and measurable gains in intake, live-weight gain and milk yield relative to untreated straw (Gunun et al., 2013). Combining urea with calcium hydroxide has, in some trials, produced comparable or superior digestibility gains at lower urea cost and with lower ammonia loss risk (Wanapat et al., 2009). Ammoniation of low-quality roughage continues to be identified in the recent literature as one of the most cost-effective upgrading strategies available to dry-season ruminant feeding systems (Hussain et al., 2026). Alkali treatment using sodium hydroxide, calcium hydroxide or combined lime-urea protocols achieves similar lignin disruption but raises concerns over chemical handling, cost and sodium load in the final ration.

4.3 Microbial and enzymatic bioconversion

White-rot fungi (Pleurotus, Phanerochaete, Trametes and related genera) selectively degrade lignin through ligninolytic enzymes lignin peroxidase, manganese peroxidase and laccase while leaving cellulose comparatively intact, offering an environmentally benign alternative to chemical delignification (van Kuijk et al., 2015). Solid-state fermentation of straw with Pleurotus species has been shown to raise crude protein and reduce NDF, ADF and lignin content while improving in-vitro rumen digestibility (Wang et al., 2023), and intraspecies variation among white-rot fungal strains suggests further gains are achievable through strain selection (van Kuijk et al., 2015). Yeast fermentation (notably Saccharomyces cerevisiae) contributes probiotic and protein-enrichment effects, bacterial fermentation supports preservation and reduction of anti-nutritional factors, and exogenous enzymes (cellulase, xylanase, β-glucanase, laccase, protease) offer a further route to cell-wall hydrolysis. A review of bioprocessing technologies highlights the combined role of fungi, yeast, bacteria and enzymes in upcycling agro-industrial and food wastes into higher-value animal feed, while noting that most technologies remain constrained by cost and scale-up difficulty outside controlled research settings (Karnjanapratum et al., 2022).

4.4 Conservation: hay and silage

Haymaking preserves surplus forage through controlled drying but risks nutrient loss and fungal contamination if moisture content is not adequately reduced before storage. Ensiling, based on anaerobic lactic-acid fermentation, is more broadly applicable across residue types, including maize residue, sugarcane tops, and fruit and vegetable waste, and is now a major focus of research on retail and food-loss silage (Ominski et al., 2025). Feed efficiency or the fermentation of maize, sorghum or sugarcane silages specifically (Oliveira et al., 2017). This finding is important for the present review because it demonstrates that the benefit of a given processing technology is forage-specific rather than universal a theme returned.

Table 2. Processing Technologies for Agricultural Residue Upgrading

Technology	Primary mechanism	Expected benefit	Major limitation	Source(s)
Chopping	Particle-size reduction	Improved intake and handling	Limited effect on lignin	Sahoo et al. (2020)
Urea treatment	Ammoniation / fibre disruption	Higher CP and digestibility	Management and safety needs	Gunun et al. (2013)
Alkali treatment	Lignin disruption	Improved fibre accessibility	Chemical handling and cost	Sundstøl et al. (1978)

Technology	Primary mechanism	Expected benefit	Major limitation	Source(s)
Ensiling	Anaerobic fermentation	Preservation, palatability	Risk of poor fermentation	Ominski et al. (2025)
LAB inoculation	Controlled fermentation	Fermentation stability	Cost and variable response	Oliveira et al. (2017)
Fungal treatment	Selective lignin degradation	Improved fibre digestibility	Slow process, scale-up cost	van Kuijk et al. (2015)
Enzyme treatment	Cell-wall hydrolysis	Improved digestibility	Enzyme cost	Karnjanapratum et al. (2022)
Pelleting	Densification	Transport and storage efficiency	Energy requirement	Sahoo et al. (2020)
Drying	Moisture reduction	Extended shelf life	Energy requirement	Dou et al. (2024)

5. Effects on Dairy Productivity

Feeding trials across the literature show that treated crop residues genuinely move the needle on both feed performance and milk output, though the gains come with trade-offs worth managing: on the intake and digestibility side, urea and urea-lime treated straw consistently boosts voluntary intake by roughly 10–15% over untreated straw along with similar gains in total digestible nutrients (Walli, 2011), and controlled Latin-square trials with lactating dairy cows confirmed that urea-treated rice straw improves dry matter intake and organic matter digestibility, with urea-plus-calcium-hydroxide treatment matching those gains at a lower urea cost (Wanapat et al., 2009), this translates directly into milk performance on-farm trials report milk yield rising by roughly 0.5–1.5 litres per cow per day with urea-treated straw versus untreated (Walli, 2011), and fat-corrected milk yield along with protein and fat concentration followed a clear pattern, highest in cows fed urea-plus-calcium-hydroxide treated rice straw, moderately better with urea-treated straw alone, and lowest in untreated controls (Wanapat et al., 2009), with similar performance benefits showing up further down the ration too brewers' grains improve feed efficiency despite a modest dip in dry-matter intake, provided they stay under 20% of the diet (Chelkapally et al., 2024), and lactic acid bacteria inoculation lifts milk yield specifically in grass- and legume-silage diets (Oliveira et al., 2017); none of this comes free of management considerations, however, since ammoniation and alkali treatment measurably shift rumen pH and ammonia-nitrogen levels, meaning producers have to balance better fiber accessibility against the risk of excess ruminal ammonia (Wanapat et al., 2009), and oilseed cakes bring their own caution cottonseed products containing gossypol are generally manageable in moderate amounts since ruminants can detoxify it in the rumen, but high intakes risk reproductive and liver effects and beyond simple yield, these feeds also reshape milk quality in ways that matter commercially, with oilseed supplementation shifting the fatty-acid profile toward more conjugated linoleic acid, vaccenic acid, and unsaturated fats, at the cost of small reductions in milk fat and protein percentage, a trade-off that's particularly relevant for premium or health-focused dairy markets (Ramírez-Bribiesca et al., 2022).

6. Farmer Livelihoods and Economic Feasibility

Residue-based feeding strategies matter to farm economics primarily through feed-cost displacement rather than through dramatic yield gains alone. Urea treatment of paddy straw fed to lactating buffaloes has been reported to displace as much as 60% of oilseed cake requirement in the concentrate ration while maintaining a comparable milk response (Walli, 2011), directly reducing purchased-input cost. Brewers' grains inclusion improves feed efficiency, which combined with typically low or negative acquisition cost as an agro-industrial by-product improves margin per litre of milk even where absolute milk yield is not increased (Chelkapally et al., 2024). Residue collection, chopping, ensiling and custom feed-processing also generate rural non-farm employment, a benefit largely absents from conventional feeding-trial literature but repeatedly emphasised in circular-economy assessments of livestock systems in Africa and South Asia (Kaur et al., 2026).

7. Integrated Circular Bioeconomy Framework

The evidence synthesised can be organised into a single conceptual model (Figure 3) that treats crop production, residue processing, dairy feeding, milk output, manure recycling and soil nutrient return as one closed loop rather than as separate literatures. Crop production generates agricultural residues and

agro-industrial by-products, which undergo physical, chemical or biological processing to become upgraded dairy feed. The dairy animal converts this feed into milk (income, food security, nutrition) and manure (organic fertiliser, biogas, nutrient recovery). Manure returns nutrients to the soil, supporting the next crop cycle, while farm profit from milk sales supports reinvestment in feed technology and crop inputs. The loop is embedded within, and depends upon, external enablers technology availability, finance, extension services, policy incentives and functioning feed markets without which individual farmers cannot practically close the loop even where the underlying biology and economics are favourable.

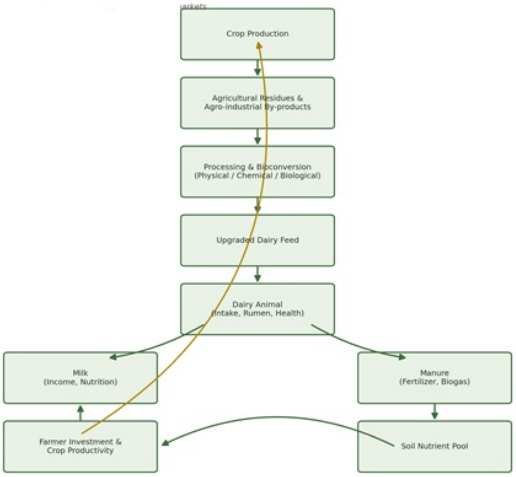


Figure 3. Integrated circular bio economy framework linking crop, feed, dairy animal, milk, manure and soil systems

8. Discussion

The evidence assembled in this review supports a central reframing of the question that most published feeding trials implicitly ask. The relevant question is not simply "does this feed increase milk yield?" but rather "does this biomass pathway produce more milk and farmer income per unit of resource use, while reducing waste and environmental burden, without compromising soil health or feed safety?" This reframing changes the review from a conventional animal-nutrition synthesis into a systems-level circular bioeconomy analysis, and it has three practical implications for researchers, extension services and policymakers.

First, technology recommendations should be residue-specific and context-specific rather than generic: the same lactic-acid-bacteria inoculation that reliably improves milk yield in grass and legume silage has no measurable effect in maize, sorghum or sugarcane silage (Oliveira et al., 2017), and urea treatment that is highly cost-effective for cereal straw is neither necessary nor economical for already protein-rich oilseed cakes. Second, environmental claims require an explicit accounting of the soil-residue trade-off; blanket statements that residue removal is environmentally beneficial are not supported by the evidence once soil organic carbon and erosion effects are included (Dutta et al., 2022). Third, technical efficacy alone does not predict adoption; the behavioural-economics literature reviewed shows that farmers weigh visible, short-term returns disproportionately, meaning that even nutritionally sound technologies with a demonstrated milk response may see limited uptake without complementary extension, credit and market-access interventions (Nyanga et al., 2021).

This review is subject to several limitations. It is a systematized rather than a full systematic review, and the literature base, while broad, is not exhaustive; several individual estimates cited (particularly on economic returns and adoption determinants) are drawn from context-specific studies whose findings may not generalise across agro-ecological zones.

9. Conclusion

Agricultural residues and agro-industrial by-products represent a substantial, currently under-used resource for dairy feeding, capable of simultaneously addressing feed shortages, reducing the environmental burden of residue burning and disposal, and improving smallholder farm profitability. The evidence reviewed here shows consistent, measurable gains in digestibility, intake and milk yield from physical, chemical and biological upgrading of cereal straw and other fibrous residues, alongside well-documented feed-cost and feed-efficiency benefits from oilseed cakes, brewers grains and fruit and vegetable by-products. These benefits are not, however, unconditional. They depend on matching the processing technology to the residue type, accounting for the trade-off between residue removal and soil health, ensuring food safety where food-loss streams are involved, and critically addressing the behavioural, institutional and financial barriers that determine whether a nutritionally sound technology is actually adopted and sustained on real farms. The integrated circular bioeconomy framework proposed in this review, linking crop production, residue processing, dairy feeding, milk output, manure recycling and soil nutrient return, offers a structure within which future research, extension and policy can jointly evaluate these dimensions rather than treating them in isolation. Waste-to-feed conversion in dairy systems is best understood not as a single technical fix but as a decision framework: identifying when, how and where agricultural residues should be converted into dairy feed to deliver the best combined nutritional, economic and environmental outcome.

References

1. Bakshi, M. P., Kaur, J., & Wadhwa, M. (2012). Nutritional evaluation of sun dried tomato pomace as livestock feed. Indian Journal of Animal Nutrition, 29, 136–144.
2. Chelkapally, S. C., Terrill, T. H., Ogunade, I. M., Estrada-Reyes, Z. M., & Pech-Cervantes, A. A. (2024). Meta-analysis of the effects of the dietary inclusion of brewers grains on feed intake, milk yield, and feed efficiency of lactating dairy cows. JDS Communications, 6(2), 172–177. https://doi.org/10.3168/jdsc.2024-0626
3. Deshmukh, S., Patel, R., & Joshi, D. (2026). Review: Nutritional, production, and safety aspects of converting food loss and waste into feed for livestock. Animal, 20(2), 101110.
4. Devendra, C. (2012). Rainfed areas and animal agriculture in Asia: The wanting agenda for transforming productivity growth and rural poverty alleviation. Agricultural Sciences, 3(2), 241–254.
5. Dou, Z., Fang, J., Zhang, Y., & Chen, S. (2024). Effects of fruit and vegetable waste addition on corn stalk silage quality. Animal Bioscience. Advance online publication. https://doi.org/10.5713/ab.24.0106
6. Dutta, A., Patra, A., Hazra, K. K., Nath, C. P., Kumar, N., & Rakshit, A. (2022). A state of the art review in crop residue burning in India: Previous knowledge, present circumstances and future strategies. Environmental Challenges, 8, 100581. https://doi.org/10.1016/j.envc.2022.100581
7. Frontiers in Sustainable Food Systems. (2022). Protein for human consumption from oilseed cakes: A review. Frontiers in Sustainable Food Systems, 6, 856401. https://doi.org/10.3389/fsufs.2022.856401
8. Gunun, P., Wanapat, M., & Anantasook, N. (2013). Rumen fermentation and performance of lactating dairy cows fed diets containing anhydrous milk fat and rice straw treated with urea. Asian-Australasian Journal of Animal Sciences, 26(9), 1295–1303. https://doi.org/10.5713/ajas.2013.13058
9. Hussain, Z., Rehman, A., & Iqbal, S. (2026). Ammoniation of low-quality roughages for dry-season ruminant feeding: A review. Tropical Animal Health and Production, 58, 145.
10. Iqbal, M. F., Cheng, Y. F., Zhu, W. Y., & Zeshan, B. (2008). Mustard oil cake as a protein supplement for lactating buffaloes. Tropical Animal Health and Production, 40(3), 175–181.
11. Jalal, H., Giaccone, N., Cascone, G., & Randazzo, C. L. (2023). Potential of fruits and vegetable by-products as an alternative feed source for sustainable ruminant nutrition and production: A review. Animals, 13(2), 286. https://doi.org/10.3390/ani13020286
12. Karnjanapratum, S., Prasertsan, P., & Yamsaengsung, R. (2022). Bioprocessing to upcycle agro-industrial and food wastes into high-nutritional value animal feed for sustainable food and agriculture systems. Resources, Conservation and Recycling, 190, 106847. https://doi.org/10.1016/j.resconrec.2022.106847
13. Kaur, R., Singh, M., & Chauhan, A. (2026). Circular food resources as feed in South Asia: Practices, gaps and implications for livestock systems – A systematic review with a focus on dairy production. Journal of Cleaner Production. Advance online publication.
14. Khan, N. A., Habib, G., & Sultan, A. (2011). Milk production of indigenous cattle fed supplements of mustard oil cake or azolla meal (Azolla filiculoides). Livestock Research for Rural Development, 26(4), Article 65.
15. Malla, B. A., Rastogi, A., Sharma, R. K., Ishfaq, A., & Farooq, J. (2015). Kinnow mandarin (Citrus nobilis lour × Citrus deliciosa tenora) fruit waste silage as potential feed for small ruminants. Veterinary World, 8(1), 19–23. https://doi.org/10.14202/vetworld.2015.19-23
16. National Dairy Research Institute. (2020). Challenges and opportunities in utilization of paddy straw as animal feed. Indian Farming, 70(5), 34–38.
17. Nyanga, A., Kessler, A., & Tenge, A. (2021). Determinants of smallholder farmers' adoption of short-term and long-term sustainable land management practices. Renewable Agriculture and Food Systems, 36(6), 552–564. https://doi.org/10.1017/S1742170520000441
18. Oliveira, A. S., Weinberg, Z. G., Ogunade, I. M., Cervantes, A. A. P., Arriola, K. G., Jiang, Y., Kim, D., Li, X., Gonçalves, M. C. M., Vyas, D., & Adesogan, A. T. (2017). Meta-analysis of effects of inoculation with homofermentative and facultative heterofermentative lactic acid bacteria on silage fermentation, aerobic stability, and the performance of dairy cows. Journal of Dairy

Science, 100(6), 4587–4603. https://doi.org/10.3168/jds.2016-11815
19. Ominski, K. H., Rinne, M., & McAllister, T. A. (2025). Ensiling of food waste for subsequent inclusion in ruminant diets. Canadian Journal of Animal Science. Advance online publication. https://doi.org/10.1139/cjas-2025-0021
20. Ramírez-Bribiesca, J. E., Hernández-Camacho, E., & Cobos-Peralta, M. (2022). Oilseed supplementation improves milk composition and fatty acid profile of cow milk: A meta-analysis and meta-regression. Animals, 12(13), 1699. https://doi.org/10.3390/ani12131699
21. Sahoo, A., Meena, D. K., & Chakurkar, E. B. (2020). Feeding value of paddy straw and its improvement strategies for ruminant livestock. Indian Journal of Animal Nutrition, 37(1), 1–13.
22. Sarwar, M., Shahzad, M. A., Nisa, M. U., Afzal, D., Sharif, M., & Saddiqi, H. A. (2011). Feeding value of urea molasses-treated wheat straw ensiled with fresh cattle manure for growing crossbred cattle calves. Tropical Animal Health and Production, 43(3), 543–548. https://doi.org/10.1007/s11250-010-9727-0
23. Teklewold, H., Mekonnen, A., & Kohlin, G. (2021). Farmer adoption of sustainable intensification technologies in the maize systems of the Global South: A review. Agronomy for Sustainable Development, 41, Article 5. https://doi.org/10.1007/s13593-020-00658-9
24. van Kuijk, S. J. A., Andres Sanchez, D., Cone, J. W., Baars, J. J. P., Hendriks, W. H., & Sonnenberg, A. S. M. (2016). Intraspecies variation offers potential to improve white rot fungi for increasing degradability of lignocellulose for ruminants. Journal of Fungi, 10(12), 858.
25. van Kuijk, S. J. A., Sonnenberg, A. S. M., Baars, J. J. P., Hendriks, W. H., & Cone, J. W. (2015). Fungal treated lignocellulosic biomass as ruminant feed ingredient: A review. Biotechnology Advances, 33(1), 191–202. https://doi.org/10.1016/j.biotechadv.2014.10.014
26. Walli, T. K. (2011). Improving nutritional qualities of straw with urea. National Dairy Research Institute.
27. Wanapat, M., Polyorach, S., Boonnop, K., Mapato, C., & Cherdthong, A. (2009). Effects of treating rice straw with urea or urea and calcium hydroxide upon intake, digestibility, rumen fermentation and milk yield of dairy cows. Livestock Science, 125(2–3), 238–243. https://doi.org/10.1016/j.livsci.2009.05.001