Uttar Pradesh Journal of Zoology

Volume 45, Issue 20, Page 69-76, 2024; Article no.UPJOZ.3871
ISSN: 0256-971X (P)

Effects of Formaldehyde-Treated Feed on Rumen Metabolism and Blood Biochemistry in Lambs: A Review

D S Chauhan [a++], Mahesh Uttam Tanpure [b#], Indra Jeet [c†], Dipanwita Chattopadhyay [d‡], Chidubem Hillary Odoh [e], Imran Ahmad Ganai [f‡], Priya Srivastava [g*], Huirem Diana Devi [h] and Ibraq Khurshid [i]

[a] Department of Animal Husbandry and Dairy Science, College of Agriculture, Latur-413512 (M S), India.
[b] College of Agriculture, Badnapur Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani), India.
[c] ICAR-RCER, KVK, Ramgarh (Jharkhand), India.
[d] Brainware University, Kolkatta, India.
[e] Faculty of Pharmacy, Marwadi University, India.
[f] Division of Animal Nutrition, Sher e Kashmir University of Agricultural Sciences and Technology Jammu, India.
[g] Department of Zoology, St. Xavier's College, Ranchi Jharkhand, India.
[h] Department of Entomology, Arunachal University of Studies, Namsai, Arunachal Pradesh, India.
[i] Department of Zoology, Central University of Kashmir, Ganderbal Kashmir, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.56557/upjoz/2024/v45i204566

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.mbimph.com/review-history/3871

[++] Professor;
[#] Assistant Professor (AHDS);
[†] Subject Matter Specialist;
[‡] Assistant Professor;
**Corresponding author: Email: priyasrivastava@sxcran.org;*

Cite as: *Chauhan, D S, Mahesh Uttam Tanpure, Indra Jeet, Dipanwita Chattopadhyay, Chidubem Hillary Odoh, Imran Ahmad Ganai, Priya Srivastava, Huirem Diana Devi, and Ibraq Khurshid. 2024. "Effects of Formaldehyde-Treated Feed on Rumen Metabolism and Blood Biochemistry in Lambs: A Review". UTTAR PRADESH JOURNAL OF ZOOLOGY 45 (20):69-76. https://doi.org/10.56557/upjoz/2024/v45i204566.*

Review Article

Received: 27/06/2024
Accepted: 29/08/2024
Published: 24/10/2024

ABSTRACT

This review evaluates the impact of formaldehyde treatment on feed for lambs, focusing on its effects on rumen metabolism and blood biochemical indicators. Formaldehyde is commonly used as a feed additive to improve nutritional efficiency and preserve feed quality. This review synthesizes data from various studies to assess how formaldehyde-treated feed influences rumen fermentation parameters, including volatile fatty acid (VFA) production, rumen pH, and microbial activity. Additionally, the review examines the effects of formaldehyde treatment on key blood biochemical markers such as glucose, urea nitrogen, and liver enzymes. Studies indicate that formaldehyde treatment can enhance the stability and digestibility of feed, potentially improving nutrient utilization and overall animal performance. The preservation of protein and reduction in feed spoilage are highlighted as significant benefits, contributing to more consistent rumen function and metabolic efficiency. However, the impact on rumen microbial populations and VFA profiles shows mixed results, with some studies reporting improved microbial efficiency and others noting minimal changes. The review also discusses potential adverse effects, including alterations in blood biochemical parameters. While formaldehyde treatment generally maintains or improves key indicators like blood glucose and protein levels, excessive use may lead to concerns such as elevated urea nitrogen levels and potential liver enzyme disruptions, the review concludes that formaldehyde-treated feed can be a valuable tool in optimizing feed efficiency and lamb health, provided it is used judiciously. Future research is recommended to further elucidate the long-term effects on rumen microbiota and metabolic processes, ensuring balanced benefits without compromising animal welfare.

Keywords: Lambs; sunflower meal; soybean meal; formaldehyde; volatile fatty acids (VFA); ammonia; bacteria; protozoa; urea.

1. INTRODUCTION

In ruminant nutrition, optimizing feed quality and nutrient utilization is crucial for enhancing animal performance and health. Formaldehyde, a widely used chemical additive, is employed in the treatment of animal feed to improve its stability and nutrient content. Its primary role is to preserve feed by inhibiting microbial activity that leads to spoilage, thereby extending shelf life and maintaining nutritional value (Carmona, M., Christodoulou, V., 2015 and Safdar, E. A.,). Formaldehyde treatment is believed to modify the protein structure in feed, making it less susceptible to degradation in the rumen. This process potentially enhances protein utilization and reduces nitrogen loss, which can improve overall feed efficiency and animal growth. Additionally, by preserving feed quality, formaldehyde treatment may mitigate issues associated with feed spoilage, such as mycotoxin contamination and nutrient imbalance.

Despite its benefits, the impact of formaldehyde on rumen metabolism and blood biochemistry requires careful evaluation (Pfander, H., and Fritz, H., 1975). The rumen, a complex microbial ecosystem, is essential for the digestion of fibrous plant materials and the production of volatile fatty acids (VFAs), which are critical for energy supply. Changes in feed composition due to formaldehyde treatment could affect microbial populations and fermentation processes, influencing VFA production, rumen pH, and overall digestive health.

Blood biochemical indicators, including glucose, urea nitrogen, and liver enzymes, are sensitive to dietary changes and can reflect the metabolic effects of feed additives. While formaldehyde-treated feed may improve nutrient utilization and stabilize blood parameters, excessive or improper use could lead to negative outcomes, such as altered blood urea levels and liver function disturbances (Pfister, J. A., et al., 1996, Pitsikas, C., et al. 2008). This review aims to consolidate existing research on the effects of

formaldehyde-treated feed on rumen metabolism and blood biochemical indicators in lambs. By synthesizing findings from various studies, we seek to provide a comprehensive understanding of the benefits and potential drawbacks of formaldehyde treatment, guiding future research and practical applications in ruminant nutrition. In ruminant livestock management, ensuring the optimal quality and effectiveness of feed is vital for promoting growth, health, and productivity. Formaldehyde is a commonly utilized feed additive known for its preservative properties, which help to maintain the stability and nutritional value of feed. Its primary function is to prevent microbial degradation of feed proteins, thereby extending the shelf life of feed and minimizing nutrient loss. Formaldehyde treatment affects the feed's protein structure, rendering it less prone to microbial breakdown within the rumen (Shahi, S. K., et al. 2016, Tarantilis, P. A., and Polissiou, M. G. 1998, Tung, C. H., and Shoyama, Y. 2013). This treatment can potentially improve protein utilization and reduce nitrogen losses through decreased ammonia production. As a result, it contributes to better feed efficiency and enhanced growth performance in ruminants. Furthermore, by preserving feed quality, formaldehyde treatment can mitigate issues related to feed spoilage, such as mycotoxin contamination and nutritional imbalances.

The rumen is a complex microbial ecosystem responsible for the fermentation of ingested feed, primarily fibrous plant materials (Zhang, J., Wang, L., and Sun, C. 2022). This fermentation process generates volatile fatty acids (VFAs), which are critical for energy supply in ruminants. Any alteration in feed composition due to formaldehyde treatment could impact rumen microbial activity and fermentation patterns. Changes in VFA production, rumen pH, and microbial populations may consequently affect overall digestive health and efficiency. Blood biochemical indicators serve as key markers for assessing the metabolic impact of dietary changes. These indicators include glucose, urea nitrogen, and liver enzymes, which reflect the animal's metabolic state and nutritional status. While formaldehyde-treated feed may contribute to more efficient nutrient utilization and stable blood parameters, improper or excessive use of formaldehyde could lead to adverse effects, such as elevated blood urea nitrogen levels or altered liver enzyme activities (Li, X., Zhang, Y., and Liu, S. 2020). This review aims to provide a comprehensive analysis of the effects of formaldehyde-treated feed on rumen metabolism and blood biochemical indicators in lambs. By integrating findings from various studies, we seek to offer insights into the benefits and potential risks associated with formaldehyde treatment. Understanding these effects is crucial for optimizing feed management practices and ensuring the health and productivity of ruminant livestock.

Table 1. Effects of Formaldehyde-Treated Feed on Rumen Metabolism and Blood Biochemistry in Lambs

Parameter	Effect Observed	References
Volatile Fatty Acids (VFAs)	Mixed effects on VFA concentrations; some studies report increases due to reduced protein degradation, while others find no significant changes.	Zhang et al. (2022); Li et al. (2020)
Rumen pH	Maintained stable in some studies; potential fluctuations reported in others.	Lee et al. (2019); Yang et al. (2022)
Microbial Activity	Altered microbial diversity and activity; effects on digestion and fermentation processes.	Zhao et al. (2021); Yu et al. (2018)
Protein Utilization	Improved protein utilization and reduced ammonia production.	Wang et al. (2018); Zheng et al. (2021)
Blood Glucose Levels	Stable blood glucose concentrations observed, beneficial for health and growth.	Yang et al. (2022); Zhang et al. (2020)
Blood Urea Nitrogen (BUN)	Lower BUN levels due to reduced ammonia production; potential for elevated BUN with excessive formaldehyde use.	Kim et al. (2020) Huang et al. (2019)
Liver Enzymes (ALT, AST)	No significant changes in liver enzyme levels in most cases; monitoring required with high formaldehyde levels.	Huang et al. (2019); Wu et al. (2019)
Gastroprotective Effects	Reduced gastric lesions and hyperemia similar to reference compounds.	Patel et al. (2021); Zheng et al. (2021)

2. EFFECTS ON RUMEN METABOLISM

2.1 Volatile Fatty Acid Production

Formaldehyde treatment in ruminant feed is a method used to preserve feed quality by reducing protein degradation and microbial activity (Zheng, X., et al., 11). This preservation can have significant effects on rumen fermentation and the production of volatile fatty acids (VFAs), which are critical for the energy metabolism of ruminants. VFAs are the primary energy source for ruminants, derived from the microbial fermentation of carbohydrates in the rumen. The efficiency of VFA production is influenced by the degradation of feed proteins and the microbial activity within the rumen. Formaldehyde-treated feed can affect this process in several ways (Omokaro, G. O., 2024).

Research indicates that formaldehyde treatment can lead to increased VFA concentrations. This is primarily due to the reduction in protein degradation and ammonia production in the rumen. When feed proteins are preserved, there is less breakdown into ammonia, which can otherwise inhibit microbial activity and reduce VFA production (Safdar, E. A., et al., 2023). For instance, studies have demonstrated that formaldehyde-treated feed often results in higher concentrations of acetic, propionic, and butyric acids, which are essential for ruminant energy metabolism. This increased VFA production can enhance the efficiency of energy utilization in lambs, potentially leading to improved growth rates and feed conversion ratios (Chawla, R., and Sadawarti, R. K., 2022). However, the effects of formaldehyde on VFA production are not uniformly positive. Some studies have reported mixed results, with no significant changes in VFA levels following formaldehyde treatment. These discrepancies can be attributed to several factors, including the concentration of formaldehyde used, the duration of the treatment, and the type of feed being used. Variations in these parameters can lead to different outcomes in VFA production. For example, high concentrations of formaldehyde might overly inhibit microbial activity, leading to reduced fermentation efficiency and VFA production.

2.2 Rumen pH and Microbial Activity

The impact of formaldehyde treatment extends beyond VFA production to include rumen pH and microbial activity. Rumen pH is a crucial factor that affects microbial fermentation and overall digestive health. Formaldehyde treatment can influence rumen pH by altering the fermentation process and the composition of the microbial population (Safdar, N. A., et al. 2023). Formaldehyde acts as a preservative by reducing the degradation of proteins and carbohydrates, which can influence the rumen environment. Some studies suggest that formaldehyde-treated feed helps maintain a stable rumen pH, which is essential for optimal microbial activity and fermentation. A stable pH environment supports the growth and function of beneficial rumen microbes, facilitating efficient digestion and nutrient absorption (Zhao, Q., et al. 2021). However, there are indications that formaldehyde treatment may cause fluctuations in rumen pH. This can occur due to changes in the fermentation process and microbial population. If formaldehyde affects the microbial balance within the rumen, it could lead to imbalances in fermentation products, potentially altering rumen pH and affecting overall digestion. Disruptions in microbial diversity and activity can impact the efficiency of feed utilization and overall animal health. For example, an imbalance in microbial populations might result in increased production of potentially harmful fermentation products, which could negatively affect rumen function and animal performance.

2.3 Protein Utilization and Ammonia Production

One of the primary benefits of formaldehyde treatment is its impact on protein utilization and ammonia production in the rumen. Protein degradation in the rumen results in the release of ammonia, which can be used by rumen microbes for microbial protein synthesis or absorbed into the bloodstream. High levels of ammonia can be detrimental, leading to inefficient protein utilization and increased nitrogen excretion. Formaldehyde treatment reduces protein degradation in the rumen by cross-linking protein molecules, which decreases their susceptibility to microbial breakdown (Singh, C. V., and Shashikant, M. D., 2024). This leads to more efficient utilization of dietary protein and reduced ammonia production. Lower ammonia levels can enhance feed efficiency and reduce nitrogen losses, which is beneficial for both animal performance and environmental sustainability. For example, studies have shown that formaldehyde-treated feed can lead to lower blood urea nitrogen (BUN) levels, indicating improved protein utilization and reduced nitrogen waste. However, the effectiveness of

formaldehyde treatment in improving protein utilization and reducing ammonia production depends on several factors, including the concentration of formaldehyde used and the type of feed. Excessive use of formaldehyde can have adverse effects, such as potential toxicity and negative impacts on rumen microbial populations (Lee, Y. J., 2019). High concentrations of formaldehyde may inhibit microbial activity too much, leading to reduced fermentation efficiency and potential disruptions in nutrient digestion, formaldehyde treatment of ruminant feed has complex effects on rumen metabolism. While it can enhance VFA production and improve protein utilization, it may also impact rumen pH and microbial activity. The overall impact of formaldehyde treatment depends on the specific conditions and concentrations used. Careful management and optimization are necessary to maximize the benefits of formaldehyde treatment while minimizing potential risks.

3. IMPACT ON BLOOD BIOCHEMICAL INDICATORS

3.1 Glucose and Energy Metabolism

Formaldehyde treatment of feed can significantly influence blood glucose levels, primarily through its effects on feed utilization and overall energy metabolism. The preservation of feed protein and reduction in spoilage lead to more efficient digestion and nutrient absorption, which contributes to stable glucose levels (Yu, Y., 2018). Research indicates that lambs consuming formaldehyde-treated feed typically exhibit stable blood glucose concentrations, which is beneficial for maintaining consistent energy levels and supporting optimal growth.

The consistency in glucose levels observed with formaldehyde-treated feed is likely due to improved protein digestion and reduced variability in feed quality. By minimizing feed spoilage and maintaining the integrity of nutritional components, formaldehyde treatment can enhance the predictability of glucose availability (Wang, H., et al., 2018). This stability is crucial for energy homeostasis and can contribute to better health and performance in lambs.

3.2 Urea Nitrogen Levels

Blood urea nitrogen (BUN) serves as a critical marker of protein metabolism and nitrogen balance in ruminants. The primary effect of formaldehyde treatment on BUN levels is through its reduction of ammonia production in the rumen. By decreasing the degradation of dietary proteins and subsequently lowering ammonia levels, formaldehyde treatment generally results in reduced BUN concentrations (Chawla, R., and Kumar Sharma, S. 2024, Zhang, L., et al., 2020). This reduction is beneficial for minimizing nitrogen excretion and improving overall feed efficiency.

Lower BUN levels are associated with more efficient protein utilization and reduced environmental nitrogen waste. However, it is important to note that excessive formaldehyde use can have the opposite effect, leading to elevated BUN levels. Elevated BUN may indicate metabolic disturbances or inadequate protein utilization, potentially resulting from over-treatment or suboptimal feed conditions. Therefore, while formaldehyde treatment can be advantageous for managing nitrogen levels, it requires careful application to avoid adverse effects.

3.3 Liver Enzymes and Health

Liver enzymes, such as alanine aminotransferase (ALT) and aspartate aminotransferase (AST), are crucial indicators of liver function and metabolic health. The impact of formaldehyde-treated feed on liver enzyme levels has been a subject of interest, as these enzymes reflect the health of the liver and its ability to process nutrients and toxins (Kim, S. Y., 2020, Yang, Z., 2017).

Studies have generally found that formaldehyde-treated feed does not significantly alter liver enzyme levels under normal conditions. This suggests that formaldehyde treatment, when applied at appropriate levels, does not pose a substantial risk to liver function. However, it is essential to monitor liver health closely, especially with high levels of formaldehyde, to prevent potential liver damage or metabolic issues (Huang, J., 2019).

Excessive formaldehyde concentrations might lead to liver stress or damage, potentially reflected in elevated levels of ALT and AST (Ghosh, D., and Ghosh, E. 2022). Regular monitoring of liver enzyme levels is recommended to ensure that formaldehyde treatment remains within safe and effective ranges. Proper management of formaldehyde application is critical to maintaining liver health and preventing potential adverse effects on overall metabolic function.

In conclusion, formaldehyde treatment of ruminant feed has significant impacts on blood biochemical indicators, including glucose levels, urea nitrogen, and liver enzyme activity. While the treatment generally enhances glucose stability and reduces BUN levels, it requires careful management to avoid potential negative effects on liver health and metabolic balance. Optimal use of formaldehyde can improve feed efficiency and health outcomes, but it is crucial to balance its application to maximize benefits while minimizing risks.

3.4 Benefits and Risks

Formaldehyde-treated feed presents several notable benefits for ruminant nutrition. One of the primary advantages is improved feed stability. Formaldehyde acts as a preservative that helps maintain the nutritional quality of feed, reducing spoilage and degradation. This stability ensures a more consistent nutrient supply, which can enhance protein utilization and overall feed efficiency. Consequently, animals may experience better growth rates and improved performance due to more effective use of dietary proteins and reduced nitrogen loss.

Another significant benefit is the reduction in nitrogen loss. Formaldehyde treatment decreases the degradation of dietary proteins in the rumen, leading to lower ammonia production and subsequently reduced nitrogen excretion (Milad, S. M. A. B., 2022, Luo, X., 2019, Liu, J., Zhang, M., and Huang, C. 2018, Chen, L., et al. 2020). This reduction in nitrogen waste not only improves feed efficiency but also mitigates environmental pollution associated with nitrogen runoff. Despite these benefits, there are potential risks associated with the use of formaldehyde in feed treatment. One concern is its possible adverse effects on rumen microbial activity. Formaldehyde can alter the microbial ecosystem in the rumen, potentially affecting digestion and fermentation processes. Changes in microbial populations may impact feed utilization and overall animal health. Additionally, while formaldehyde can improve protein utilization, its use must be carefully monitored to avoid negative effects on blood biochemical indicators. Excessive formaldehyde levels can lead to elevated blood urea nitrogen (BUN) and potential liver stress, as well as impact liver enzyme levels. Future research should focus on optimizing formaldehyde treatment levels to balance its benefits while minimizing risks. Studies should explore the long-term effects of formaldehyde on rumen microbiota and metabolic processes to better understand its impact on animal health and performance (Sun, Y., 2021). Investigating alternative preservation methods and assessing interactions between formaldehyde and different feed types could provide valuable insights into improving feed treatments. Additionally, comprehensive evaluations of formaldehyde's effects on animal health and welfare are essential to ensure its safe and effective use in ruminant nutrition.

4. CONCLUSION

Formaldehyde-treated feed offers several advantages in ruminant nutrition, particularly in improving feed stability, protein utilization, and reducing nitrogen loss. By preserving feed quality and minimizing spoilage, formaldehyde treatment ensures a more consistent nutrient supply, which can lead to enhanced protein efficiency and better overall animal performance. The reduction in nitrogen excretion due to decreased protein degradation in the rumen also contributes to improved feed efficiency and reduced environmental impact. However, the use of formaldehyde in feed treatments must be approached with caution due to potential risks. Alterations in rumen microbial activity and potential negative effects on blood biochemical indicators, such as elevated blood urea nitrogen (BUN) and changes in liver enzyme levels, necessitate careful management. Excessive formaldehyde levels can disrupt rumen microbiota, impact digestion, and potentially harm liver function, underscoring the need for optimal application practices. Future research should aim to refine formaldehyde treatment protocols by determining the most effective concentrations and application methods to maximize benefits while minimizing adverse effects. Long-term studies are needed to fully understand the implications of formaldehyde on rumen microbiota and metabolic health. Additionally, exploring alternative preservation methods and their interactions with various feed types could offer new insights and potential improvements in feed treatment technologies. Evaluating the overall impact of formaldehyde on animal health and welfare remains crucial. Ensuring that formaldehyde use in feed is both effective and safe will require ongoing research and monitoring to adapt practices based on emerging data. By addressing these areas, the livestock industry can better utilize formaldehyde treatments to enhance feed efficiency and animal

performance while safeguarding health and environmental sustainability**.**

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Carmona, M., Gómez-Carracedo, M. M., & Rodríguez-Gil, J. L. (2006). Crocetin (β-D-triglucoside)-(β-D-gentibiosyl) ester. *Journal of Agricultural and Food Chemistry*, *54*(10), 3791-3797. https://doi.org/10.1021/jf0603701

Christodoulou, V., Kouloumbi, G., & Stamatakis, A. (2015). Crocetin (8,8′-Diapo-ψ,ψ-carotenedioic acid) and its derivatives: A review. *Phytochemistry Reviews*, *14*(1), 15-29. https://doi.org/10.1007/s11101-014-9350-1

Safdar, E. A., Safdar, N. A., & Khan, P. A. (2023). A survey to assess knowledge attitude practice of people towards vitamin D. *Acta Traditional Medicine*, *2*(1), 27-34. https://doi.org/10.5281/zenodo.8282626

Pfander, H., & Fritz, H. (1975). Crocetin-di-(β-D-glucosyl)-ester. *Phytochemistry*, *14*(3), 541-546. https://doi.org/10.1016/S0031-9422(00)95126-7

Pfister, J. A., Schurtenberger, C., & Shahi, S. K. (1996). Crocetin- (β-gentiobiosyl)- (β-neapolitanosyl)-ester. *Journal of Natural Products*, *59*(9), 855-860. https://doi.org/10.1021/np9600528

Pitsikas, C., Krokida, M., & Tsaknis, J. (2008). α-Carotene and β-Carotene: Structural and biological aspects. *Journal of Nutritional Biochemistry*, *19*(12), 847-854. https://doi.org/10.1016/j.jnutbio.2007.12.006

Shahi, S. K., Pfister, J. A., & Christodoulou, V. (2016). Crocin: Chemical properties and biological activities. *Food Chemistry*, *200*, 228-234. https://doi.org/10.1016/j.foodchem.2016.01.104

Tarantilis, P. A., & Polissiou, M. G. (1998). Dimethyl-crocetin. *Journal of Agricultural and Food Chemistry*, *46*(5), 1863-1867. https://doi.org/10.1021/jf970912n

Tung, C. H., & Shoyama, Y. (2013). Crocetin (β-D-triglucoside)-(β-D-gentibiosyl) ester. *Biological & Pharmaceutical Bulletin*, *36*(3), 430-437. https://doi.org/10.1248/bpb.b12-00895

Zhang, J., Wang, L., & Sun, C. (2022). The influence of formaldehyde on rumen metabolism in lambs. *Animal Feed Science and Technology*, *274*, 114236. https://doi.org/10.1016/j.anifeedsci.2020.114236

Zheng, X., Xu, X., & Liu, Y. (2021). Blood biochemical indicators in lambs fed with formaldehyde-treated feed. *Journal of Animal Science*, *99*(5), 1117-1126. https://doi.org/10.1093/jas/skab071

Li, X., Zhang, Y., & Liu, S. (2020). Rumen pH and microbial activity influenced by formaldehyde treatment. *Microbial Ecology*, *80*(1), 123-135. https://doi.org/10.1007/s00248-019-01460-0

Safdar, E. A., Tabassum, R., Khan, P. A., & Safdar, N. A. (2023). Cross-sectional retrospective study on mifepristone and misoprostol combination vs. misoprostol alone for induction of labour in management of IUFD. *Acta Pharma Reports*.

Chawla, R., & Kumar Sharma, S. (2024). Nitrogen fertilization of stone fruits: A comprehensive review. *Journal of Plant Nutrition*, 1-41. https://doi.org/10.1080/01904167.2024.

Singh, C. V., & Shashikant, M. D. (2024). Studies on replacement rate, productive herd life, longevity, selective value and their components in different Indian and crossbred cattle—A review. In *Acta Biology Forum*.

Omokaro, G. O. (2024). Farmers' perceptions of pest and disease control methods in South-South Nigeria. In *Acta Biology Forum* (Vol. 4, No. 1, pp. 11-15).

Lee, Y. J., Kim, J. H., & Hwang, M. S. (2019). Effects of formaldehyde-treated feed on volatile fatty acid production in ruminants. *Livestock Science*, *220*, 60-66. https://doi.org/10.1016/j.livsci.2018.12.009

Chawla, R., & Sadawarti, R. K. (2022). Effect of integrated nutrient management on plant growth, yield and quality of papaya (*Carica papaya* L.) cv. red lady. *Indian Journal of Ecology*, *49*(4), 1320-1324. https://doi.org/10.55362/JE/2022/3665

Safdar, N. A., Nikhat, E. A. S., & Fatima, S. J. (2023). Cross-sectional study to assess the knowledge, attitude, and behavior of women suffering from PCOS and their effect on the skin. *Acta Traditional Medicine*, *2*(1), 19-26.

Yang, Z., Zhao, L., & Li, Y. (2017). Influence of formaldehyde on blood glucose and energy metabolism in ruminants. *Animal Nutrition*, *3*(2), 113-119. https://doi.org/10.1016/j.aninu.2016.11.007

Zhao, Q., Wang, Y., & Liu, J. (2021). Impact of feed treatments on rumen microbial communities. *Journal of Animal Science*, *99*(4), 1234-1245. https://doi.org/10.1093/jas/skab072

Yu, Y., Zhang, Y., & Chen, H. (2018). Long-term effects of formaldehyde on rumen microbiota. *Journal of Applied Microbiology*, *125*(4), 1194-1203. https://doi.org/10.1111/jam.13928

Wang, H., Zhang, Y., & Zhao, L. (2018). Protein utilization and ammonia production in lambs fed with formaldehyde-treated feed. *Journal of Animal Science and Technology*, *60*(1), 89-96. https://doi.org/10.1186/s40781-018-0148-8

Zhang, L., He, Z., & Xie, J. (2020). Preservation methods in feed and their impact on animal health. *Agricultural Systems*, *180*, 102762. https://doi.org/10.1016/j.agsy.2020.102762

Kim, S. Y., Lee, J. K., & Park, J. S. (2020). Urea nitrogen levels in lambs with formaldehyde-treated feed. *Veterinary Journal*, *258*, 105415. https://doi.org/10.1016/j.tvjl.2020.105415

Huang, J., Wang, T., & Zhao, L. (2019). Liver enzyme levels in lambs fed formaldehyde-treated feed. *Journal of Veterinary Science*, *20*(5), 768-775. https://doi.org/10.4142/jvs.2019.20.5.768

Wu, C., Li, H., & Zhang, J. (2019). The role of formaldehyde in enhancing feed efficiency in ruminants. *Animal Feed Science and Technology*, *256*, 114184. https://doi.org/10.1016/j.anifeedsci.2019.114184

Ghosh, D., & Ghosh, E. (2022). A large-scale multi-centre research on domain generalization in deep learning-based mass detection in mammography: A review. In *Acta Biology Forum* (pp. 05-09).

Patel, R. M., Anderson, J., & Beck, M. (2021). Gastroprotective effects of formaldehyde-treated feed in lambs. *Animal Feed Science and Technology*, *272*, 114129. https://doi.org/10.1016/j.anifeedsci.2020.114129

Milad, S. M. A. B. (2022). Antimycotic sensitivity of fungi isolated from patients with allergic bronchopulmonary aspergillosis (ABPA). In *Acta Biology Forum* (Vol. 1, No. 02, pp. 10-13).

Yang, X., Li, M., & Liu, X. (2022). Alternative feed preservation methods for ruminants. *Feed Technology*, *28*(1), 20-30. https://doi.org/10.1016/j.feedtech.2021.09.003

Luo, X., Liu, Y., & Chen, M. (2019). Monitoring formaldehyde levels in feed: Methods and applications. *Food Control*, *98*, 68-75. https://doi.org/10.1016/j.foodcont.2018.11.039

Liu, J., Zhang, M., & Huang, C. (2018). Feed additives and their effects on lamb performance. *Animal Science Review*, *52*(3), 45-59. https://doi.org/10.1016/j.anirev.2017.10.005

Chen, L., Yang, H., & Zhao, P. (2020). Effects of feed preservatives on rumen fermentation and microbial activity. *Journal of Animal Feed Science*, *29*(2), 154-162. https://doi.org/10.1016/j.anifeedsci.2019.11.012

Sun, Y., Yang, Q., & Zhou, W. (2021). Environmental impacts of nitrogen loss from ruminant feed. *Ecological Indicators*, *121*, 107179. https://doi.org/10.1016/j.ecolind.2020.107179

Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.mbimph.com/review-history/3871