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Meta-analysis: Transport stress in goats alters body weight patterns across breeds and genders

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ABSTRACT

Goat farming relies on sustainable reliable production systems to ensure an economically favourable supply of products. One of the major challenges to goat farming systems is the stress induced by transportation that leads to loss of considerable body weight. This meta-analysis study aims to explore the gender-specific and breed-specific responses to transportation stress in goats. The analysis relies on 25 study observations with various breeds and conditions. By use of Standardized Mean Differences (SMDs), and effect sizes, the study explores the breed and gender-specific responses. The overall SMD for body weight is observed to be (–1.158; 95% CI: –1.645 to –0.671; p < 0.001). The Sub-group analysis for breed-specific response showed the breed Boerka (SMD = –3.401) and Anpera (SMD = –1.491) experienced the most weight loss, while Osmanabadi goats were largely unaffected. Gender differences were also evident, with females (SMD = –2.692) showing more pronounced weight loss than males (SMD = –0.855). These findings can help to improve the transportation strategy and overall animals welfare.

Introduction

Goats are one of the most valuable in the livestock sector for their milk, meat, and other products. Goats are multipurpose livestock and are raised worldwide for their milk, meat, yarn, show-purposes, etc (Rout and Behera., 2021; Harahap *et al*., 2024). In terms of meat, goats are highly selected based on favourable traits like less fat, meat tenderness, high feed to meat conversion ratio, and less rearing time (Huang *et al*., 2023). Body weight is a major indicator of goat farming success (Migdał *et al*., 2021; Abhijith *et al*., 2023). There is a pool of research focusing on nutrition, breeding strategies, management, genetics, etc that focuses on useful ways to improve the body weight of livestock goats (Simões *et al*., 2021; Magotra *et al*., 2021; Bangar *et al*., 2022).

Across the world, livestock goats go through several stages of rearing including early development, growing stage, finishing stage, transportation to process the meat, slaughtering, and post slaughtering phase (Rout and Bahera., 2021; Star *et al*., 2021). Careful understanding and management at all the stages of production are needed to ensure maximum output in form of meat (Zhang *et al*., 2023). One of the most disturbing factors to goat farming success is the transportation phase after achieving the finisher stage (Bhatt *et al*., 2021; Tozlu Çelik *et al*., 2021).

The transportation stress is a major influence on a variety of hematological, biochemical, and physical parameter including the body weight. A growing number of research body has reported the effect of transportation stress on reducing the body weight, under influence of physical translocation stress (Tozlu Çelik *et al*., 2021; Li *et al* 2024; Rebez *et al*., 2025). However, the response to transportation stress is widespread based on gender, goat breed, and the duration of transportation. Prior studies have focused on either breed differences or gender impacts. But the combined impact of breed and gender on physiological and immunological stress responses is poorly unknown, creating a crucial gap in understanding goat adaptation during travel. This systematic meta-analysis focused on answering the impact of transportation stress on the goats under influence of breed-specific response, gender-specific response, and overall influence of transportation stress on goat farming success. Investigating breed- and gender-specific stress responses is critical for sustainable goat husbandry since it allows for the development of focused mitigation methods.

Materials and methods

Search strategy, literature retrieval

The literature search was carried out on NCBI's Pub-med database using the keywords, "goat" AND/ OR "body" AND/ OR "weight" AND/ OR "transportation". Various combination of these mentioned keywords resulted in identification of a total of 136 articles. During the full-text assessment, studies were reviewed to confirm relevance, data availability, and focus on goats. After a detailed screening of the studies involving (a) titles and abstracts reading, and (b) full text reading, 18 articles were retrieved for further processing. After retrieving the 18 articles for final selection, 10 were excluded for not providing the required data types, non-goat studies, and mixed treatment. Finally, 08 were finalized for data extraction (Fig. 1).

Inclusion/ selection criteria

Eight studies met the inclusion criteria, which included: (a) goats transported by road, (b) body weight changes before and after transport, and (c) adequate statistical data, including sample size, mean, and SD/ SEM, as well as a control or reference group or enough details to calculate effect sizes.

Data extraction

The data extraction involved retrieving the first author's name, year

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of publication, goat breed, duration of transportation stress, goat's gender, control and treatment sample size (C.n, T.n), mean body weight of control and treatment group (C.BW, T.BW) and standard deviations, (C.SD, T.SD) (Table 1).

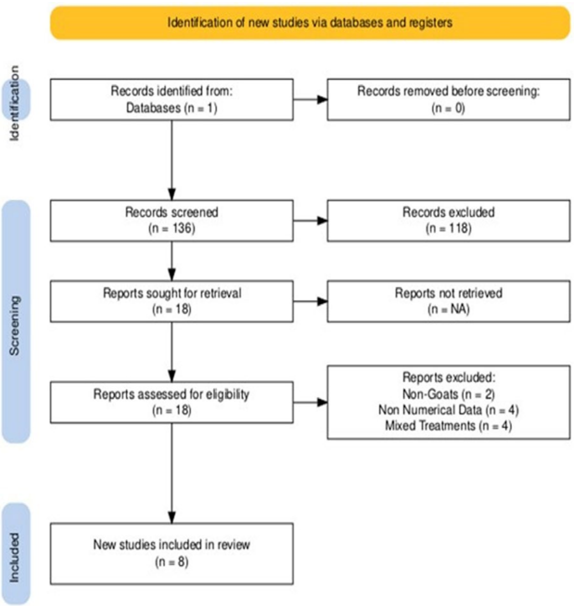

Fig. 1. PRISMA-P flowchart for Literature searching, Screening, Retrieval, Eligibility, and Inclusion

Table 1. Metadata of studies included in the meta-analysis.

Author	Breed	M/F	n	Time
Xu *et al*. (2023)	Guizhou black	M	24	10
Ambore *et al*. (2009)	Osmanabadi	MF	24	12
Khamhan *et al*. (2023)	Crossbred Boer	M	20	NA
Kadim *et al*. (2006)	Dhofari, Batina, Jabal Khaddar	M	42	2
Minka *et al*. (2009)	Red Sokoto	MF	60	12
Minka *et al*. (2009)	Red Sokoto	MF	40	12
Nwunuji *et al*. (2014)	Boer	F	24	3
Tresia *et al*. (2023)	Anpera, Boerka	M, F	33	72

Data analysis

By using OpenMEE software, meta-analysis was conducted using the random-effects approach. The random-effects model was chosen over the fixed-effects model because significant heterogeneity was expected between studies in terms of goat breeds, and gender. This approach accounts for inter-study heterogeneity, leading in further adaptable and precise estimations. Standardized mean differences (SMD) were utilized as the primary effect size measure to analyze the effect of treatment (transportation stress). The analysis yielded the heterogeneity results as well and forest plots were reported to visualize the trend across studies to show distributions of weighing of the impact estimates across the observation. Sub-group analysis was carried out using categorical variables such as goat breed and gender. Heterogeneity was assessed using Cochran's Q statistic and I^2 index.

Results

Standard meta-analysis for body weight

The analysis was carried out using the mean body weights, n, and SD of the control and treatment groups via random effects model using Hedges' d for variability across the observations. The overall standardized mean difference (SMD) showed statistically significant influence of transportation stress on the body weight of goats with SMD of –1.158 (95% CI: –1.645 to –0.671), with a standard error of 0.249 ($p < 0.001$), indicating a consistent pattern of weight loss following transport (Figs. 2 and 3). The substantial variability observed among the observations via Q statistic was 133.97 (df = 24, $p < 0.001$), and I^2 reached 82.1%, confirming a high level of heterogeneity. The between-study variance (τ^2) was estimated at 1.220, suggesting that contextual factors.

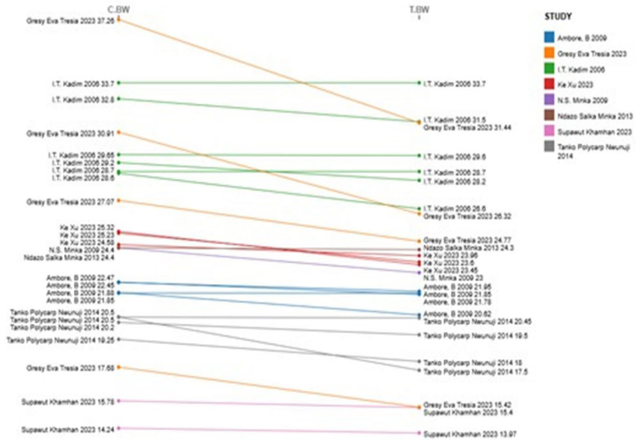

Fig. 2. Variation of body weight post-transportation stress across the selected studies.

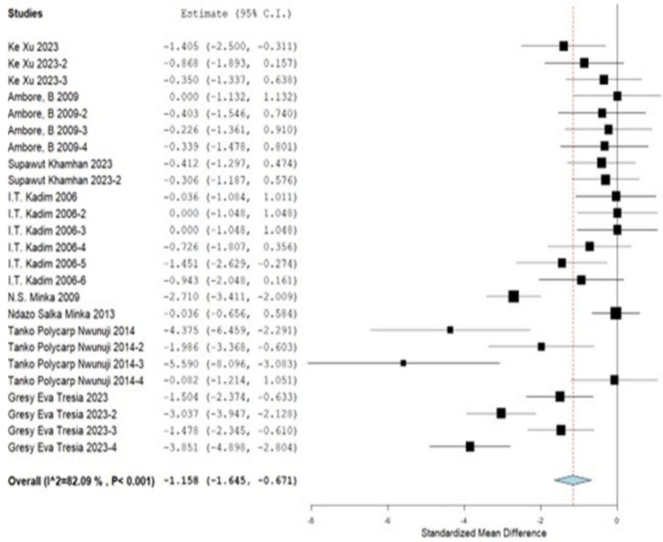

Fig 3. Forest plot of standard meta-analysis of body weight.

Subgroup breed

To explore the breed-specific responses in body weight changes under transportation stress, sub-group analysis was carried out using the continuous random-effects model (DerSimonian–Laird method), to quantify the effect. Boerka goats showed the greatest sensitivity to transport, with a substantial weight reduction (Hedges' d = –3.401; 95% CI: –4.194 to –2.608; $p < 0.001$). Anpera goats also experienced a marked decline (d = –1.491; 95% CI: –2.105 to –0.876; $p < 0.001$), while Boer goats exhibited (d = –2.821; 95% CI: –5.142 to –0.500; p = 0.017), though the wide confidence interval suggests variability or small sample sizes.. The comparatively more resilient breeds were the Osmanabadi goats that had a negligible effect size (d = –0.241; p = 0.407), while Crossbred Boer, Dhofari, Batina, Jabal Khaddar, and Red Sokoto goats also trended toward weight loss, but their results were not statistically robust. The pooled estimate across all breeds remained consistent with the main analysis (d = –1.158; 95% CI: –1.645 to –0.671; $p < 0.001$), reaffirming that transportation generally leads to significant weight loss in goats. However, the severity of the impact clearly varies across the Breeds.

The forest plot displays effect sizes for each breed (Fig. 4). Boerka goats stood out with the most extreme value, shown as a long bar well to the left of the zero line. Anpera and Boer goats also had pronounced bars indicating significant weight loss. In contrast, breeds with less dramatic or non-significant changes had shorter bars that crossed or neared the no-effect line. The pooled effect is shown as a bold diamond (centered clearly on the negative side) at the bottom of the forest plot.

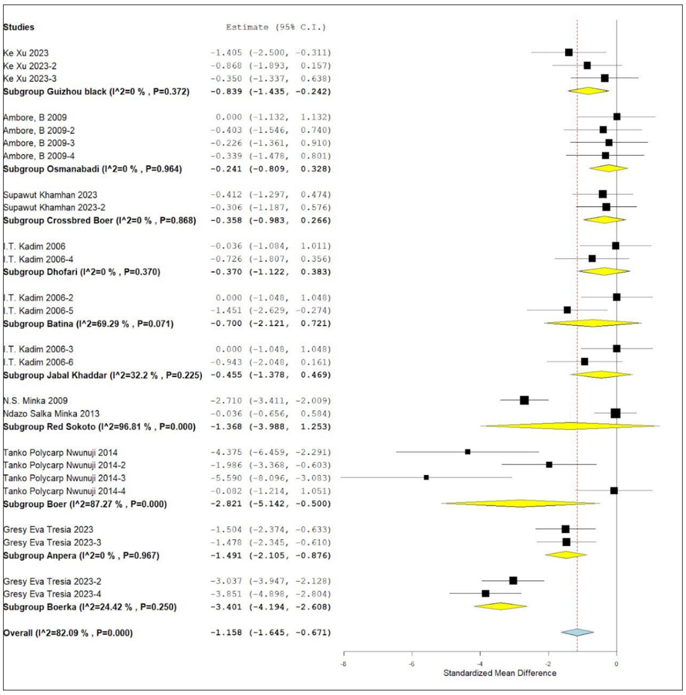

Fig. 4. Forest plot of standard meta-analysis of body weight with Breed as subgroup.

Subgroup gender

In order to explore the gender-specific responses in body weight changes under transportation stress, sub-group analysis was carried out using the continuous random-effects model (DerSimonian–Laird method), to quantify the effect. The Sub-Group 1 (Male) is seen to have statistically significant SMD effect size of –0.855 (95% CI: –1.346 to –0.365; $p < 0.001$). The yellow diamond (overall effect) in the forest plot is to the left of zero line, confirming the impact (Fig. 5). The Sub-Group 2 (Female) experienced more substantial weight reduction with a pooled effect size of –2.692 (95% CI: –4.157 to –1.227; $p < 0.001$). In the forest plot, this effect is represented by a yellow diamond (overall effect) entirely to the far left of the zero line, signalling both the strength and consistency of the outcome. The Sub-Group 12 (Males and Females) with mixed or unclassified gender showed a smaller and non-significant effect ($d = –0.649$; 95% CI: –1.692 to 0.395; $p = 0.223$). The forest plot reflects this with a yellow diamond that crosses the null line to the moderate left.

Discussion

This meta-analysis analyzed the 25 study points (observations) originating from 8 different research studies covering diversity based on goat breeds, transportation duration (time in hours), and gender (Minka *et al.*, 2009; Minka and Ayo, 2013; Nwunuj *et al.*, 2014; Xu *et al.*, 2023; Khamhan *et al.*, 2023). The most influential study weight effect sizes were attributed to studies by Ndazo Salka Minka, likely due to larger sample sizes and lower variance. Some observations including (Nwunuji *et al.*, 2014) reported more pronounced losses, whereas others reported more modest effects. Overall, the majority of the effect sizes tend to fall on the left side of the null line as depicted in the forest plot (Fig. 3). This trend towards the left of zero line indicates a decline in body weight in treatment groups as compared to control groups reinforcing the idea that transportation has a detrimental effect on goat body weight. The bluish vertical line at –1.158 marks the overall estimate, while the red dashed line at zero denotes the threshold for no effect. The evidence strongly supported by SMD and forest plot enforces that transport stress leads to meaningful weight loss in goats. However, the wide variability in effect sizes points to potential moderators like breed-specific resilience, environmental stressors, and transport conditions (Minka *et al.*, 2009; Kumar *et al.*, 2021).

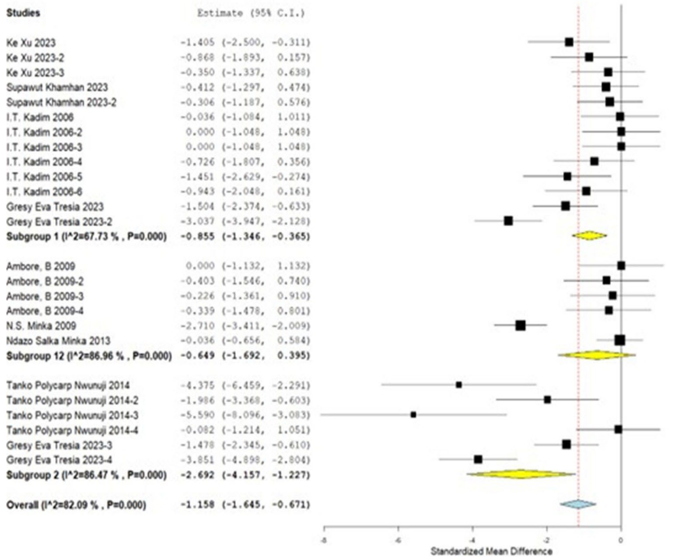

Fig. 5. Forest plot of standard meta-analysis of body weight with Gender as subgroup. (Denoted as Male:Subgroup 1, Female:Subgroup 2, Mix:Subgroup 12)

Dehydration, reduced feeding, catabolism, disturbed behaviour, microbiome changes and biochemical alternations are some of the major effects of transportation stress. The effects are spread across metabolic disturbances, physiological triggering, and behavioral changes (Hogan *et al.*, 2007, Wang *et al.*, 2023). Together, these factors influence combine to loss of body weight, productivity, and well-being (Bhatt *et al.*, 2021). The changes pre and post transportation are under the combined effect of transportation duration, goat breed, goat, gender, climatic conditions, handling methods, vehicle design, food availability, etc (Sejian *et al.*, 2021). The pre-transport feeding practices and post-tranport recovery practices can largely contribute to combat the loss of body weight and well-being of the animal (Xu *et al.*, 2023). Some of the precautionary measures include periodic resting points, pre transport and post transport feeding practices, etc (Yadav *et al.*, 2024). Future research studies are required to explore the biomarkers of transportation-induced stress to better predict the susceptible breeds of goats.

The genetics of an individual are one of the major factors that determine the response towards any kind of environmental stressors. The genetics influence the various metabolic states, overall behaviour to stimuli, physiology, excitability, and other responses to stressors (Durosaro *et al.*, 2023; Mason *et al.*, 2024). The stress responses variation depends on breed across the livestock including the goats (Durosaro *et al.*, 2023). The breeds with higher metabolic rates tend to be vulnerable toward the stress and experience much more dehydration and catabolic losses under these conditions (Lima *et al.*, 2022). The local breeds that have adapted to their native habitats are much more resilient to such losses due to tolerance owing to their evolutionary adaptation and usual environmental shifts (Sejian *et al.*, 2021). The studies should focus on applying standardized transportation protocols across various breeds to assess the breed-specific responses. Recognizing these differences is essential for developing targeted management strategies that reduce stress-related losses and improve the welfare and performance of goats during the finishing and marketing phases. Boerka and Boer goats likely exhibit higher sensitivity to transportation stress due to their greater muscle mass, higher basal metabolic rates, and lower adaptability to environmental changes, which may accelerate dehydration and catabolic processes. In contrast, Anpera goats are moderately sensitive, while Osmanabadi goats show resilience likely linked to genetic adaptation and efficient water retention mechanisms. These additions provide a deeper understanding of breed-specific physiological responses (Tresia *et al*., 2023; Nwunuji *et al*., 2014).

The gender-based variations are visible due to difference in hormonal regulation, stress coping abilities, metabolic states, etc (Aoyama *et al*., 2003). The female goats' livestock generally are more sensitive to environmental stressors especially during reproductive stages, lactation, and ovulation due to metabolic needs, hormonal fluctuations, reduced water retention ability and generally increased sensitivity (Olsson *et al*., 2001; Jaber *et al*., 2013). The male goats on the other hand, are comparatively better at behavioral responses like breathing, movements, and heart rate that results in less body weight loss under stress (Aoyama *et al*., 2003; Kadim *et al*., 2006; Kitajima, *et al*., 2021; Khamhan *et al*., 2023; Tresia *et al*., 2023). The above variation of effect sized based on genders clearly depicts the gender-specific trends in weight loss across the 25 observations under 8 different studies (Kadim *et al*. 2006; Ambore *et al*., 2009; Tresia, *et al*. 2023). These results can be used to integrate the sex-based considerations into transport planning, potentially including shorter duration, gentler handling, or post-transport recovery strategies tailored to more susceptible groups.

Conclusion

This meta-analysis study effectively summarizes that transportation stress in goats negatively influences body weight on the basis of breed and gender. These results highlight the necessity of modifying transportation procedures to accommodate various goat populations' differing sensitivities. Stress-related losses can be minimized by improved ventilation, lower loading densities, and specialized handling techniques for females or breeds that are more susceptible into place. Such focused approaches assist more sustainable and effective goat production systems by improving animal well-being and lowering economic consequences.

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Conflict of interest

The authors have no conflict of interest to declare.

References

Abhijith, A., Warner, R.D., Dunshea, F.R., Leury, B.J., Ha, M., Chauhan, S.S., 2023. A review of some aspects of goat meat quality: future research recommendations. Anim. Prod. Sci. 63, 1361–1375.

Ambore, B., Ravikanth, K., Maini, S., Rekhe, D.S., 2009. Haematological profile and growth performance of goats under transportation stress. Vet. World 2, 195–198.

Aoyama, M., Negishi, A., Abe, A., Maejima, Y., Sugita, S., 2003. Sex differences in stress responses to transportation in goats: effects of gonadal hormones. Jpn. J. Anim. Sci. 74, 511–519.

Bangar, Y.C., Magotra, A., Yadav, A.S., Chauhan, A., 2022. Estimation of genetic parameters for early reproduction traits in Beetal goats. Zygote 30, 279–284.

Bhatt, N., Singh, N.P., Mishra, A.K., Kandpal, D., Jamwal, S., 2021. A detailed review of transportation stress in livestock and its management techniques. Int. J. Livest. Res. 11, 30–41.

Durosaro, S.O., Iyasere, O.S., Ilori, B.M., Oyeniran, V.J., Ozoje, M.O., 2023. Molecular regulation, breed differences and genes involved in stress control in farm animals. Domest. Anim. Endocrinol. 82, 106769.

Harahap, M.A., Widodo, S., Handayani, U.F., Altandjung, R.I., Wulandari, A.A., Baihaqi, Z.A., 2024. Examining performance, milk, and meat in ruminants fed with macroalgae and microalgae: a meta-analysis perspective. Trop. Anim. Health Prod. 56, 243.

Hogan, J.P., Petherick, J.C., Phillips, C.J.C., 2007. Physiological and metabolic impacts on sheep and cattle of feed and water deprivation before and during transport. Nutr. Res. Rev. 20, 17–28.

Huang, Y., Liu, L., Zhao, M., Zhang, X., Chen, J., Zhang, Z., Ren, C., 2023. Feeding regimens affecting carcass and quality attributes of sheep and goat meat: a comprehensive review. Anim. Biosci. 36, 1314–1325.

Jaber, L., Chedid, M., Hamadeh, S., 2013. Water stress in small ruminants. In: Responses of Organisms to Water Stress. Springer, pp. 115–149.

Kadim, I.T., Mahgoub, O., Al-Kindi, A., Al-Marzooqi, W., Al-Saqri, N.M., 2006. Effects of transportation at high ambient temperatures on physiological responses, carcass and meat quality characteristics of three breeds of Omani goats. Meat Sci. 73, 626–634.

Khamhan, S., Tathong, T., Phoemchalard, C., 2023. Effects of fresh hemp leaf (Cannabis sativa) supplementation on physiological, carcass characteristics and meat quality in transported goats. Anim. 13, 3881.

Kitajima, K., Oishi, K., Miwa, M., Anzai, H., Setoguchi, A., Yasunaka, Y., Hirooka, H., 2021. Effects of heat stress on heart rate variability in free-moving sheep and goats assessed with correction for physical activity. Front. Vet. Sci. 8, 658763.

Kumar, P., Giri, A., Bharti, V.K., Kumar, K., Chaurasia, O.P., 2021. Evaluation of various biochemical stress markers and morphological traits in different goat breeds at high-altitude environment. Biol. Rhythm Res. 52, 261–272.

Li, R., Wang, L., Chen, B., Zhang, Y., Qi, P., 2024. Effects of transportation on blood indices, oxidative stress, rumen fermentation parameters and rumen microbiota in goats. Anim. 14, 1616.

Lima, A.R.C., Silveira, R.M.F., Castro, M.S.M., De Vecchi, L.B., Rocha Fernandes, M.H.M., Resende, K.T., 2022. Relationship between thermal environment, thermoregulatory responses and energy metabolism in goats: a comprehensive review. J. Therm. Biol. 109, 103324.

Magotra, A., Bangar, Y.C., Chauhan, A., Malik, B.S., Malik, Z.S., 2021. Influence of maternal and additive genetic effects on offspring growth traits in Beetal goats. Reprod. Domest. Anim. 56, 983–991.

Mason, M.A., Briefer, E.F., Semple, S., McElligott, A.G., 2024. Goat emotions, cognition, and personality. In: The Welfare of Goats. Springer, Cham, Switzerland, pp. 77–120.

Migdał, W., Kawęcka, A., Sikora, J., Migdał, Ł., 2021. Meat quality of the native Carpathian goat breed in comparison with the Saanen breed. Anim 11, 2220.

Minka, N.S., Ayo, J.O., 2013. Physiological and behavioral responses of goats to 12-hour road transportation, lairage and grazing periods, and the modulatory role of ascorbic acid. J. Vet. Behav. 8, 349–356.

Minka, N.S., Ayo, J.O., Sackey, A.K.B., Adelaiye, A.B., 2009. Assessment and scoring of stresses imposed on goats during handling, loading, road transportation and unloading, and the effect of pretreatment with ascorbic acid. Livest. Sci. 125, 275–282.

Nwunuji, T.P., Mayowa, O.O., Yusoff, S.M., Bejo, S.K., Salisi, S., Mohd, E.A.W., 2014. Ameliorative effect of ascorbic acid on oxidative status, live weight and recovery rate in road transport-stressed goats in a hot humid tropical environment. J. Anim. Sci. 85, 611–616.

Olsson, K., Josäter-Hermelin, M., Hossaini-Hilali, J., Cvek, K., Hydbring, E., Dahlborn, K., 1996. Reproductive period affects water intake in heat-stressed dehydrated goats. Comp. Biochem. Physiol. A Physiol. 113, 323–331.

Rebez, E.B., Sejian, V., Silpa, M.V., Devaraj, C., Kalaignazhal, G., Shashank, C.G., Bhatta, R., 2025. Transportation of goats during summer season. In: Sustainable Goat Production in the Changing Climate. Academic Press, London, UK, pp. 21–38.

Rout, P.K., Behera, B.K., 2021. Goat and sheep farming. In: Sustainability in Ruminant Livestock: Management and Marketing. Springer, Singapore, pp. 33–76.

Sejian, V., Silpa, M.V., Reshma Nair, M.R., Devaraj, C., Krishnan, G., Bagath, M., Bhatta, R., 2021. Heat stress and goat welfare: adaptation and production considerations. Anim. 11, 1021.

Simões, J., Abecia, J.A., Cannas, A., Delgadillo, J.A., Lacasta, D., Voigt, K., Chemineau, P., 2021. Managing sheep and goats for sustainable high-yield production. Anim. 15, 100293.

Star, M., Rolfe, J., Morrish, F., Lyons, B., 2021. Supply chains of the sheep and goat meat industry. University of Southern Queensland, Toowoomba, Australia.

Tozlu Çelik, H., Aslan, F.A., Us Altay, D., Kahveci, M.E., Konanç, K., Noyan, T., Ayhan, S., 2021. Effects of transport and altitude on hormones and oxidative stress parameters in sheep. PLoS One 16, e0244911.

Tresia, G.E., Trisiana, A.F., Tiesnamurti, B., 2023. Effects of road transportation on some physiological stress measures in Anpera and Boerka goats. Bull. Anim. Sci. 47, 142–151.

Wang, Q., Ye, W., Tao, Y., Li, Y., Lu, S., Xu, P., Qiang, J., 2023. Transport stress induces oxidative stress and immune response in juvenile largemouth bass (Micropterus salmoides): analysis of oxidative and immunological parameters and the gut microbiome. Antioxidants 12, 157.

Xu, K., Yang, K., Yang, Y., Wu, W., Zhou, C., 2023. Supplementation of feed and water after long-duration road transportation: effects on welfare and rumen fermentation in goats. Front. Vet. Sci. 10, 1135666.

Yadav, D.C., Sisodia, N., Hashmi, M.I., 2024. Transportation and health management of goats. In: Trends in Clinical Diseases, Production and Management of Goats. Springer, Singapore, pp. 191–202.

Zhang, X., Wu, J., Zhou, C., Wang, M., Tan, Z., Jiao, J., 2023. Temporal changes in muscle characteristics during growth in the goat. Meat Sci. 200, 109145.