



GARLIC AS A NATURAL FEED ADDITIVE IN DAIRY CALVES: A META-ANALYSIS ON PERFORMANCE AND HEALTH OUTCOMES


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Abstract: This study aimed to provide a comprehensive evaluation of the effects of garlic supplementation on average daily gain (ADG), feed intake (FI), feed conversion ratio (FCR), and fecal score (FS) of dairy calves through a meta-analysis of the available research data. Nine articles met the inclusion criteria and were included in the review, out of 321 studies identified. The results of the meta-analysis revealed that garlic administration significantly improved the ADG in dairy calves ($P<0.01$). Moreover, feed intake was significantly higher in garlic supplemented calves than in control calves ($P<0.01$). Although garlic supplementation resulted in a numerically higher FCR, the difference between groups was not statistically significant, probably due to significant differences between the included studies. The meta-analysis also revealed that garlic administration led to a significant decrease in FSs of calves ($P<0.05$), indicating a positive effect on intestinal health and gut microbiota. These findings suggest that garlic may play a critical role in promoting growth in dairy calves, as it positively influences both feed intake was significantly ADG and feed consumption. Additionally, reductions in FSs point to garlic's potential to support digestive health. The results indicate that garlic may be a viable natural option to support the health and performance of dairy calves in place of antibiotics.

Keywords: Garlic, Feed additive, Feed intake, Fecal score, Antibiotic alternative, Meta- analysis

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1. Introduction

Calves are the future milk producers of dairy cattle farms and raising healthy calves is essential to the future productivity and sustainability of enterprises. Nevertheless, ensuring their health in early life presents a major challenge, as they are highly susceptible to infectious agents during this vulnerable stage (Svensson et al., 2006; Lora et al., 2018). This susceptibility is primarily due to their underdeveloped immune systems, especially during the first few weeks after birth (Lopez and Heinrichs, 2022). Diarrhea is one of the most common and economically important health issues affecting young calves (Cho and Yoon, 2014). According to the National Animal Health Surveillance System 2007 report, diarrhea accounts for 57% of total calf deaths (NAHMS, 2008). Various factors contribute to the onset of calf diarrhea, including environmental stressors, poor management practices, malnutrition, weak immunity, and infection with enteric pathogens (Wang et al., 2022). In many cases, calves with diarrhea are found to be co-infected with multiple pathogens, such as enterotoxigenic *Escherichia coli*, rotavirus, coronavirus, *Cryptosporidium* spp. and *Salmonella* spp. (Berchtold and Constable, 2009). Calf diarrhea not only reduces FI and weight gain, but also increases vulnerability to secondary infections. Traditionally, antibiotics have been the most widely used

treatment to prevent diarrhea in calves (Smith, 2015; Allam et al., 2024). Nevertheless, the widespread application of antibiotics has sparked increasing concerns among the public, this is particularly concerning since the World Health Organization (WHO) has identified antimicrobial resistance as one of the top three global threats to human health (Oliveira et al., 2024). The prolonged and overuse of antibiotics in veterinary and human medicine has significantly contributed to the emergence of bacteria resistant to antibiotics on a global scale (Lan et al., 2020; Kaur et al., 2024). In response, many countries have introduced strict regulations to limit the use of veterinary antibiotics in an effort to slow the spread of antimicrobial resistance among bacterial populations (Smulski et al., 2020). These restrictions have led scientists and livestock producers to explore alternative strategies for disease prevention and growth promotion in animals. Among these, natural feed additives are of increasing interest. These plants have been used in folk medicine for centuries and are now being re-evaluated for their potential role in modern livestock production (Chaachouay and Zidane, 2024). Herbal products have many advantages as compared to non-herbals, such as being well tolerated, more effective in treating long-standing ailments, readily available, easily accessible, easy to prepare and administer, and



cost-effective (Kuralkar and Kuralkar, 2021). Recent studies provide strong evidence supporting the effectiveness of various herbs in supporting animal health and enhancing performance (Tao et al., 2019). Among these, garlic (*Allium sativum*) attracts considerable attention with its rich array of bioactive compounds, including phenolics, sulfur-containing molecules, polysaccharides, and saponins (Shang et al., 2019). These compounds have been shown to exert a wide range of physiological effects, including anticancer, antimicrobial, anti-inflammatory, immunomodulatory, antioxidant, antihypertensive, and lipid-lowering actions (Qin et al., 2020; Ding et al., 2023). Garlic has been widely studied in calves for its ability to enhance immunity, reduce disease risk, and promote early-stage growth and development. Garlic supplementation has been reported to improve ADG, feed efficiency and FI in several studies (Ghosh et al., 2010; Ghosh et al., 2011; Balamurugan et al., 2015; Mishra et al., 2020). These beneficial effects are often linked to increased appetite and enhanced nutrient absorption (Ding et al., 2023). In fact, garlic is frequently used as a natural remedy to manage diarrhea in young calves in organic cattle production systems (Habing et al., 2016). Several studies have demonstrated that garlic and its main active compound, allicin, are effective in combating a range of bacterial pathogens commonly linked to calf diarrhea (Olson et al., 1998; Ghosh et al., 2010; Ghosh et al., 2011; Kekana et al., 2020). However, findings in the literature are not entirely consistent, with some studies reporting no statistically significant benefit of garlic supplementation (Gholipour et al., 2016; Jagota et al., 2021; Ozkaya et al., 2023; Sorang et al., 2023). Given these differences, a comprehensive meta-analysis is essential to accurately assess garlic's efficacy in supporting dairy calf health, particularly during the pre-weaning stage. A meta-analysis could provide valuable information to inform more effective and sustainable calf rearing practices.

2. Materials and Methods

2.1. Selection of Articles and Organization of Data

In this study, articles examining the effects of garlic supplementation on some performance and health traits in dairy calves were evaluated by meta-analysis method. The articles indexed in databases such as Web of Science and Scopus between 1984 and 2024 were analyzed. During the literature search, various combinations were created by using the keywords 'garlic', 'garlic powder', 'garlic oil', 'sarımsak', 'herbal', 'calf', 'calves' and 'calf' and related studies were identified accordingly. In addition, additional studies were accessed through the references in the review articles and cross-checking was performed. As a result of the search, a total of 321 peer-reviewed articles were found. Studies were chosen for the meta-analysis based on particular eligibility requirements. In this context:

- Studies conducted in bovine calves,
- Experimental studies with a control group,
- Studies in which only garlic, garlic powder or oil was used in the experimental group,
- The results obtained are associated with yield characteristics,
- The findings were required to be reported as standard deviation (SD) or standard error of the mean (SE/SEM). Data reported as SE or SEM were converted to SD and used in the analyses. Conversion formulae are as follows (equations 1 and 2):

$$SD = SEM \times \sqrt{n} \quad (1)$$

$$SE = SD \times \sqrt{n} \quad (2)$$

No language restriction was made while screening the articles. Although the articles used were in English, articles in languages such as Persian, Chinese, German, and Japanese were found, but these were excluded because they used different methodologies. A total of 321 peer-reviewed articles were identified through the search process. After removing 87 duplicate records, 234 articles remained for screening. During the screening stage, 17 articles were excluded based on the evaluation of titles, abstracts, conference papers, book chapters, and other non-eligible formats. Consequently, 217 articles were retained for full-text assessment. During this phase, 208 articles were excluded due to differences in breeds, methodology, and other reasons. Ultimately, 9 articles met the eligibility criteria and were included in the final analysis. (Figure 1). In the collected publications, the use of garlic in calf nutrition was evaluated in relation with ADG, FI, FCR and FS characteristics (Table 1).

A standardized Excel form was used to independently extract study data and content. The information collected from each study included the first author's name, publication year, breed, total number of animals studied, control group details for each characteristic, the number of animals in control groups, experimental group details for each characteristic, the number of animals in experimental groups, standard deviation of means, and the level of statistical significance of correlations. To minimize errors, all data was thoroughly checked multiple times.

2.2. Statistical Analysis

Model selection was based on the degree of homogeneity of effect sizes between studies in the meta-analysis. Fixed effect model was preferred when effect sizes were homogeneous, and random effect model was preferred when heterogeneity was observed (Higgins and Thompson, 2002). The Q statistic was used to assess heterogeneity across the studies, and the level of heterogeneity was quantitatively evaluated using the Chi-square test, which incorporates the I^2 statistic. The calculation of effect size was based on Cohen's method for standardized mean difference (SMD) (Cohen et al., 1988). All statistical analyses were performed using Stata 11.2 software (version 11.2; Stata Corp LLC, Texas, USA).

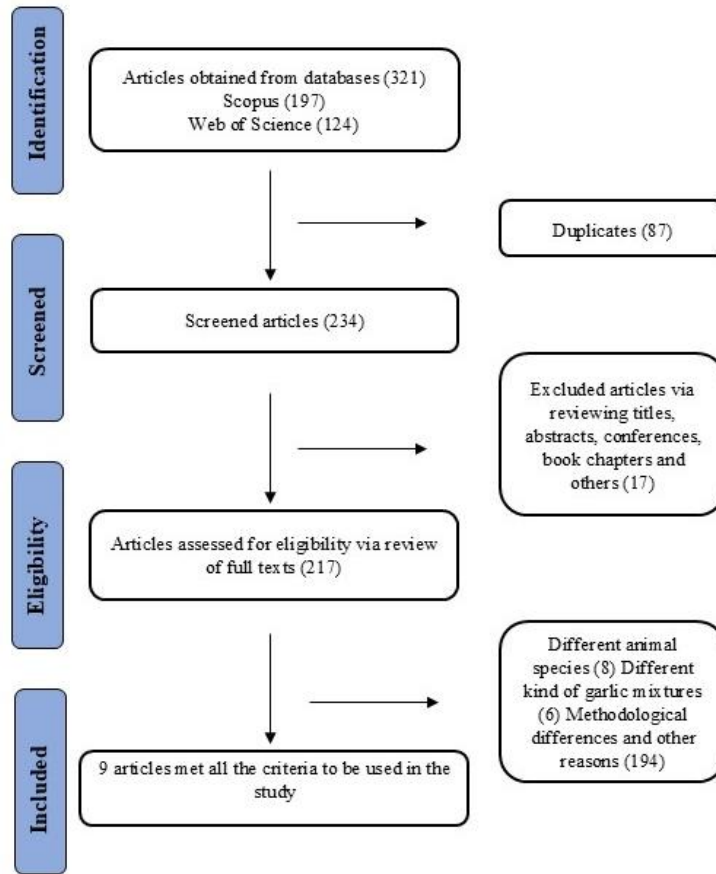


Figure 1. Flow chart of the literature search and article selection procedure.

Table 1. Information from included studies on the effects of garlic in calves

Studies	Country	Breed	Treatment	Dose	N	Outcomes
Balamurugan et al., 2015	India	Jersey crossbred	garlic powder	250 mg/kg	18	ADG
Gholipour et al., 2016	Iran	Jersey crossbred	garlic powder	0.5% of dietary DM	18	ADG, FI, FCR
Ghosh et al., 2010	India	Holstein cross	garlic extract	250 mg/kg	12	ADG, FI, FS, FCR
Ghosh et al., 2011	India	Holstein cross	garlic extract	250 mg/kg	36	ADG, FI, FS, FCR
Kekana et al., 2020	South Africa	Holstein calves	garlic powder	5 g	16	ADG, FS
Ozkaya et al., 2023	Türkiye	Holstein calves	garlic powder	10mg, 30mg	30	ADG, FI, FS, FCR
Ünlü and Erkek, 2013	Türkiye	Holstein calves	garlic	250 mg/kg	24	ADG, FI, FS
Jagota et al., 2021	India	Crossbred calves	garlic powder	250 mg/kg	12	ADG, FI
Sorang et al., 2023	India	Sahiwal Calves	garlic powder	250 mg/kg	12	FI

The strength of association between means for each yield trait was calculated using standardized mean differences (SMD) and standard deviations (SD) with 95% confidence intervals (CI). This method was applied for multiple pairwise comparisons of variants. In SMD calculations, Cohen's method (Cohen, 1988) was preferred when the number of studies was more than 10

and Hedges' method (Hedges, 1992) was preferred when the number of studies was less than 10. In meta-analyses with a high number of studies, Cohen's method provides an advantage despite its tendency to overestimate the effect size. On the other hand, Hedges' method is considered more appropriate in analyses with a limited number of studies (Ozdemir et al., 2018). Publication bias

was subjected to Begg's test and it was aimed to examine whether there was publication bias in published studies that examined the effects of garlic supplementation on the traits, and Funnel Plot was also used to test for publication bias (Duval and Tweedie, 2000).

3. Results

Table 2 shows the pooled effect sizes of garlic administration on FI, ADG, FS, and FCR of dairy calves.

3.1. Average Daily Gain

According to the results of the meta-analysis, garlic administration showed significant effects on some performance parameters in calves. The effects of garlic

supplementation on ADG were pooled from a total of 11 comparisons. The results of the SMD and the 95% confidence interval (CI) for examined studies are displayed in Table 2. The effects of garlic administration on ADG of are presented as forest plots in Figure 2. The findings from the meta-analysis showed a notable improvement in ADG among dairy calves supplemented with garlic ($P < 0.01$). A funnel plot was used to assess the presence of publication bias (Figure 3). According to the results of the test applied in the published studies examining the relationship between garlic supplementation and ADG, it is seen that there is no publication bias ($P > 0.05$).

Table 2. Pooled effect sizes of garlic administration on FI, ADG, FS, and FCR of dairy calves

Variables	N	Effect Size			Heterogeneity	
		SMD	95% CI	P	I ²	P
Average Daily Gain	11	0.67	[0.20, 1.14]	0.005	56.1%	0.012
Feed Intake	9	0.44	[0.12, 0.76]	0.007	22.1%	0.246
Feed Conversion Ratio	6	-0.36	[-1.08, 0.35]	0.320	67.5%	0.009
Fecal Score	6	-1.47	[-2.70, -0.24]	0.019	87.8%	< 0.001

SMD= Standardized Mean Differences; CI= Confidence Intervals; I²= Statistics of heterogeneity.

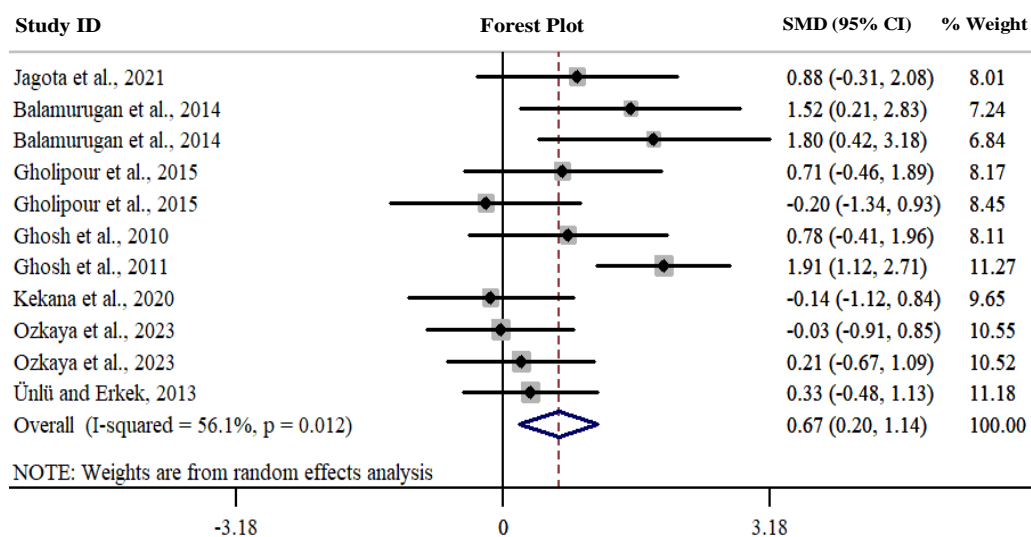


Figure 2. Forest plot for average daily gain of dairy calves.

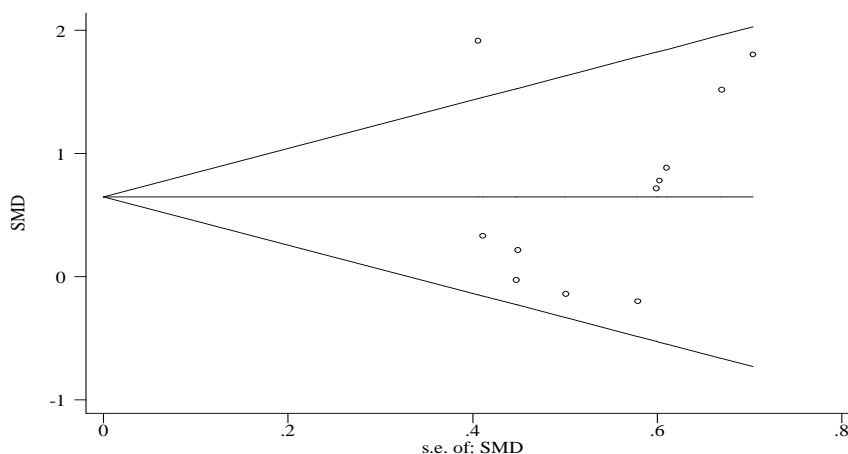


Figure 3. Funnel plot illustrating potential publication bias in studies assessing the impact of garlic administration on average daily gain in calves.

3.2. Feed Intake

Nine comparisons were included to assess the impact of garlic supplementation on dairy calves' FI. The combined effect size was SMD = 0.44, with a 95% confidence interval of 0.12 to 0.76. The meta-analysis indicated a significant increase in FI due to garlic supplementation in dairy calves (P<0.01). In the analysis of FI, heterogeneity was not significant, with an I² value of 22.1% (P>0.05). A forest plot summarizing the influence of garlic on FI is shown in Figure 4, with Figure 5 illustrating the associated funnel plot of SMDs and their standard errors.

3.3. Feed Conversion Ratio

The results of the SMD and the 95% CIs for FCR of dairy calves supplemented with garlic is presented in Table 2.

For the effects of garlic on the FCR in dairy calves, a total of 6 comparisons were pooled. The results of the meta-analysis revealed that garlic administration had no statistically significant effect on the FCR of the calves (SMD=-0.36; 95% CI: -1.08, 0.35; P=0.32). In the analysis of the FCR, with an I² value of 67.5% (P<0.01), a significant level of heterogeneity was observed. This suggests that there is some inconsistency in the results between studies, as approximately 67.5% of the variation in effect size was due to differences in study results. Figure 6 represents the forest plot for the FCR of dairy calves. A potential asymmetry, which may reflect a bias in the reporting of feed efficiency results, is indicated by visual inspection of the funnel plot (Figure 7), the publication bias of the studies examining the effect of garlic on FCR in calves has shown that there is no publication bias (P>0.05).

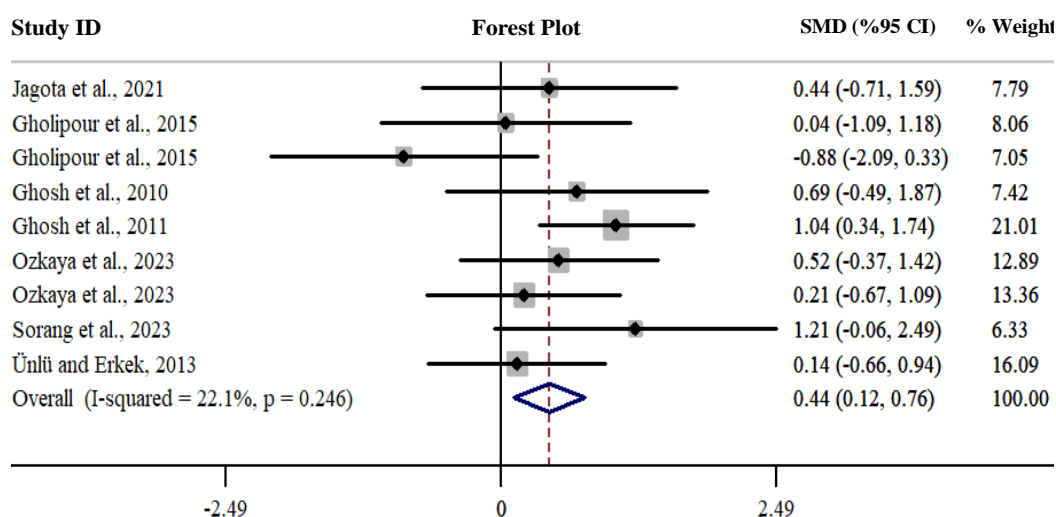


Figure 4. Forest plot for feed intake of dairy calves.

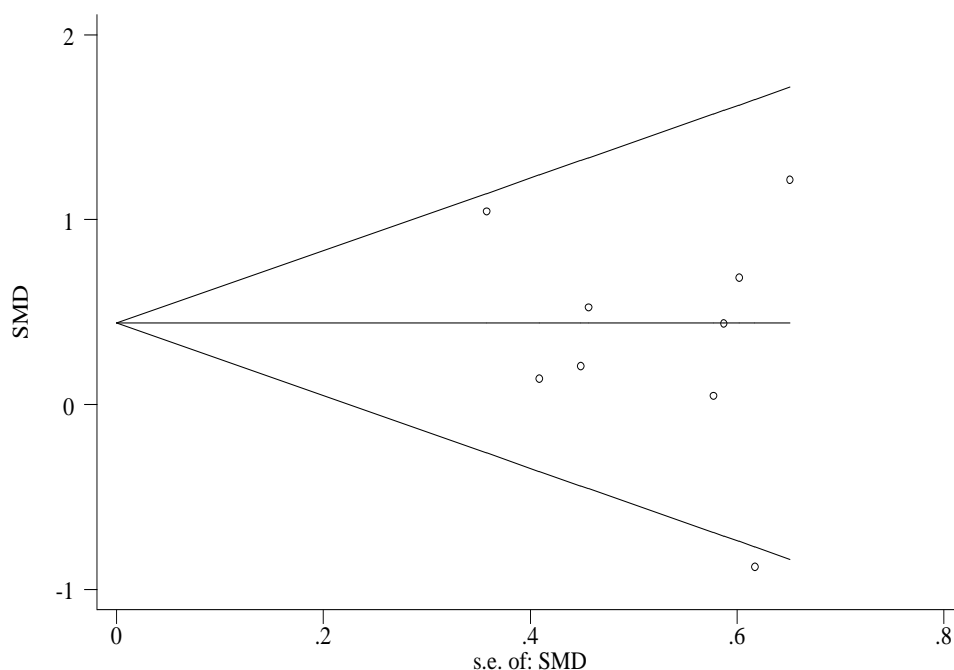


Figure 5. Funnel plots of the publication bias of the studies examining the effect of garlic on Feed Intake of calves.

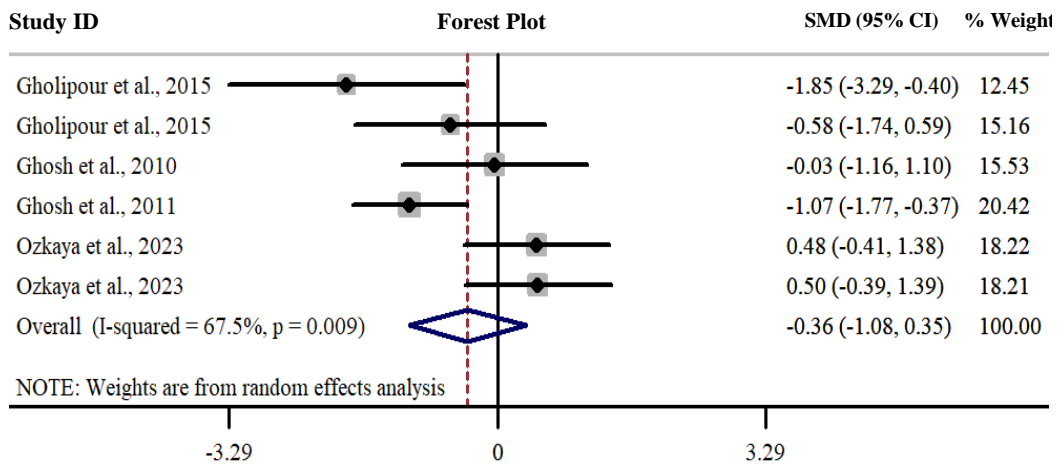


Figure 6. Forest plot for feed conversion ratio of dairy calves.

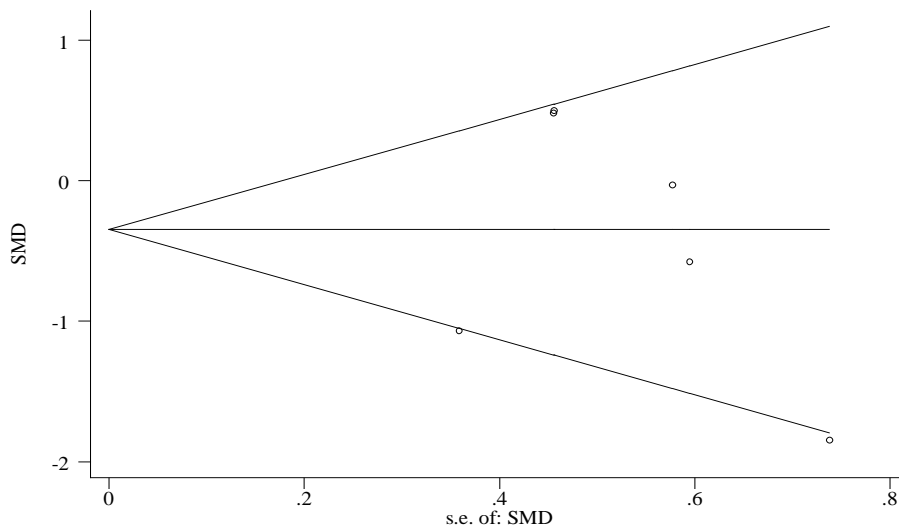


Figure 7. Funnel plots of the publication bias of the studies examining the effect of garlic supplementation on feed conversion ratio in calves.

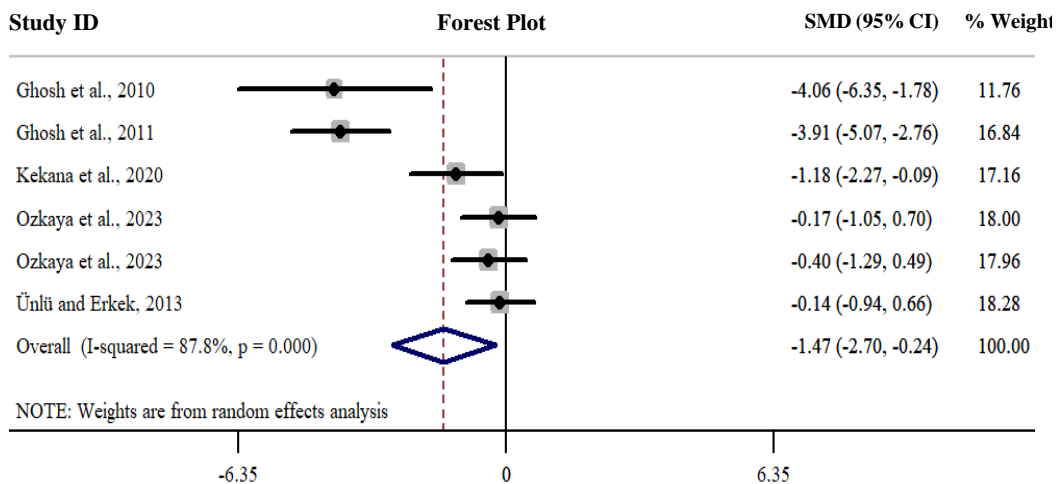


Figure 8. Forest Plot for Fecal Score of dairy calves.

3.4. Fecal Score

Six comparisons were included in a meta-analysis designed to explore the effects of garlic supplementation on dairy calf FSs. Table 2 shows the summarized results of the SMD and the 95% confidence interval (CI) for each study. Figure 8 shows the effect of garlic administration

on the FS of calves as forest plots. FS was lower in calves consumed garlic (P<0.05). (SMD=-1.47; 95%; -2.67, -0.24; I² = 87.8%; P<0.001). The presence of publication bias was assessed using a funnel plot in Figure 9, it was determined that there was no publication bias (P>0.05).

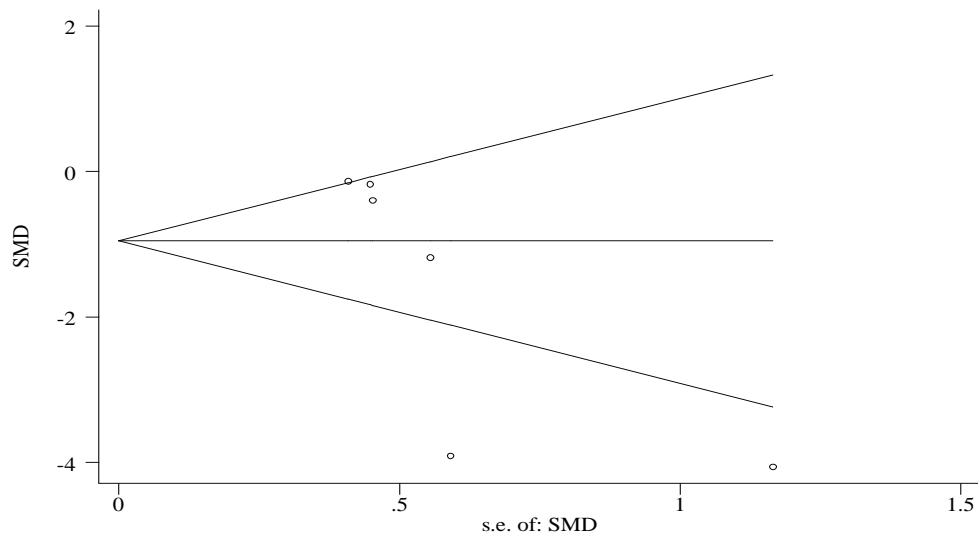


Figure 9. Funnel plots of the publication bias of the studies examining the effects of garlic on fecal score of calves.

4. Discussion

Raising healthy calves is a primary requirement for sustainable and profitable dairy cattle farming. Calves are highly vulnerable in their early lives, because their immune systems are not yet fully developed (Cangiano et al., 2024). Antibiotics are widely used to fight infections at this stage in traditional cattle farming (Sandelin et al., 2022). However, due to increasing public concern and restrictions on the use of antibiotics in animal husbandry, interest in natural alternative feed additives has increased significantly in recent years (Rusli et al., 2022). Garlic (*Allium sativum*) which is known as natural antibiotic has a special place among the plant-based products due to its rich phenolic compound profile (Shang et al., 2019; Ogbuewu et al., 2019). The potential of garlic in improving the immunity, treating diseases and enhancing the early life performance in calves has been studied by many researchers (Ghosh et al., 2010; Ghosh et al., 2011; Gholipour et al., 2016; Jagota et al., 2021; Ozkaya et al., 2023; Sorang et al., 2023). In the current study, a meta-analysis was performed to assess the efficiency of garlic on especially ADG, FI, FCR and FS in calves.

ADG is significant indicator for the health and well-being of calves in their early life. Improvement in ADG is critical to minimize raising costs and increase first lactation milk yield of calves in their future life (Hyde et al., 2021). The findings of the current meta-analysis have shown that garlic supplementation is highly effective in improving ADG of dairy calves ($P < 0.01$). Furthermore, garlic is proven to modulate the gut microbiota by displaying probiotic-like effects (Ettihad-Marvasti et al., 2022; Ha et al., 2024). Phenolic and nutritional composition also provide significant antioxidant activity (Jang et al., 2018; Petropoulos et al., 2018). During the first few weeks of their life newborn calves experience significant oxidative stress (Abuelo et al., 2014), which negatively impacts the ability of calves to build an immune response leading to increase their performance (Cuervo et al., 2021). Garlic

may also help to relieve the pressure on the immune system by limiting the proliferation of pathogens, allowing energy to be directed to growth and thus increasing ADG. Another key indicator of health and well-being in calves is their FI (Duthie et al., 2021). The meta-analysis results showed that garlic supplementation significantly enhanced the feed intake (FI) of calves ($P < 0.01$). Garlic supplementation has been reported to increase appetite and FI by improving the palatability in the ruminant diets (Naggar and Ibrahim, 2018; Martin and Chaudhry, 2024). Distinct volatile compounds and odor of garlic may have increased the feed palatability and appetite of calves. Except for Ghosh et al. (2011), the majority of the literature findings reported no significant effect of FCR with garlic supplementation (Ghosh et al., 2010; Gholipour et al., 2016; Ozkaya et al., 2023). Similar to the previous researches in this study garlic supplementation showed no statistically significant effect on FCR ($P > 0.05$).

Diarrhea is the primary cause of calf losses in dairy cattle farms (Becker et al., 2020). Even in cases where calves recover, this can lead to long-term complications such as reduced weight gain and increased vulnerability to other diseases (Schinwald et al., 2022; Ozdemir and Yanar, 2024). While antibiotics have traditionally been the most widely used intervention for calf diarrhea (Allam et al., 2024), rising concerns about antimicrobial resistance have sparked greater interest in natural alternatives. Similar to antibiotics, garlic exhibits broad-spectrum antimicrobial activity via organosulfur compounds such as allicin and ajoene (Rouf et al., 2020). Along with its antimicrobial properties, garlic offers immune-boosting (Kekana et al., 2020; Abd El-Ghany, 2024), antioxidant (Petropoulos et al., 2018), and anti-inflammatory (Zugaro et al., 2023) benefits, all of which contribute to intestinal health and help reduce diarrhea in calves. While some studies, such as Ozkaya et al. (2023), found no statistically significant change, the findings of the current meta-analysis show a significant reduction in FSs in

calves supplemented with garlic compared to controls ($P < 0.05$). Similarly, garlic has been shown to promote the development of beneficial probiotics and modulate the intestinal microbiota as reported by Ha et al. (2024). In particular, allicin acts against pathogenic bacteria by first partially disrupting DNA and protein synthesis and then completely inhibiting RNA synthesis, the latter being the primary mode of action (Gharib et al., 2017). This mechanism may also explain the potential of garlic to control pathogens that cause diarrhea in calves. Furthermore, the improvement in fecal consistency likely plays a role in increasing both FI and ADG, thus supporting overall calf development.

5. Conclusion

In conclusion, our results suggest that garlic supplementation has a critical role in improving growth performance by increasing ADG and FI in dairy calves. In addition, garlic supplementation appears to be effective in reducing FS and hence the incidence of diarrhea, which is the main cause of calf losses in dairy farms. Garlic had no statistically significant effect on calf FCR. This study suggests that garlic may be a promising natural alternative to antibiotics to improve health and performance in dairy calf farming. However, studies on this subject are limited. More comprehensive studies are needed to confirm the effects of garlic on dairy calves and to better understand its mechanism of action.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	K.E.	V.F.Ö.	M.Ö.
C	45	45	10
D	30	50	20
S	30	30	40
DCP	50	30	20
DAI	15	15	70
L	30	40	30
W	30	60	10
CR	30	40	30
SR	50	30	20

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

References

- Abd El-Ghany, W. A. (2024). Potential effects of garlic (*Allium sativum* L.) on the performance, immunity, gut health, antioxidant status, blood parameters, and intestinal microbiota of poultry: An updated comprehensive review. *Animals*, *14*(3), 498. <https://doi.org/10.3390/ani14030498>
- Abuelo, Á., Pérez-Santos, M., Hernández, J., & Castillo, C. (2014). Effect of colostrum redox balance on the oxidative status of calves during the first 3 months of life and the relationship with passive immune acquisition. *The Veterinary Journal*, *199*(2), 295-299.
- Allam, S. A., Elnomrosy, S. M., & Mohamed, S. M. (2024). Virulent-MDR-ESBL *Escherichia coli* and *Klebsiella pneumoniae* report from North Sinai calves diarrhea and in vitro antimicrobial by *Moringa oleifera*. *BMC Veterinary Research*, *20*(1), 259. <https://doi.org/10.1186/s12917-024-04088-7>
- Balamurugan, N., Sundaram, S. M., Sivakumar, T., & Rajkumar, J. S. I. (2015). Effect of garlic (*Allium sativum*) supplementation on the growth performance of crossbred calves. *Animal Production*, *16*(2), 78-87.
- Becker, J., Schüpbach-Regula, G., Steiner, A., Perreten, V., Wüthrich, D., Hausherr, A., & Meylan, M. (2020). Effects of the novel concept 'outdoor veal calf' on antimicrobial use, mortality and weight gain in Switzerland. *Preventive Veterinary Medicine*, *176*, 104907. <https://doi.org/10.1016/j.prevetmed.2020.104907>
- Berchtold, J. F., & Constable, P. D. (2009). Antibiotic treatment of diarrhea in preweaned calves. *Veterinary Clinics of North America: Food Animal Practice*, *2009*, 520-525.
- Cangiano, L. R., Villot, C., Guan, L. L., Ipharraguerre, I. R., & Steele, M. A. (2024). Graduate student literature review: Developmental adaptations of immune function in calves and the influence of the intestinal microbiota in health and disease. *Journal of Dairy Science*, *107*(4), 2543-2555. <https://doi.org/10.3168/jds.2023-24195>
- Chaachouay, N., & Zidane, L. (2024). Plant-derived natural products: A source for drug discovery and development. *Drugs and Drug Candidates*, *3*(1), 184-207. <https://doi.org/10.3390/ddc3010011>
- Cho, Y. I., & Yoon, K. J. (2014). An overview of calf diarrhea— infectious etiology, diagnosis, and intervention. *Journal of Veterinary Science*, *15*(1), 1-17. <https://doi.org/10.4142/jvs.2014.15.1.1>
- Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Lawrence Erlbaum Associates.
- Cuervo, W., Sordillo, L. M., & Abuelo, A. (2021). Oxidative stress compromises lymphocyte function in neonatal dairy calves. *Antioxidants*, *10*(2), 255. <https://doi.org/10.3390/antiox10020255>
- Ding, H., Ao, C., & Zhang, X. (2023). Potential use of garlic products in ruminant feeding: A review. *Animal Nutrition*, *14*, 343-355. <https://doi.org/10.1016/j.aninu.2023.04.011>
- Duthie, C. A., Bowen, J. M., Bell, D. J., Miller, G. A., Mason, C., & Haskell, M. J. (2021). Feeding behaviour and activity as early indicators of disease in pre-weaned dairy calves. *Animal*, *15*(3), 100150. <https://doi.org/10.1016/j.animal.2020.100150>
- Duval, S., & Tweedie, R. (2000). Trim and fill: A simple "funnel plot"-based method of testing and adjusting for publication bias in meta-analysis. *Biometrics*, *56*(2), 455-463. <https://doi.org/10.1111/j.0006-341X.2000.00455.x>
- Ettehad-Marvasti, F., Ejtahed, H. S., Siadat, S. D., Soroush, A. R., Hoseini-Tavassol, Z., Hasani-Ranjbar, S., & Larijani, B. (2022). Effect of garlic extract on weight loss and gut microbiota composition in obese women: A double-blind randomized

- controlled trial. *Frontiers in Nutrition*, 9, 1007506.
- Gharib, A. A., Sleim, M. A., Hegazy, M. I., & Adly, S. H. (2017). Bacteriological and molecular studies of garlic effect on some virulence genes of *Escherichia coli* of chicken origin. *Benha Veterinary Medical Journal*, 32(1), 29–40.
- Gholipour, A., Foroozandeh Shahraki, A. D., Tabeidian, S. A., Nasrollahi, S. M., & Yang, W. Z. (2016). The effects of increasing garlic powder and monensin supplementation on feed intake, nutrient digestibility, growth performance and blood parameters of growing calves. *Journal of Animal Physiology and Animal Nutrition*, 100(4), 623–628. <https://doi.org/10.1111/jpn.12402>
- Ghosh, S., Mehla, R. K., Sirohi, S. K., & Roy, B. (2010). The effect of dietary garlic supplementation on body weight gain, feed intake, feed conversion efficiency, faecal score, faecal coliform count and feeding cost in crossbred dairy calves. *Tropical Animal Health and Production*, 42(5), 961–968.
- Ghosh, S., Mehla, R. K., Sirohi, S. K., & Tomar, S. K. (2011). Performance of crossbred calves with dietary supplementation of garlic extract. *Journal of Animal Physiology and Animal Nutrition*, 95(4), 449–455.
- Ha, J., Kim, J., Kim, S., Lee, K. J., & Shin, H. (2024). Garlic-induced enhancement of *Bifidobacterium*: Enterotype-specific modulation of gut microbiota and probiotic populations. *Microorganisms*, 12(10), 1971. <https://doi.org/10.3390/microorganisms12101971>
- Habing, G., Djordjević, C., Schuenemann, G. M., & Lakritz, J. (2016). Understanding antimicrobial stewardship: Disease severity treatment thresholds and antimicrobial alternatives among organic and conventional calf producers. *Preventive Veterinary Medicine*, 130, 77–85.
- Hedges, L. V. (1992). Modeling publication selection effects in meta-analysis. *Statistical Science*, 7(2), 246–255. <https://doi.org/10.1214/ss/1177011364>
- Higgins, J. P., & Thompson, S. G. (2002). Quantifying heterogeneity in a meta-analysis. *Statistics in Medicine*, 21(11), 1539–1558. <https://doi.org/10.1002/sim.1186>
- Hyde, R. M., Green, M. J., Hudson, C., & Down, P. M. (2021). Factors associated with daily weight gain in preweaned calves on dairy farms. *Preventive Veterinary Medicine*, 190, 105320. <https://doi.org/10.1016/j.prevetmed.2021.105320>
- Jagota, P., Patil, A. K., Mehta, M. K., Jamra, M. S., & Agrawal, V. (2021). Effect of garlic (*Allium sativum*) supplementation on growth performance and feed conversion efficiency in crossbred calves. *Ruminant Science*, 10(1), 81–84.
- Jang, H. J., Lee, H. J., Yoon, D. K., Ji, D. S., Kim, J. H., & Lee, C. H. (2018). Antioxidant and antimicrobial activities of fresh garlic and aged garlic by-products extracted with different solvents. *Food Science and Biotechnology*, 27, 219–225.
- Kaur, K., Singh, S., & Kaur, R. (2024). Impact of antibiotic usage in food-producing animals on food safety and possible antibiotic alternatives. *The Microbe*, 4, 100097. <https://doi.org/10.1016/j.microb.2024.100097>
- Kekana, T. W., Nherera-Chokuda, V. F., Baloyi, J. J., & Muya, C. M. (2020). Immunoglobulin G response and performance in Holstein calves supplemented with garlic powder and probiotics. *South African Journal of Animal Science*, 50(2), 263–270.
- Kuralkar, P., & Kuralkar, S. V. (2021). Role of herbal products in animal production—An updated review. *Journal of Ethnopharmacology*, 278, 114246.
- Lan, R., Zhao, Z., Li, S., & An, L. (2020). Sodium butyrate as an effective feed additive to improve performance, liver function, and meat quality in broilers under hot climatic conditions. *Poultry Science*, 99(11), 5491–5500. <https://doi.org/10.1016/j.psj.2020.06.042>
- Lopez, A. J., & Heinrichs, A. J. (2022). Invited review: The importance of colostrum in the newborn dairy calf. *Journal of Dairy Science*, 105(4), 2733–2749.
- Lora, I., Gottardo, F., Contiero, B., Dalla Villa, B., Bonfanti, L., Stefani, A., & Barberio, A. (2018). Association between passive immunity and health status of dairy calves under 30 days of age. *Preventive Veterinary Medicine*, 152, 12–15.
- Martin, R. S. H., & Chaudhry, A. S. (2024). The effects of garlic as a feed additive on ruminal fermentability and ruminant performance: A meta-analysis. *Journal of Agriculture and Food Research*, 18, 101531.
- Mishra, R. K., Singh, S. K., Palod, J., Mondal, B. C., Singh, B., & Singh, V. S. (2020). Effect of dietary supplementation of garlic (*Allium sativum*) and turmeric (*Curcuma longa*) powder on growth and nutrient utilization of female crossbred calves during winter season. *Journal of Entomology and Zoology Studies*, 8(4), 2288–2292.
- Naggar, S., & Ibrahim, E. M. (2018). Impact of incorporating garlic or cumin powder in lambs ration on nutrients digestibility, blood constituents and growth performance. *Egyptian Journal of Nutrition and Feeds*, 21(2), 355–364.
- NAHMS. (2008). National Animal Health Monitoring System: Dairy 2007. Part II: Changes in the U.S. dairy cattle industry, 1991–2007. National Animal Health Monitoring System.
- Ogbuewu, I. P., Okoro, V. M., Mbajiorgu, E. F., & Mbajiorgu, C. A. (2019). Beneficial effects of garlic in livestock and poultry nutrition: A review. *Agricultural Research*, 8(4), 411–426.
- Oliveira, M., Antunes, W., Mota, S., Madureira-Carvalho, Á., Dinis-Oliveira, R. J., & da Silva, D. D. (2024). An overview of the recent advances in antimicrobial resistance. *Microorganisms*, 12(9), 1920. <https://doi.org/10.3390/microorganisms12091920>
- Olson, E. J., Epperson, W. B., Zeman, D. H., Fayer, R., & Hildreth, M. B. (1998). Effects of an allicin-based product on cryptosporidiosis in neonatal calves. *Journal of the American Veterinary Medical Association*, 212(7), 987–990.
- Ozdemir, M., Kopuzlu, S., Topal, M., & Bilgin, O. C. (2018). Relationships between milk protein polymorphisms and production traits in cattle: A systematic review and meta-analysis. *Archives of Animal Breeding*, 61(2), 197–206. <https://doi.org/10.5194/aab-61-197-2018>
- Ozdemir, V. F., & Yanar, M. (2024). Effects of propolis extract administration on immune parameters, faecal consistency scores, and growth performance of Holstein–Friesian calves. *Tropical Animal Health and Production*, 56(8), 259.
- Ozkaya, S., Kumbul, B. S., Erbaş, S., Mutlucan, M., Altınay, R., & Demirel, E. (2023). Effects of garlic powder-supplemented milk on growth and health indicators in Holstein calves. *Animal Biotechnology*, 34(8), 3819–3826.
- Petropoulos, S., Fernandes, Á., Barros, L., Ćirić, A., Soković, M., & Ferreira, I. C. (2018). Antimicrobial and antioxidant properties of various Greek garlic genotypes. *Food Chemistry*, 245, 7–12.
- Qin, W., Huber, K., Popp, M., Bauer, P., Buettner, A., Sharapa, C., et al. (2020). Quantification of allyl methyl sulfide, allyl methyl sulfoxide, and allyl methyl sulfone in human milk and urine after ingestion of cooked and roasted garlic. *Frontiers in Nutrition*, 7, 565496.
- Rouf, R., Uddin, S. J., Sarker, D. K., Islam, M. T., Ali, E. S., Shilpi, J. A., Nahar, L., Tiralong, E., & Sarker, S. D. (2020). Antiviral potential of garlic (*Allium sativum*) and its organosulfur compounds: A systematic update of pre-clinical and clinical data. *Trends in Food Science & Technology*, 104, 219–234. <https://doi.org/10.1016/j.tifs.2020.08.006>
- Rusli, R. K., Sadarman, S., Hidayat, C., Sholikin, M. M., Hilmi, M.,

- Yuniza, A., Mutia, R., Jayanegara, A., & Irawan, A. (2022). A meta-analysis to evaluate the effects of garlic supplementation on performance and blood lipids profile of broiler chickens. *Livestock Science*, 263, 105022.
- Sandelin, A., Hälli, O., Härtel, T., Herva, T., Kaartinen, L., Tuunainen, E., Rautala, H., Soveri, T., & Simojoki, H. (2022). Effect of farm management practices on morbidity and antibiotic usage on calf rearing farms. *Antibiotics*, 11(2), 270. <https://doi.org/10.3390/antibiotics11020270>
- Schinwald, M., Creutzinger, K., Keunen, A., Winder, C. B., Haley, D., & Renaud, D. L. (2022). Predictors of diarrhea, mortality, and weight gain in male dairy calves. *Journal of Dairy Science*, 105(6), 5296–5309.
- Shang, A., Cao, S. Y., Xu, X. Y., Gan, R. Y., Tang, G. Y., Corke, H., Mavumengwana, V., & Li, H. B. (2019). Bioactive compounds and biological functions of garlic (*Allium sativum* L.). *Foods*, 8(7), 246. <https://doi.org/10.3390/foods8070246>
- Smith, G. (2015). Antimicrobial decision making for enteric diseases of cattle. *Veterinary Clinics of North America: Food Animal Practice*, 31(1), 47–60.
- Smulski, S., Turlewicz-Podbielska, H., Wylandowska, A., & Włodarek, J. (2020). Non-antibiotic possibilities in prevention and treatment of calf diarrhoea. *Journal of Veterinary Research*, 64(1), 119–126.
- Sorang, Z. K., Deka, R. J., Baruah, D. K., Hussain, J., Saikia, G., Shome, A., & Kaushik, P. (2023). Effect of supplementation garlic powder (*Allium sativum*) in the growth parameters of Sahiwal calves. *International Journal of Bio-resource and Stress Management*, 14(9), 1313–1320.
- Svensson, C., Linder, A., & Olsson, S. O. (2006). Mortality in Swedish dairy calves and replacement heifers. *Journal of Dairy Science*, 89(12), 4769–4777. [https://doi.org/10.3168/jds.S0022-0302\(06\)72526-7](https://doi.org/10.3168/jds.S0022-0302(06)72526-7)
- Tao, H., Si, B., Xu, W., Tu, Y., & Diao, Q. (2019). Effect of *Broussonetia papyriera* L. silage on blood biochemical parameters, growth performance, meat amino acids and fatty acids compositions in beef cattle. *Asian-Australasian Journal of Animal Sciences*, 33(5), 732–741.
- Ünlü, H. B., & Erkek, R. (2013). Effects of oregano and garlic essential oils on performance of calves and some parameters of faeces and blood. *Ege Üniversitesi Ziraat Fakültesi Dergisi*, 50(3), 299-310.
- Wang, S., Cui, D., Lv, Y., Yan, Z., & Zhang, J. (2022). Cangpu oral liquid as a possible alternative to antibiotics for the control of undifferentiated calf diarrhea. *Frontiers in Veterinary Science*, 9, 879857. <https://doi.org/10.3389/fvets.2022.879857>
- Zugaro, S., Benedetti, E., Caioni, G. (2023). Garlic (*Allium sativum* L.) as an ally in the treatment of inflammatory bowel diseases. *Current Issues in Molecular Biology*, 45(1), 685–698. <https://doi.org/10.3390/cimb45010046>