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Role of Effective Microorganisms (EM) in Livestock Nutrition and Performance: A Review

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ABSTRACT

The use of effective microorganisms (EM), is a sustainable solution for addressing nutrient deficiencies and improving feed quality in all four major livestock species (dairy and beef cattle, sheep, goats and swine), as it promises to enhance animal production, by the improving nutrient digestibility, feed conversion efficiency, overall animal health and environmental sustainability in a profitable way. This review synthesized the findings from accepted peer-reviewed academic journal articles written only in English. The findings revealed the positive effect of EM on gut health, nutrient digestibility, feed conversion efficiency, production performances, product quality and the environmental effects of the livestock industry. Despite these positive effects, multifunctional action with combined alternative feedstuff stains, mechanisms of action, influence on reproductive performances and impact on newborn offspring, major knowledge gaps were identified. Addressing these gaps, through well-developed studies, especially species-specific responses and the long-term effects of EM on livestock will be vital for improving EM use in the livestock production sector.

Key words: Direct feed microbes, Environmental sustainability, Manure management, Probiotics, Sustainable feeding.

Effective microorganisms (EM), a mixture of beneficial bacterial and other microorganisms' cultures, can be used as an innovative dietary approach to address the challenges in livestock nutrition and waste management (Higa, 2000; Sheikh *et al*., 2018). This technology was invented by Dr. Teruo Higa in 1980s by first introduced to improve soil health (Higa, 1999; Ezeagu *et al*., 2023), without harming the ecosystem through the way of reducing agricultural chemicals (Kodippili and Nimalan, 2018). Afterwards, it expanded to various fields, such as waste management, environmental consideration and other allied fields (Jarosz *et al*., 2022; Sung *et al*., 2023). When it gained attention in the livestock sector, it first focused on the application of waste management and then gained attention on animal nutrition (Amin and Mao, 2021). Effective microorganisms have shown promising results in livestock nutrition by enhancing digestion efficiency (Pitta *et al*., 2018; Soliman, 2022). The incorporation of EM into livestock feed aims to improve the gut microbial diversity in target livestock species and feed quality (Shen *et al*., 2024; Isaac *et al*., 2024). These mixtures of beneficial bacteria, yeasts and fungi act symbiotically by breaking down feed components that would otherwise be less digestible, thus enhancing nutrient availability (Nelson and Martini, 2009; Guo *et al*., 2020). The fact that EM has the potential to improve feed efficiency, waste reduction, reduce enteric gas accumulation and enhance overall gastric performance has gained significant momentum in come forward in recent years (Higa, 1999 and 2000; Mohamed *et al*., 2018; Min *et al*., 2022). Moreover, EM showed promising results in improving immune responses and mitigating environmental pollution by reducing greenhouse gas emissions (Mohamed *et al*., 2018). Apart from that, some studies revealed that the EM has not influenced the overall performance of livestock and poultry (Tu-Kitaw *et al*., 2013; Yacout *et al*., 2021; Min *et al*., 2022). Those inconsistent results and limited understanding of EM demanded a comprehensive study in major livestock and poultry species, focusing on cattle, sheep, goat, swine and poultry.

A narrative review process was employed to synthesize the findings. Recently published peer-reviewed research articles and reputable websites (Lim *et al*., 2022) were used to collect and analyze the data. Relevant studies were identified in the Google Scholar database using the advanced search function. The keywords "effective microorganisms," "livestock nutrition," "EM supplementation," "EM bokashi", "Probiotics" and "animal health" were used for filtering the related articles. All the articles written in English were selected and their findings were reviewed and synthesized focusing on the major livestock categories; cattle (dairy and beef), goats, sheep and swine.

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Dairy cattle

The dietary supplementation of EM has been studied to evaluate its efficacy on nutrient digestibility and rumen fermentation of dairy cows (Yacout *et al*., 2021). Soliman (2022) showed that EM improves fibre digestibility in forages containing high lignocellulose content. This improvement in fibre digestion enhances the production of volatile fatty acids (VFA), which are the primary by-products of ruminal fibre fermentation (Guo *et al*., 2020). Enhancements in fibre degradation and VFA production are crucial for dairy cows, as fibre is a major component of their diet and VFAs serve as their primary energy source (Nelson and Martini, 2009). Moreover, the excessive VFA production improves the energy availability, that especially necessary during the metabolic stress periods, *i.e.* parturition and early lactation of dairy cows (Vicente *et al*., 2024).

Furthermore, Pitta *et al*. (2018) revealed that microbial fermentation fulfills approximately 70% of energy and 50% of protein requirements in dairy cows. Therefore, EM supplementation, by enhancing the microbial ecosystem, holds promise for improving energy and protein availability to meet the nutritional demands of the cows. Moreover, Mohamed *et al*. (2018) demonstrated that supplementing cross-bred dairy cows with EM solution containing *Lactobacillus* spp. led to an increase in milk yield while reducing milk fat percentage compared to the control group. Additionally, Sun *et al*. (2013) conducted a similar study evaluating the effect of EM strain *Bacillus subtilis natto*, isolated from fermented soybean, when supplemented in dairy cows. The study showed the supplementation of *Bacillus subtilis natto* at leat level of 0.5×10^{11} CFU increased the milk production and improved the milk compositions while reducing the somatic cell count (SSC), which is an important indicator of milk quality. These findings further confirmed that supplementing EM-based beneficial microorganisms could be beneficial for dairy production while improving feed efficiency, milk volume, quality and cow health. However, a study conducted by Tu-Kitaw *et al*. (2013) showed that the supplementation of EM with sprayed native pasture hay, including a concentrate mix, does not influence the milk volume and composition. This variation in the study observed may be attributed to differences in EM product composition, the specific EM strain used, cattle breed, seasonal factors, environmental conditions and geographical region.

Beef cattle

The EM's promising approach to the beef production system, coupled with the better utilization of protein and fibre digestion, significantly contributed to the improved performance in beef cattle (Loor *et al*., 2016; Min *et al*., 2022). As observed in dairy cattle, beef cattle supplemented with EM have been reported the enhance ruminal fermentation and fiber digestion. Supplementation of microbes as probiotics has also been reported to improve protein synthesis and utilization, which are crucial for improving muscle mass and growth rates in beef cattle (Markowiak and Śliżewska, 2018). Beef cattle fed with *Lactobacillus acidophilus* (strain BT-1386) improved the feed conversion efficiency by 4.2% and average daily gain by 3.06% (Feedstuffs.com, 2020). The improvement of feed efficiency means less feed requirement for the fulfilment of daily nutritional needs of beef cattle (Ojo *et al*., 2024). This approach greatly supports beef production systems, whereas the feed cost is the most critical component in the total production cost in beef production systems, which accounts for 60%-70% of the total production (Kenny *et al*., 2018; Ojo *et al*., 2024).

When considering the production parameters of beef cattle, weight gain and carcass quality are crucial. Maamouri and Ben-Salem *et al*. (2022) showed that supplementing *Saccharomyces cerevisiae* to the fattening calves resulted highest average daily gain (400 g calf^{-1}) with the highest feed conversion rate. Furthermore, a similar study conducted by Mousa and Marwan (2019) investigated the effect of *Bacillus subtilus* supplementation on calves. The results showed that supplementation of *B. subtilus* 0.3 g kg^{-1} to their diets improved the average body weight gain and FCR. Further, the supplementation of basal diet with 20 g d^{-1} cattle brewer's yeast and cellulose resulted in the improvement of final body weight and FCR, with a 3.86% of net meat weight (Gao *et al*., 2022). These findings highlight the potential of EM to enhance beef production systems by improving feed utilization, promoting growth and enhancing carcass quality, ultimately leading to healthier steers.

Goat and sheep

Goats and sheep are also corresponding of the group of ruminants and are considered as small ruminants. They also play a crucial role in the livestock industry by contributing to producing meat, milk, wool, hides, *etc*. (Mazinani and Rude, 2020; Rout *et al*., 2021). Small ruminants with different rumen microbiota compared to cattle also showed a positive impact on supplementation of EM. Gemiyo *et al*. (2017) conducted an experiment supplementing *Chlorias gayana* hay with different levels of EM-bokashi in lambs. The results showed that a 26.6% increase in EM supplementation led to improved daily weight gain and enhanced economic profitability. Dietary supplementation of live yeast as EM to growing lambs increased feed intake and growth rate while also enhancing the population of ciliate protozoa and entodinomorphs (Tripathi and Karim, 2011). This process happens through effective ruminal fermentation by enhancing nutrient absorption in small ruminants fed with EM (Amin and Mao, 2021). The improved fermentation enables the better digestion of complex carbohydrates and fibrous compounds abounded in the sheep and goats' diet (Kilula, 1997; Tripathi and Karim, 2011; Li *et al*., 2019). Apart from that, the EM-supplemented group of goats showed a reduction in faecal worm egg count and reduced anaemia condition (Razak *et al*., 2018). Moreover, improved nutrient intake from ruminal fermentation enhances the overall performance of small ruminants, leading to better growth, increased milk production, reduced worm burden and decreased anaemia conditions (Amin and Mao, 2021; Wahyono *et al*., 2022).

Moreover, Razak *et al*. (2018) conducted a study supplementing EM to female goats, resulting in improved body weight and blood metabolites. Further, supplementation with bacterial isolated commercial enzymes and yeast in lactating goats led to an increase in body weight, milk production and milk composition (Abou-Elenin *et al*., 2015). Apart from that, two studies showed that supplementing a low protein diet with 5% EM bokashi® in lambs and goats resulted in higher body weight gain (Gemiyo *et al*., 2017; Direkvandi *et al*., 2020). Based on the key studies discussed above, the use of EM in sheep and goat nutrition is recommended due to its positive impact on improving nutrient absorption, feed efficiency, production performance and overall health, particularly through reducing intestinal worm burden.

Swine

Swine are denoted as monogastric animals, with the group of omnivores, which means acidic with a low pH value in their gastric sap (Saha and Pathak, 2021; Joysowal *et al*., 2021). Pigs, as omnivorous animals, consume a wide variety of feedstuffs, which can often lead to dyspepsia. While these issues are usually mild, in some cases, they can become severe and result in significant economic losses (Ponamarev *et al*., 2022). The supplementation of EM showed promising results for the condition of dyspepsia by enhancing digestive function, balancing the gut microbial population, alleviating gut pathogenic bacterial activity and improving immunity function in swine (Liao and Nyachoti, 2017; Shen *et al*., 2024). Further, Radzikowski and Milczarek (2021) revealed that supplementing beneficial microorganisms to different age groups of pigs increased feed intake, piglets' weight gain and sows' milk yield, boosting pig immunity and reducing pathogens from the gastrointestinal tract, by enhancing growth and development of the beneficial bacterial microflora. These results were in line and further explained by Jarosz *et al*. (2022) that supplementing EM Bokashi® for the late pregnant sows resulted in improved immunological quality of the colostrum and its milk, subsequently improving the piglets' vigour against infections. Further, the use of beneficial microbes, particularly EM has contributed to less nitrogen excretion with the faeces, evidenced by better protein utilization. The way of reduction of nitrogen excretion is favourable for the environment, by better protein digestion, it also reduces waste generation and emissions (Yuquilema, 2019; Duarte and Kim, 2022; Jarosz *et al*., 2022; Sung *et al*., 2023).

When late pregnant and early lactating sows were fed with EM Bokashi® showed improved immunological quality of colostrum. Further, it also improved the piglets' survival rate (Jarosz *et al*., 2022). Giang *et al*. (2011) showed that the supplementing mixture of beneficial bacteria and yeast improves the average daily gain and the FCR of the growing pigs. Further, Rybarczyk *et al*. (2021a) showed similar results when treating the fattening pigs fed with EM Bokashi®. Moreover, when fatteners fed with EM Bokashi® probiotics resulted in higher lean percentage, mineral (Na, Mg and Se) and lower fat content in the carcass, promising good quality pork (Rybarczyk *et al*., 2021b). While considering the effect of EM on the performance of swine, the use of EM has positively influenced swine performance by improving colostrum quality, enhancing piglet survival rate, boosting growth performance and improving carcass quality.

Livestock manure management and environmental effects

Overall, studies have demonstrated the positive impact of the use of EM as a dietary modification. Additionally, from an environmental perspective, the livestock sector significantly contributes to environmental pollution, negatively affecting the ecosphere (Haque, 2018). Major studies have focused on promising solutions to mitigate this pollution. The livestock industry contributes to environmental issues by releasing greenhouse gases, disrupting the nitrogen cycle and eutrophication in lakes and waterbodies (Abdel *et al*., 2023). There have been various strategies introduced to the field, but their efficacy and economic feasibility are somewhat hard for small and medium-scale livestock producers (Gerber *et al*., 2013; Herrero *et al*., 2016). The EM technology has been shown to significantly reduce greenhouse gas (GHG) production, manure emissions and odour from the livestock units without affecting the animal performance (Mori *et al*., 2017; Zhen *et al*., 2020). The studies conducted using beneficial microbes as the dietary modification for ruminants reduced enteric methane (CH_4) production by ~30% (Hristov *et al*., 2013; Beauchemin *et al*., 2015; Min *et al*., 2022). Further, EM improves protein and mineral digestion, reduces the nitrogen (N) and sulfur (S) excretion through manure and helps decrease the release of odour-forming compounds such as ammonia (NH_3) and hydrogen sulfide (H_2S) and other nitrogenous compounds (Mori *et al*., 2017; Zhen *et al*., 2020; Vasilev, 2023). Moreover, the direct application of EM to the manure management yards increased manure degradation and boosted the decomposition rate (Zhang *et al*., 2019). Thus, the use of EM as the dietary modifier and, as manure management is promised as the eco-friendly approach to use in livestock production by reducing ecological footprint.

Future directions

The supplementation of EM has offered clear benefits in the livestock sector (Fig 1). However, several challenges have been identified. The variability of results could be a variation of the microbial strain of the respective product contained, variation of EM inoculated feed ingredient, livestock breed and species, duration of the particular study, climatic season and finally, geographical location.

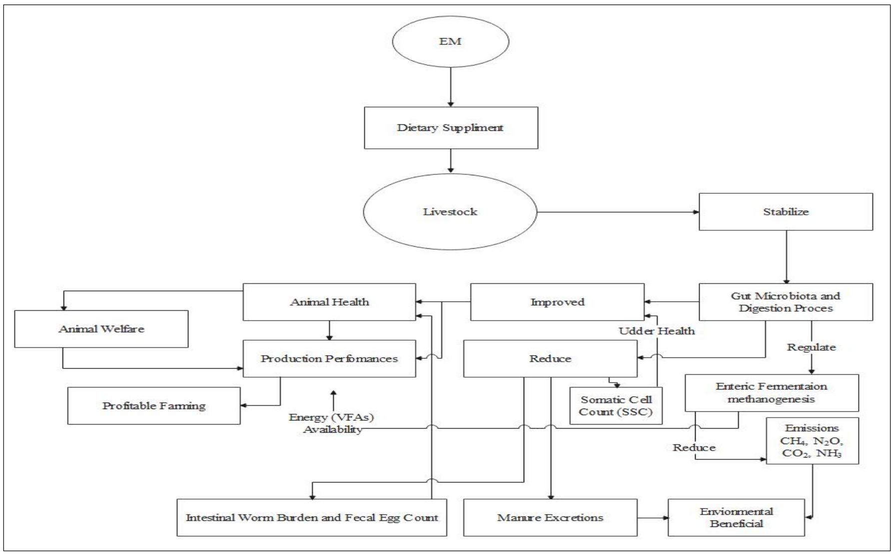

Fig 1: Effect of EM on livestock and poultry.

Moreover, the lack of understanding of the mechanisms and long-term effectiveness, mutual effect with different feed modifiers, should be further investigated.

CONCLUSION

Effective microorganisms provide promising results for improving livestock nutrient and environmental sustainability across cattle, goat, sheep and swine. The critically synthesised results from the existing studies revealed that EM improves nutrient digestibility and enhances production performances while mitigating environmental impact. However, further studies are required to investigate the multifunctional action and properties of EM, combined microbial stains and the mechanisms of action. Based on the synthesised knowledge, EM presents a promising approach in livestock nutrition, enhancing colostrum, milk and meat quality, while simultaneously reducing livestock emissions, contributing to improved environmental sustainability.

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Conflict of interest

All authors have no conflict of interest in this study.

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