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# Effective Microorganisms (EM): A Promising Approach to Sustainable Dairy Production: A Review

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## ABSTRACT

The dairy sector is vital to global food production and the economy. In dairy farming, the cost incurred for animal nutrition accounts for approximately two-thirds of total production costs and contributes significantly to the ecological footprint. Therefore, reducing production costs while maintaining optimal animal performance is essential. Thus, alternative, sustainable feeding sources should be researched. Effective microorganisms (EM) are considered a mixture of beneficial bacterial inoculants and have the potential to be used as an alternative feeding supplement to enhance the digestibility and subsequently enhance the production. Effective microorganism technology was developed in Japan in 1980 and since then, limited studies have focused on animal nutrition. For this study, a narrative review process was employed. Google Scholar's advanced search function was employed to filter the papers, with the keywords "Effective Microorganisms" OR "EM" OR "Direct Feed Microorganisms" OR "Probiotics" AND "Dairy Cow" OR "Cow" OR "Dairy Production" AND "Cow Health" OR "Gut Health" OR "Nutrition". Recently published, peer-reviewed articles written only in English, journal articles and leading web articles and reports were selected for the synthesis of the results. Based on synthesized knowledge, EM supplementation has significantly improved nutrient digestibility, gut health, milk production and overall performance in cows while reducing manure nutrient excretion.

**Key words:** Animal welfare, Microbial synergy, Nutrient bioavailability, Rumen health, Sustainable agriculture.

In the modern world, there is a growing trend of exploring alternative feed ingredients for the dairy sector to enhance production efficiency (Vlaicu and Untea, 2024). The term "effective microorganisms (EM)" is often used to introduce consortia of different genera of beneficial microorganisms, which could help the digestion process and nutrient absorption, as well as have probiotic effects (Abraheem *et al.*, 2024; Natt and Katyal, 2022; Sugandhi *et al.*, 2018). Effective microorganisms contain the strains of lactic acid bacteria (LAB), yeast, actinomycetes, photosynthetic bacteria and substrates such as molasses (Ezeagu *et al.*, 2023). In addition, EM could be contained with beneficial enzymes and some crude extracts. Malaysian company (EMRO, 2024) has defined "EM as a feed additive that contains only naturally occurring three major genera of microorganisms, which are yeast, LAB and photosynthetic bacteria". The fermentation process of these consortia of bacteria secretes additional beneficial substrates of bioavailable vitamins, chelated minerals and organic acids as well as antioxidants (Sawant *et al.*, 2025).

Effective microorganisms have been applied in the livestock industry for purposes such as reducing odour and manure management (Tu-Kitaw *et al.*, 2013). They have also been used as feed supplements to improve animal performance, including milk and egg production (Yitbarek, 2023; Kumar *et al.*, 2017). Effective microorganisms can be supplied through feed, water and in some cases, via fermented products such as Bokashi.

Various interventions aimed at improving animal performance have been discussed in the literature, however, relatively few studies have focused specifically on dairy cows.

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Existing research has primarily focused on odour reduction, then it has expanded to one of the mitigation strategies of livestock greenhouse gas (GHG) emission (Riaz *et al.*, 2024). Moreover, with its beneficial probiotic activity, EM enhance the gut health and subsequently improves the animal performance as well (Fig 1).

However, limited studies have focused on the effects of EM on dairy cattle performance, focusing on the essential areas of nutrient digestibility, manure management and gut function (Nalla *et al.*, 2022). At present, the dairy sector faces different challenges, including high feed costs, seasonal forage scarcity, poor-quality feed and climate variability (Damunupola *et al.,* 2022; Vidanarachchi *et al*., 2019). Hence, it is worth reviewing the EM technology as a sustainable approach to improve nutrient utilisation, milk production and potentially reduce environmental impact. Therefore, this review summarises the current knowledge, study gaps and suggestions for future research to optimise the use of EM in dairy production.

## Effective microorganisms on milk yield and quality in dairy farming

Milk production is the main purpose of dairy cattle farming and improvement in production over time is important for profitable dairy farming (OECD, 2025). Today, the best nutritional regime and feeding management that influences milk production is of great importance (Qin *et al*., 2025). Hence, the investigation for other sustainable alternatives for feeding is imperative (Ngesi *et al*., 2025; Chanda *et al*., 2024). Therefore, this section centres around the effect of EM on milk production, with a particular focus on nutrient digestion, absorption and their overall influence on dairy performance.

The rumen is the largest of the anterior fore-stomach compartments of ruminant herbivores and together with the reticulum, it creates a spacious fermentation vessel (Pokhrel and Jiang, 2024; Liu *et al*., 2023; Gupta *et al*., 2016). In the rumen, there are a massive population of bacteria, fungi and protozoa, which is held at ~39°C under a continuous culture system (Mayulu and Christiyanto, 2025; Zahra *et al*., 2022). As already mentioned, dietary substrates passing to the rumen are fermented by the rumen microbes and the products of fermentation, which are volatile fatty acids (VFA), are the major source of energy in cows (Dhakal *et al*., 2024; Fang *et al*., 2021) and microbial protein and gases such as methane ($CH_4$) and carbon dioxide ($CO_2$) (Iddi-Mrutu *et al*., 2023; Parchami *et al*., 2024). Addition of EM to the system improves the rumen ecosystem and microbial diversity (Gao *et al*., 2022; Lv *et al*., 2020). With the process of fermentation, it is believed that EM can improve fermentation and subsequently milk synthesis (Jiang *et al*., 2025; Marinho *et al*., 2025; Tadesse *et al*., 2024).

It was found that microbial solution supplementation enhanced the cellulolytic bacterial population and their activity in the rumen (Nair *et al*., 2025). It causes more extensive degradation of complex fibrous feed ingredients and results in greater VFA production, especially in the form of acetate and propionate (Jiang *et al*., 2025). Faster release of acetate and propionate and faster production by efficient fibre digestion subsequently increase milk fat and volume (Yang *et al*., 2024; Shi *et al*., 2023; Mitchell *et al*., 2023). Alternatively, stimulating production or supplementation of butyrate enhances the rumen epithelial development and function by facilitating the required energy for better rumen wall function and performance (Fukumori *et al*., 2022; Steele *et al*., 2016). Based on the above discussion, EM as the probiotic significantly helps to improve milk production and its quality by enhancing the availability of VFA for better cow performance (Cappellozza *et al*., 2023; Nalla *et al*., 2022).

Supplementation of EM in small ruminants has been shown to improve ruminal degradability and improve the nitrogen utilisation and microbial protein synthesis (Direkvandi *et al*., 2020). The EM affects the rumen microbial population and optimises the rumen microbial protein synthesis, which is achieved by optimising the conditions in the rumen. Produced microbial proteins are a great source of amino acids, which drives protein synthesis for milk production (Tadesse *et al*., 2024; Zeeshan *et al*., 2023). Further, studies have shown that supplementation of microbial-based feeding enhances the body weight and milk yield in cows by efficient utilisation of available energy and microbial protein, especially increasing the synthesis of casein, which is the dominant protein found in milk (Tadesse *et al*., 2024; Carresi *et al*., 2024).

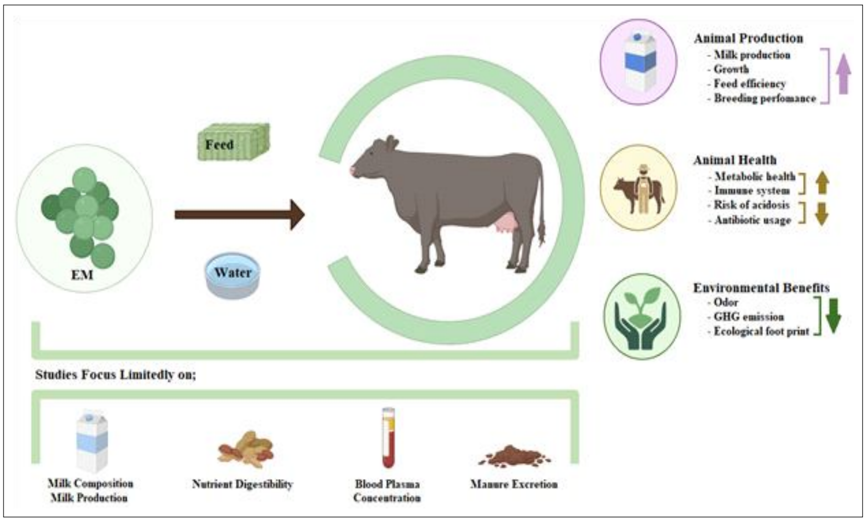


**Fig 1:** The role of effective microorganisms in enhancing dairy production.

Rumen fat digestion occurs only in minute quantities because dietary fat can be detrimental to the microbes. To alleviate this problem, microbes process fats by lipolysis and biohydrogenation (Bionaz *et al*., 2020; Vasta *et al*., 2019). Lipolysis in the rumen secretes glycerol, which may be fermented by the microbes into propionates and other VFAs that may enhance milk yield and performance in cows (Yang *et al*., 2025; Kupczyñski *et al*., 2020; Torres *et al*., 2021). Such changes in energy production processes in the rumen are accomplished through intervention from efficient microorganisms that modify and change the microbial consortia within the rumen, with the end goal being to maximise milk yield (Mohanty *et al*., 2023).

As shown in Fig 2, supplementation with microbial blends including EM supports quality milk production (Polyorach *et al*., 2023) by producing beneficial enzymes, minerals and vitamins, such as B vitamins (thiamine, riboflavin, pyridoxine, *etc*.), which are crucial for fibre, protein and fat digestion and absorption (Shukla *et al*., 2024). By enhancing nutrient absorption, EM plays a crucial role in improving overall milk yield and composition.

Other than that, recent studies have shown that high-yielding and longer lifetime dairy cows reduce the ruminal bacterial diversity, due to a greater adaptation to lactation-specific diets. Thus, supplementation with direct-fed microbials such as *Lentilactobacillus buchneri, Bifidobacterium longum* and *Pediococcus pentosaceus,* improved digestibility of both crude protein and neutral detergent fibre while improving milk protein percentage through optimization of ruminal fermentation and microbial protein synthesis (Yang *et al*., 2025; Mu *et al*., 2019; Tong *et al*., 2018). This may be literary evidence that the supplementation of EM could support and improve the longer lifetime of dairy rumen microbial diversity. Moreover, supplementation with EM results in an increase in milk yield together with improved quality parameters of milk, thereby supporting longevity of production through improved interactions between the microbiome and host (Yang *et al*., 2025; Wu *et al*., 2024).

## Effective microorganisms on nutrient utilisation and digestive efficiency in dairy cows

This section explores the effect of EM on nutrient digestibility, enzyme activities and the digestion of fibre, fat and protein, as well as its role in nutrient absorption. Many studies in dairy cows and other ruminants showed that beneficial microorganisms (*e.g*., yeast, *Bacillus* spp.) interact with native rumen microbes and promote the proliferation of cellulolytic and amylolytic bacteria (such as *Fibrobacter* and *Ruminococcus*) while suppressing pathogenic and competitive microbes (Halfen *et al*., 2021; Lopreiato *et al*., 2020).

Usually, a cow's diet consists of high-fibrous feed ingredients, which are particularly difficult to digest without fermentation (Jardstedt *et al*., 2018). Supplementation with microbial additives (EM) has been shown in some studies to increase the fibrinolytic bacterial population (*e.g*., *Ruminococcus, Fibrobacter*) in the rumen, which may enhance the digestion process by accelerating the fermentation process (Wang *et al*., 2024; Wei *et al*., 2022; Mamuad *et al*., 2019). Ingested fibrous materials are fermented and broken down by the rumen native microbes (*Ruminococcus spp, Fibrobacter spp*, *etc*.) in a blend with EM by producing enzymes that break cellulose and hemicellulose and subsequently produce simple sugars such as glucose, which are the base substrates for VFA production (Firrincieli *et al*., 2024; Weimer, 2022). In anaerobic conditions in the rumen, sugars (glucose) produced from fibrous feeds are converted into pyruvate through glycolysis and then converted into different VFS (*e.g*., acetate, propionate, butyrate), which supply energy to the cows (Zhu *et al*., 2025; Hassan and Karsl, 2022). Effective microorganisms influence the process of fiber digestion by altering the rumen environment (Tadesse *et al*., 2024; Sheikh *et al*., 2018).

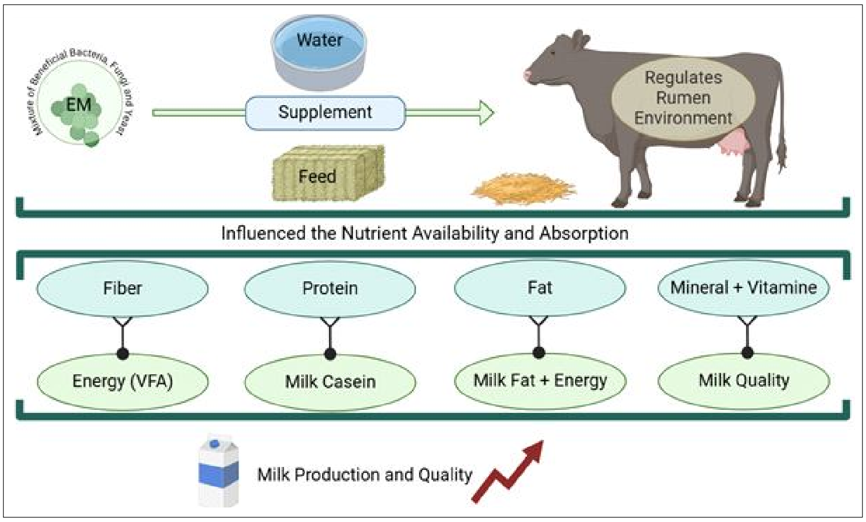


**Fig 2:** Biological mechanisms of effective microorganisms in improving milk yield and quality of dairy cow.

Focusing on N utilization and protein digestion, cows ingest N and protein sources from the legume forages, by-products, concentrates like soybean meal, cotton seed meal and supplemented non-protein nitrogen (NPN) compounds (Castro-Montoya *et al*., 2021; Wilson *et al*., 2020). These proteins basically can be divided into two groups; rumen degradable protein (RDP), which is crucial for producing microbial protein and rumen undegradable protein (RUP), which is bypassed through the rumen and absorbed in the small intestine (Putri *et al*., 2021; Ahvenjärvi and Huhtanen, 2018). Both are crucial in fulfilling cows' protein requirements.

By improving the rumen ecosystem and microbial population, microbial supplementation enhances the N and protein digestion process (Jiang *et al*., 2025; Cappellozza *et al*., 2023; Hassanat and Benchaar, 2021). When RDP comes from the feed materials, they are broken down into peptides, amino acids and ammonia ($NH_3$) by the microbes through the process called proteolysis (Putri *et al*., 2021; Cherif *et al*., 2018). Then the process of deamination separates the amine group (-NH, ) by the enzymes and subsequently produces $NH_3$ (Gervais *et al*., 2017). By utilizing these $NH_3$, microbes produce microbial proteins, which are digested and absorbed in the small intestine. Moreover, by a similar mechanism, NPNs are utilized to produce microbial protein in the rumen, which converts urea into $NH_3$ (Lima *et al*., 2023; Zurak *et al*., 2023). For the efficient production of microbial protein, EM contributes by stabilizing the rumen pH, enhancing the fermenting process by altering the whole rumen environment.

While focusing on fat digestion, it is unlike fiber and protein digestion in the rumen, excessive fats could be toxic to the rumen microbes (Lee *et al*., 2019). Dietary fats are digested by lipolysis and biohydrogenation processes with minimal intervention of rumen microbes (Huang *et al*., 2022). Through the lipolysis process, the rumen microbes break down the complex fats, such as triglycerides and glycolipids, into fatty acids and glycerol by the enzyme lipase (Hao *et al*., 2021). Then the glycerol converts into VFA through microbial fermentation, which produces energy (Cantalapiedra-Hijar *et al*., 2016). Apart from that, the microbes convert unsaturated fatty acids in feed material such as oleic acid and linoleic acids into saturated fatty acids by adding additional hydrogen ($H^+$) atoms (Wei *et al*., 2018). This conversion reduces the harmful effect which can be caused by rumen microbes (Karangiya *et al*., 2016). The small intestine is where the saturated fatty acids go next and then they get mixed with the bile and pancreatic enzymes of the pancreas, which digest them into free fatty acids and monoglycerides that can be absorbed into the blood (Kand *et al*., 2018). Further, EM supplementation increases lipolysis and biohydrogenation by optimizing conditions for fat digestion and absorption (Owens and Basalan, 2016).

As stated in Fig 3, EM supplementation increases the nutrients' digestibility and absorption through optimum utilization of feed resources while enhancing FCE.

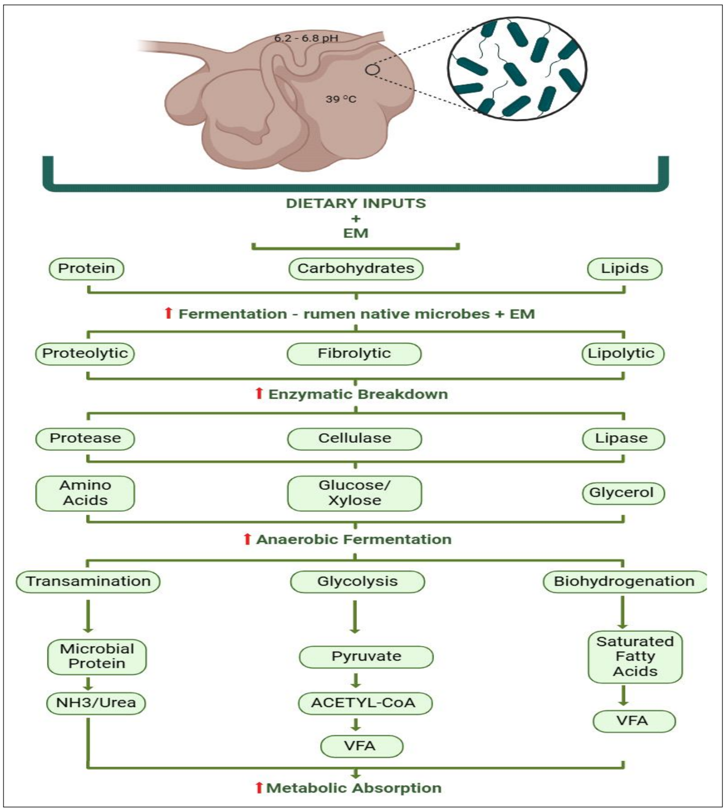


**Fig 3:** Understanding the digestive benefits of effective microorganisms in dairy cow nutrition.

Furthermore, recent findings by Liu *et al*. (2025) have highlighted that feed sorting behaviour may alter the rumen microbial ecosystem and certain metabolisms to a degree that negatively impacts the efficiency of fermentation and nutrient utilisation, underscoring the need to stabilize specific microbial populations to enhance digestive efficiency, even with balanced rations. Moreover, when comparing Sanhe with Holstein cows, differences in rumen microbiome composition were observed, indicating that relative to breed and parity, some microbiomes matured, resulting in increased binding of ATP transporters in lactating cows. This led to the enrichment of transport and bioconversion of certain monosaccharides and amino acids, which indirectly influenced digestion and nutrient metabolism (Liu *et al*., 2025). Besides, the study conducted by Alaa *et al*. (2025), which focuses on integrated metagenomic and single-cell RNA sequencing techniques deconstructing microbial consortia, exposed certain bacterial genomes linked to core cellulose, xylan and pectin polysaccharides with prominent fibre digestion efficiency, while identifying some epithelial cell subtypes that specifically absorb and metabolise VFA. Thus, improvements in microbial ecosystem functionality are able to maximise nutrient recovery within the digestive tract, reducing feeding costs and concomitant nutrient losses to the environment (Alaa *et al*., 2025; Liu *et al*., 2025).

## Effective microorganisms on blood plasma metabolites in dairy cows

Examination of blood plasma concentration is the key method for understanding how animals metabolize ingested feeds and concentrates, as well as their nutrient absorption efficiency. This section summarizes the impact of EM on important plasma parameters in dairy cows.

Blood plasma concentration can be assessed using haematological techniques, which are valuable for accurately predicting nutrition requirements, monitoring animal health and identifying metabolic disorders and other diseases. Table 1 shows the effect of EM on blood plasma concentrations, focusing on plasma nutrient levels, compositions, hormones and metabolic indicators.

As shown in Table 1, EM positively influences the important blood plasma parameters such as SUN, NEFA, Insulin-like hormones and immunoglobulins. These parameters are key indicators of efficient nutrient utilization and enhanced immunity, both of which may contribute to improved milk production when EM is supplemented.

## Effective microorganisms on manure excretion and methane emission patterns in dairy cows

Effective microorganisms have shown insightful results in manure nutrient excretion and management (Mohamed *et al*., 2018). This section focuses on the specific role of EM in manure composition and its effect on the environment.

As previously discussed, EM shows a promising intervention for digestion and nutrient absorption. Oyebade *et al*., (2023) clearly showed that the supplementation of EM increases the N utilization and protein absorption and reduces the manure N retention, enteric $CH_4$ formation and $NH_3$ emission by modifying the rumen environment. In addition, when $NH_3$ volatilization is decreased, urinary N losses are decreased (Kenney, 2013). Thus, EM application might be useful to the environment in terms of reducing malodor and the eutrophication of water bodies resulting from excessive nutrient inflow.

The EM aids the breakdown of fibrous constituents and enhances nutrient utilization toward faecal solids reduction, owing to augmented microbial activity (Maylem *et al*., 2024; Williams *et al*., 2023; Seo *et al*., 2010). In addition, EM increases a number of enzymatic processes, which results in the lowering of Phosphorus (P) and organic matter excretion in the manure (Ort *et al*., 2018).

**Table 1:** Effects of effective microorganisms on blood plasma concentration in dairy cows.

| Observed effects | Details | Reference |
|---|---|---|
| Improved immune function | Increased neutrophil and monocyte activity, enhancing immune response | Brodzki *et al*., 2024 |
| Increased serum enzyme (GGT) and glucose metabolism | Improved liver function and glucose utilization in lactating cows | Liepa and Viduža, 2018 |
| No significant effect on plasma glucose or hydroxybutyrate | No changes in glucose or ketone metabolism, but better protein content | Kassa and Diffe, 2022 |
| Lower serum urea nitrogen (SUN) and better nitrogen efficiency | Reduced waste nitrogen excretion, improving protein utilization | Oyebade *et al*., 2023 |
| Higher plasma NEFA levels and energy mobilization | Increased fat metabolism, beneficial for early lactation cows | Seo *et al*., 2010 |
| Enhanced plasma hormones (IGF-1) and better feed efficiency | Improved milk yield and feed efficiency with Bacillus subtilis DFMs | Maylem *et al*., 2024 |
| Higher serum IgG and IgA levels (immune boost) | Strengthened immune defence and reduced infection risk | Ort *et al*., 2018 |
| Modulation of plasma metabolites (ammonia-N, VFAs, *etc*.) | Improved ruminal fermentation and microbial protein synthesis | Williams *et al*., 2023 |

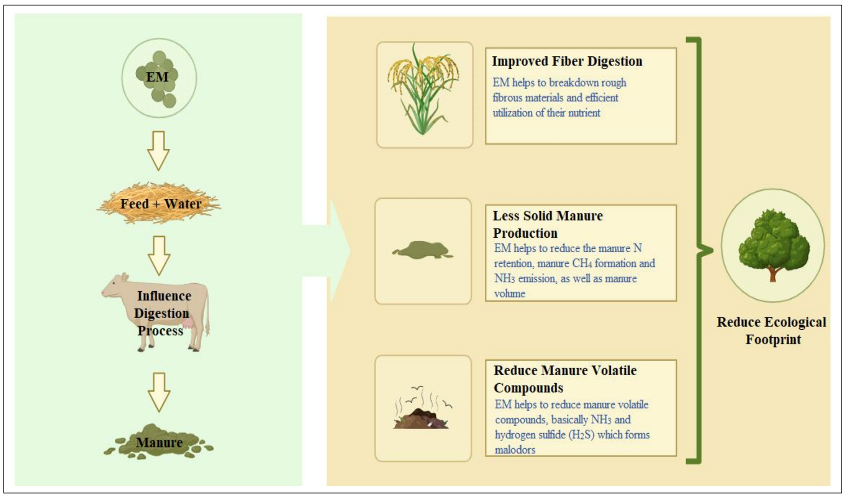


**Fig 4:** Impact of effective microorganism supplementation on manure excretion and composition in dairy cows.

Decreased digestion and nutrient absorption efficiency would increase the volume and solid content of the manure, both of which EM could alleviate.

Further, it was reported that using EM reduces volatile compounds in manure such as $NH_3$ and hydrogen sulfide ($H_2S$), which causes malodour and sometimes even mortality of cows due to toxicity would be minimized. Further, it is concluded that effective microorganisms are beneficial in reducing the manure VFA content, which may cause instability and odour production (Bastami *et al.*, 2016). Those works claim that EM controls the emission of a broad range of volatile compounds and their effects.

Moreover, contemporary mitigation strategies have shown that probiotics and direct-fed microbials concurrently address enteric $CH_4$ production and manure-based greenhouse gas emissions and meta-analyses have shown that supplementation of probiotics decreases daily $CH_4$ emission by about 11%, while improving nitrogen utilisation efficiency that consequently reduces nitrogen excretion in manure (Xie *et al.*, 2025). Methanotroph-based probiotics resulted in significant $CH_4$ reductions in beef steers, with some results exceeding 40 to 50% during *in vitro* trials, thus showing an opportunity for specialised microbial consortia to consume $CH_4$ produced during rumen fermentation directly (Tseten *et al.*, 2025). Further, comprehensive works showed that nitrous oxide and $CH_4$ emissions from dairy manure are greatly influenced by the storage period, along with management practices. Probiotics supplementation enhances nutrient retention in animals, thereby reducing the greenhouse gas emission potential from manure storage systems (Cherif *et al.*, 2018). Application of EM in manure management, therefore, results in a dual environmental benefit through a reduction of enteric $CH_4$ by 10 to 15% along with a further decrease in nitrogen excretion up to 15-20%, as well as reducing $NH_3$ volatilisation from manure by 25 to 30%, thus mitigating the atmospheric greenhouse gas contributions and nutrient pollution, further contributing toward sustainable dairy production systems (Xie *et al.*, 2025; Tseten *et al.*, 2025; Zahra *et al.*, 2024).

Fig 4 shows, EM minimizes the environmental effects by reducing nutrient excretion and the formation of GHG and odour-forming gases by efficient nutrient utilization.

## CONCLUSION

The application of effective microorganisms in dairy farming presents a promising and sustainable approach to enhancing milk production, optimizing dairy nutrition and managing manure excretion. By improving rumen fermentation, balancing microbial ecology enhancing nutrient digestibility, EM contributes to increased milk yield, improved quality and greater feed conversion efficiency. Besides, EM enhances better N and protein utilization, reduces $CH_4$ emissions and minimizes nutrient excretion in manure, thus minimizing the ecological footprint and supporting sustainable dairy farming.

As the industry trends toward eco-friendly and cost-effective feeding concepts, EM supplementation emerges as a potential alternative to conventional feed additives. However, further research is needed to fully understand its modes of action, long-term impacts and interaction with other dietary components.

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### Conflict of interest

All authors have no conflict of interest in this study.

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