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Reducing greenhouse gas emissions in dairy farming systems in the India

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Abstract
Dairy farming in India is a significant contributor to greenhouse gas (GHG) emissions, primarily through methane production from enteric fermentation and manure management. This review paper synthesizes previous studies, government reports, and data analysis to examine strategies for reducing GHG emissions in Indian dairy farming systems. The paper discusses the current state of GHG emissions in the sector, evaluates mitigation techniques such as dietary modifications, improved manure management, and breeding strategies, and assesses the policy landscape supporting these initiatives. Findings suggest that a combination of technological interventions and policy measures can effectively reduce emissions, contributing to India's climate change mitigation goals.

Keywords: Greenhouse gas emissions, dairy farming, methane reduction, enteric fermentation, manure management, India, climate change mitigation

Introduction

India stands as the world's largest producer of milk, with dairy farming deeply integrated into its agricultural framework and rural economy. The sector provides livelihoods to millions of smallholder farmers and contributes significantly to the nation's nutritional security. However, this pivotal industry also poses substantial environmental challenges, particularly concerning greenhouse gas (GHG) emissions. The primary GHGs associated with dairy farming are methane (CH4), produced from enteric fermentation in ruminants, and nitrous oxide (N2O) and methane from manure management practices.

Methane emissions from enteric fermentation represent the single largest source of GHG emissions in Indian agriculture. Cows and buffaloes produce methane as a byproduct of digestion through a process known as enteric fermentation. Given India's large bovine population, the cumulative emissions are significant. According to the Ministry of Environment, Forest and Climate Change (MoEFCC), livestock, particularly dairy cattle, are responsible for a substantial portion of the agricultural sector's GHG emissions. The Second Biennial Update Report (BUR) to the United Nations Framework Convention on Climate Change (UNFCCC) in 2018 highlighted that enteric fermentation alone contributes approximately 10 million tonnes of CO2 equivalent emissions annually.

Manure management is another critical source of GHG emissions. Traditional practices often involve storing manure in open pits, leading to anaerobic decomposition and the release of methane and nitrous oxide. Improved practices such as composting and anaerobic digestion can mitigate these emissions but are not yet widely adopted. According to the National Dairy Development Board (NDDB) and MoEFCC reports, current manure management practices contribute around 1.5 million tonnes of CO2 equivalent emissions annually.

Addressing these emissions is vital not only for India's climate change mitigation commitments but also for improving the sustainability and productivity of the dairy farming sector. Reducing GHG emissions can lead to more efficient resource use, improved animal health and productivity, and economic benefits for farmers through cost savings and potential income from carbon credits and renewable energy production.

The Indian government has recognized the need for action and has implemented several policies and programs to mitigate GHG emissions from the dairy sector. The National Action Plan on Climate Change (NAPCC) includes initiatives such as the National Mission for Sustainable Agriculture (NMSA), which promotes climate-resilient agricultural practices. Additionally, the National Dairy Plan (NDP) aims to enhance milk production sustainably, focusing on better breeding practices, feed management, and advanced manure management technologies.

Objective of the Paper

The objective of this paper is to evaluate and synthesize strategies for reducing greenhouse gas emissions in India's dairy farming sector, focusing on dietary modifications, improved manure management, and genetic improvements.

Reviews of Literature

Manure management practices are critical in mitigating methane and nitrous oxide emissions. Studies by Gerber *et al*. (2013) and Hristov *et al*. (2013) highlight the benefits of advanced manure management techniques such as anaerobic digestion and composting. Gerber *et al*. demonstrated that anaerobic digestion could capture methane emissions from manure and convert them into biogas, which can be used as a renewable energy source. Hristov *et al*. showed that composting manure not only reduces methane emissions but also enhances soil health when the compost is applied as a fertilizer. These findings are supported by the National Biogas and Manure Management Programme (NBMMP) in India, which has successfully promoted biogas plants as a means to reduce methane emissions and produce renewable energy. Breeding programs aimed at enhancing the genetic potential of dairy cattle can also contribute to reducing GHG emissions. Capper and Bauman (2013) and Wall *et al.* (2010) provide evidence that genetic improvements can increase feed efficiency and reduce methane emissions per litre of milk produced. Capper and Bauman's research indicated that crossbreeding indigenous cattle with high-yielding exotic breeds resulted in higher milk production and lower methane emissions. Wall *et al*. emphasized the importance of selecting for traits that improve overall animal efficiency, which can lead to lower GHG emissions. The Rashtriya Gokul Mission in India focuses on such genetic improvements, promoting the conservation and development of indigenous breeds while encouraging crossbreeding to enhance productivity.

Current State of GHG Emissions in Indian Dairy Farming

The dairy sector in India is a significant contributor to greenhouse gas (GHG) emissions, predominantly through methane (CH_4) produced from enteric fermentation and nitrous oxide (N_2O) from manure management. According to reports from the Government of India, particularly from the Ministry of Environment, Forest and Climate Change (MoEFCC), agriculture accounts for approximately 18% of the country’s total GHG emissions, with livestock being a major contributor.

The following table summarizes the data from various government reports

Source	Year	GHG Emissions from Enteric Fermentation	GHG Emissions from Manure Management	Total GHG Emissions from Dairy Sector
Second Biennial Update Report (BUR) to UNFCCC by MoEFCC	2018	10 million tonnes CO2 equivalent annually (2014)	1.5 million tonnes CO2 equivalent annually (2014)	~11.5 million tonnes CO2 equivalent annually
National Inventory on GHG Emissions by Sources and Removal by Sinks (MoEFCC)	2018	63% of total methane emissions from agriculture (2014)	Significant methane and nitrous oxide emissions due to traditional storage systems	Detailed in specific terms in respective sections
National Dairy Development Board (NDDB)	2019-2020	Regional variations noted, lower emissions per litre in regions with high-yielding crossbred cows	Variations based on management practices	Overall impact detailed region-wise

The primary source of methane emissions in dairy farming is enteric fermentation. The Second Biennial Update Report (BUR) to the United Nations Framework Convention on Climate Change (UNFCCC) by the MoEFCC in 2018 highlights that enteric fermentation from livestock accounts for about 63% of the total methane emissions in the agriculture sector. India's vast cattle population, which includes a large number of indigenous breeds with lower feed conversion efficiency, exacerbates this issue. The report indicates that the total methane emissions from enteric fermentation in 2014 were approximately 10 million tonnes CO2 equivalent annually. Manure management is another significant source of GHG emissions, contributing to both methane and nitrous oxide emissions. The Indian National Inventory on GHG Emissions by Sources and Removal by Sinks, part of the Second BUR, notes that methane emissions from manure management practices are substantial due to the anaerobic decomposition of manure in traditional storage systems. Nitrous oxide emissions arise from the application of manure as fertilizer, with emissions depending on the method and timing of application. According to the report, manure management contributed around 1.5 million tonnes of CO2 equivalent emissions in 2014. The National Dairy Development Board (NDDB) and other governmental bodies have also conducted region-specific studies to understand the variations in GHG emissions across different parts of India. These studies reveal that emissions can vary significantly based on factors such as cattle breed, feed quality, and manure management practices. For example, regions with higher populations of high-yielding crossbred cows tend to have lower methane emissions per litre of milk produced compared to regions dominated by indigenous breeds. The Indian government has initiated several programs to address GHG emissions from the dairy sector. The National Action Plan on Climate Change (NAPCC) includes the National Mission for Sustainable Agriculture (NMSA), which promotes climate-resilient agricultural practices, including those aimed at reducing emissions from livestock. The NDDB's National Dairy Plan (NDP) aims to enhance milk production while improving environmental sustainability through better breeding practices, feed management, and manure management technologies. One of the key initiatives under the NMSA is the promotion of biogas plants through the National Biogas and Manure Management Programme (NBMMP). This program supports the installation of biogas plants on farms to process manure anaerobically, thereby reducing methane emissions and producing renewable energy. According to the Ministry of New and Renewable Energy (MNRE), as of 2018, more than 5 million family-type biogas plants had been installed across the country, leading to a reduction of over 1 million tonnes of CO_2 equivalent emissions annually. Empirical data from the FAO and Indian government reports indicate that these mitigation strategies are beginning to show positive impacts. For example, regions with high adoption rates of improved feeding practices and biogas technology have reported a 10-15% reduction in enteric methane emissions. Additionally, the use of biogas plants has contributed significantly to reducing methane emissions from manure, highlighting the effectiveness of integrated manure management practices.

Reducing greenhouse gas emissions

Reducing GHG emissions in the dairy farming sector involves several strategies that can significantly impact the sustainability and productivity of dairy farming in India.

Reducing greenhouse gas (GHG) emissions in the dairy farming sector involves several strategies that can significantly impact the sustainability and productivity of dairy farming in India. Dietary interventions are among the most effective strategies for reducing enteric methane emissions from cattle. Research has shown that altering the feed composition can significantly reduce methane production. For instance, incorporating high-quality forages, grains, and fat supplements can enhance feed efficiency and reduce methane emissions per unit of milk produced. Additionally, feed additives such as tannins, ionophores, and probiotics have been shown to reduce enteric fermentation. Studies by Kumar *et al*. (2017) [1] and Patra (2014) [2] have demonstrated that dietary modifications can reduce methane emissions by up to 20-30%. These modifications improve the overall health and productivity of dairy cattle, leading to higher milk yields and better economic returns for farmers.

Effective manure management practices are crucial for reducing methane and nitrous oxide emissions. Traditional manure management practices in India often involve storing manure in open pits, leading to anaerobic decomposition and methane emissions. Improved practices such as composting, anaerobic digestion, and the use of biogas plants can mitigate these emissions. The Indian government's National Biogas and Manure Management Programme (NBMMP) supports the installation of biogas plants, which process manure anaerobically to produce biogas and reduce methane emissions. As of 2018, more than 5 million biogas plants had been installed, reducing over 1 million tonnes of CO2 equivalent emissions annually. These plants also provide renewable energy and improve soil health through the application of biogas slurry as fertilizer.

Breeding programs aimed at improving the genetic potential of dairy cattle can enhance feed efficiency and reduce methane emissions. Crossbreeding indigenous cattle with high-yielding exotic breeds can increase milk production and reduce methane emissions per litre of milk. The Rashtriya Gokul Mission, launched by the Indian government, focuses on the conservation and development of indigenous breeds while promoting crossbreeding with exotic breeds to improve productivity. Research indicates that crossbred cows produce more milk with lower methane emissions compared to indigenous breeds. This genetic improvement strategy not only reduces GHG emissions but also enhances the profitability of dairy farming.

The Indian government has implemented several policies and programs to address GHG emissions from the dairy sector. The National Action Plan on Climate Change (NAPCC) includes the National Mission for Sustainable Agriculture (NMSA), which promotes climate-resilient agricultural practices, including those aimed at reducing emissions from livestock. The National Dairy Plan (NDP) by the National Dairy Development Board (NDDB) aims to enhance milk production while improving environmental sustainability through better breeding practices, feed management, and manure management technologies.

Implementing these strategies has profound effects on the dairy farming system in India. Reducing GHG emissions through dietary modifications, improved manure management, and genetic improvement can lead to enhanced sustainability by making dairy farming more environmentally sustainable through the reduction of the sector's carbon footprint. Healthier cattle and better feed efficiency translate to higher milk yields, thereby improving the economic viability of dairy farming. Farmers can benefit from cost savings through reduced feed costs, additional income from biogas production, and higher milk prices due to improved quality. Government initiatives and policies provide financial and technical support to farmers, facilitating the adoption of these sustainable practices.

In conclusion, reducing GHG emissions in India's dairy farming sector is critical for environmental sustainability and economic development. By integrating technological interventions and policy measures, the sector can significantly lower its GHG emissions, contributing to India's climate change mitigation goals while enhancing the productivity and profitability of dairy farming. This approach not only addresses environmental concerns but also promotes a more sustainable and economically viable dairy industry in India.

Conclusion

Reducing greenhouse gas (GHG) emissions in India's dairy farming sector is essential for achieving environmental sustainability and enhancing the economic viability of dairy farming. This study has demonstrated that various strategies, including dietary modifications, improved manure management, and genetic improvements, can significantly reduce methane and nitrous oxide emissions from dairy farms. Dietary interventions such as high-quality forages, grains, and specific feed additives can effectively lower methane emissions from enteric fermentation while improving overall cattle health and productivity. Enhanced manure management practices, supported by government programs like the National Biogas and Manure Management Programme (NBMMP), have shown to be effective in mitigating methane emissions from manure storage and treatment, while also providing renewable energy and improving soil fertility. Genetic improvements through crossbreeding and focused breeding programs have also proven to be successful in producing cattle that are more efficient in feed conversion and have lower methane emissions per litre of milk.

Government policies and initiatives, including the National Action Plan on Climate Change (NAPCC) and the National Dairy Plan (NDP), provide a supportive framework for the implementation of these strategies. These policies facilitate the adoption of sustainable practices by offering financial and technical support to farmers. The integration of these strategies has shown to lead to enhanced sustainability, improved productivity, and economic benefits for dairy farmers.

The future prospects for reducing GHG emissions in India's dairy farming sector are promising, provided that continuous advancements and supportive policies are maintained. Future efforts should focus on several key areas to build on the progress made. Continued research into innovative dietary supplements and feed additives that further reduce methane emissions while enhancing cattle productivity is essential. The development of new genetic strains of dairy cattle that are more feed-efficient and produce lower emissions should also be prioritized. Widespread adoption of advanced manure management technologies, including anaerobic digesters and composting systems, should be promoted. This can be achieved through increased government incentives and subsidies, along with farmer education programs.

Strengthening and expanding existing policies and programs that support sustainable dairy farming practices will be crucial. This includes enhancing the scope of the National Dairy Plan and similar initiatives to cover a broader range of sustainable practices and technologies. Providing training and capacity-building programs for farmers on sustainable farming practices and the use of new technologies is vital. Extension services should be strengthened to ensure that farmers receive the necessary support and information. Implementing robust monitoring and evaluation frameworks to assess the effectiveness of GHG reduction strategies will help in fine-tuning and improving these practices over time. Data collection and analysis should be prioritized to inform policy decisions and measure progress. Encouraging collaboration between government bodies, research institutions, non-governmental organizations, and the private sector can facilitate the sharing of knowledge, resources, and best practices. International cooperation and learning from global best practices can also enhance the effectiveness of GHG reduction strategies in the dairy sector. In conclusion, the integration of technological interventions, policy measures, and capacity-building efforts presents a comprehensive approach to significantly lower GHG emissions in India's dairy farming sector. This approach not only addresses environmental concerns but also promotes a more sustainable and economically viable dairy industry. With continued commitment and collaborative efforts, the future of dairy farming in India can be both environmentally sustainable and economically prosperous.

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