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Reducing greenhouse gas emissions in livestock through farm management and nutrition

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Abstract

The livestock sector is one of the key sources of protein, and demand for milk, meat, and eggs is predicted to increase by 30%, 60%, and 80% by 2050. The animals' stocking density rate might be increased, or the current stock output could be improved. This sector, however, is a major source of greenhouse gas (GHG) emissions and is regarded as a global threat. The agriculture sector is the largest contributor to anthropogenic global warming, accounting for 53% of N_2O, 44% of CH_4, and 5% of CO_2. It is recommended that animals be managed using genetic selections in intensive management practices, with milk yields of up to 50 to 55 percent. Animal dung should be moved outside regularly to minimize N_2O emissions by 41% and CH_4 gas emissions by 55%. In contrast, nutritional manipulation increased animal productivity and reduced CH_4 gas emissions by 40% to 75%, depending on the degree of intervention. The antibacterial characteristics of plants' secondary compounds, which kill bacteria in the rumen, have the potential to reduce gas emissions. While lowering organic matter fermentation, fiber digestibility, and thus the methanogenic pathway, as well as direct inhibition of methanogenesis in the rumen by hydrogenation of unsaturated fatty acids, causes fat to suppress CH_4. Several mitigation measures could be used to address the impact of GHGs like CH_4 and N_2O in the cattle sector.

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Introduction

Ruminant animals' unique ability to ingest and utilize cellulose-rich feeds is due to the large diversity of microorganisms in the rumen. Bacteria, protozoa, and fungi use hydrolysis to break down complex compounds, producing volatile fatty acids (VFAs), primarily propionate, acetate, and butyrate (Danielsson *et al.,* 2017). Furthermore, variable quantities of formic acid, hydrogen (H_2), and carbon dioxide (CO_2), which are the end products of fermentation, will be produced (Hook *et al.,* 2010).

Most methanogenic archaea in the rumen use H_2 to reduce CO_2 and produce methane (CH_4) (Danielsson *et al.,* 2017). The generation of CH_4 is not used by the animals; instead, it represents an energy loss to the environment via eructation, which has a detrimental impact on the climate (Johnson and Johnson, 1995). The fundamental source of global climate change is greenhouse gas (GHG) emissions, which result in atmospheric warming (IPCC, 2013). In some parts of the world, for example, the livestock sector, particularly the cow industry, accounts for 14.5 percent of GHG emissions (Gerber *et al.,* 2013) and poses a significant threat to ecosystems, livestock sustainability, and the survival of numerous species (Moss *et al.,* 2000).

As a result, climate change has a significant impact on animal production by competing for natural resources; feed quality and volume; illnesses; heat stress; and biodiversity loss; and demand for livestock products is predicted to increase by 100% by the mid of the 21st century (Garnett, 2009). As a result, this analysis will highlight a number of strategies for reducing CH_4 emissions in cattle agricultural operations.

Climate change's impact on livestock production

Livestock products, such as meat and milk products, are one of the most important sources of protein. Global demand for milk, beef, and eggs is predicted to increase by 30%, 60%, and 80% by 2050, respectively (Sejian *et al.,* 2016). Due to the rising demand for meat and milk products, many farmers worldwide are expanding their farming operations by adding livestock or boosting the animal productivity of current animals. Temperature, fodder quality and quantity, water, and livestock diseases are all elements that influence animal output due to climate change (Rojas-Downing *et al.,* 2017).

Furthermore, climate change, notably global warming, substantially impacts domesticated animal performance (Chauhan and Ghosh, 2014). Heat stress is one of the environmental variables that affect animal performance and is an interesting component that has a significant impact on animal productivity (Koubkova *et al.,* 2002). However, a new understanding of animal responses to the environment is still being generated, and managing animals to mitigate climate change remains a challenge (Hahn *et al.,* 2003).

Heat stress to livestock

The impact of rising temperatures on animal performance is significant. For example, heat stress is defined as a condition in which an animal's body is unable to release enough heat to maintain body thermal balance (Mondal and Reddy, 2018). Every animal has a preferred ambient temperature in which to sustain thermoneutrality (Ali *et al.,* 2020). Animals maintain a body temperature range of 0.5 °C during the day (Henry *et al.,* 2012), and they experience heat stress when the temperature rises above the upper critical temperature range (FAO, 1986).

Fig. 1 shows the lower and higher essential temperatures for several animal species and their age categories. The critical temperature is influenced by the animals' physiological condition, species, age, and other environmental elements that affect the animals' thermal sense, such as air humidity and air velocity (Babinzsky *et al.,* 2011). For example, Dairy – Holstein, and Dairy- Brown Swiss lower temperature is -12˚C and a higher temperature is 24˚C, Dairy-Jersey's lower temperature is -1˚C and 24˚C as higher temperature while for the newborn dairy calf is 10˚C for lower temperature and 35˚C for the higher temperature. Fig. 1 also added that when humidity levels are high, the animals' comfort zones narrow, and the lower critical temperature rises while the upper critical temperature falls.

Animals' reactions to climate change

Climate change has a big impact on livestock production and the food supply. Heat stress occurs as the temperature rises, and cows show signs of reducing feed intake, decreasing activity, raising the respiratory rate, seeking shade and wind, and increasing peripheral blood flow and sweating (West, 2003). The direct effects of climate change on milk production have been demonstrated in animals (Chauhan and Ghosh, 2014). Furthermore, they stated that due to the increase in temperature, high genetic merit animals face a barrier in milk output production.

Strategies for mitigation

Agriculture contributes the most to anthropogenic global warming (Lynch, 2019), with animal agriculture accounting for 8–10% of global greenhouse gas (GHG) emissions (O'Mara, 2011). Livestock contributes significantly, accounting for 14.5 percent of global total yearly anthropogenic GHG emissions (Gerber *et al.*, 2013). Fig. 2 shows the numerous GHG anthropogenic gases created by cattle around the world, with N_2O having the biggest contribution to GHG at 53%, while methane gas is 44%, and carbon dioxide is 5%. This could be explained by the fact that larger levels of these gases negatively influence animal efficiency and output due to organic matter, nutrition, and energy losses (Gerber *et al.*, 2013).

As a result, there are numerous strategies for reducing GHG production and emissions in the atmosphere by animals. Management strategies, diet manipulation, and approaches such as reducing the overall number of the animals or improving the products that the animals generate (milk or meat). However, it is critical to developing new mitigation techniques and practices for a more cost-effective implementation of existing technology (O'Mara, 2011).

Animal production management

Animal productivity is inversely connected to greenhouse gas emissions such as CH_4 and N_2O (Gerber *et al.,* 2011). It has been pointed out that as animal productivity rises, the amount of CH_4 produced per unit of product decreases (Knapp *et al.,* 2014). Improving animal productivity requires consideration of genetic improvement, diet manipulation, feeding management, reproduction, health, and overall farming practices (Chauhan and Ghosh, 2014).

Several studies have found that genetic selection accounts for 50 to 55 percent of the increase in milk output observed during intensive management operations, with management procedures accounting for the remaining benefits (Hansen, 2000; Van Raden, 2004; Shook, 2006). It was discovered that selecting and breeding prolific animals required low food requirements while producing the same amount of product (Grossi *et al.,* 2019). Several writers illustrated their findings in Table 1 that good animal management practices, such as breed selection, increased animal health and wellbeing, lower animal mortality, improved reproductivity efficiency, and housing systems, are possible GHG mitigation solutions. However, when environmental conditions limit the animals' genetic potential, they are unable to reach their full genetic potential (Knapp *et al.,* 2014). Furthermore, improved dairy cow productivity resulted in fewer animals producing the same amount of milk, resulting in lower emissions per unit of milk produced (Pryce, 2017). Furthermore, combining different crop and animal varieties can improve heat wave and drought resistance and livestock output even when exposed to temperature and precipitation challenges (Rojas-Downing *et al.,* 2017).

Manure control for livestock

One of the sources of GHG emissions is animal manure, and the rapid growth in the population of animals will have an impact on this. As the density of the animals' increases, so does the amount of feed required, resulting in a larger volume of animal dung (Grossi *et al.,* 2019). The principal agents that degrade the organic material in the anaerobic circumstances of cattle manure are anaerobic and facultative bacteria, which produce CH4, CO_2, and stabilized organic material (Chauhan and Ghosh, 2014). Agricultural greenhouse gas emissions are directly contributed by stored animal dung (Grossi *et al.*, 2019). They also suggested that farmers take manure to an outside facility on a regular basis.

Table 1. Potential mitigating effects in methane and nitrous oxide in animal management.

Strategy	Category	Methane	Nitrous oxide
Management	Genetic selection	High	Limited data
	Animal health	low to medium	low to medium
	Decreased mortality rate	low to medium	low to medium
	Reproductive efficiency is increasing	low to medium	low to medium
	Housing systems	medium to high	medium to high

Legend: High = ≥30% mitigating effect; Medium = 10–30% mitigating effect; Low = ≤10% mitigating effect. Mitigating effects refer to percent change over a "standard practice" (Newell Price *et al.,* 2011; Borhan *et al.,* 2012; Hristov *et al.,* 2013; Montes *et al.,* 2013; Petersen, 2013; Battini *et al.,* 2014; Knapp *et al.,* 2014; Llonch *et al.,* 2017; Mohankumar Sajeev *et al.,* 2018).

Several authors described numerous potential solutions to control GHG caused by a livestock manure (Table 2). It was discovered, for example, that emptying the farm facility regularly by transferring the manure outside reduces nitrous oxide emissions by 41% and methane gas emissions by 55% (Mohankumar Sajeev *et al.,* 2018). Other solutions include adopting technology to segregate animal waste, which will reduce GHG emissions by around 30% (Montes *et al.,* 2013).

Table 2. Potential mitigating effects in methane and nitrous oxide in manure management.

Strategy	Category	Methane	Nitrous oxide
Manure storage	Solid-liquid preparation	High	Low
	Anaerobic digestion	High	High
	Reduced the length of storage	High	High
	Frequency of waste removal	High	High

Legend: High = ≥30% mitigating effect; Medium = 10–30% mitigating effect; Low = ≤10% mitigating effect. Mitigating effects refer to percent change over a "standard practice" (Newell Price *et al.,* 2011; Borhan *et al.,* 2012; Hristov *et al.,* 2013; Montes *et al.,* 2013; Petersen, 2013; Battini *et al.,* 2014; Knapp *et al.,* 2014; Llonch *et al.,* 2017; Mohankumar Sajeev *et al.,* 2018).

Nutrition for animals

Animal nutritional requirements play a critical part in their growth and development, which leads to optimum production. However, one of the contributing elements to greenhouse gas emissions is feed and feeding management.

To address the global problem of livestock-related greenhouse gas emissions, farming operations are developing techniques to reduce methane and nitrogen oxide emissions. Dietary manipulation, for example, is a simple approach that can improve animal productivity (Haque, 2018) and reduce methane gas emissions by 40%, depending on the degree of intervention (Benchaar *et al.,* 2001), and good nutrition can reduce methane gas emissions by 75% (Mosier *et al.,* 1998; Benchaar *et al.,* 2001).

Plant secondary compounds

Plant secondary chemicals are a potential antibiotic replacement (Ampode, 2019), with the potential to reduce methane gas emissions (Beauchemin *et al.,* 2008). The antibacterial properties of CH_4 gas, which destroy microorganisms in the rumen, are principally responsible for its inhibitory impact (Bodas *et al.,* 2012).

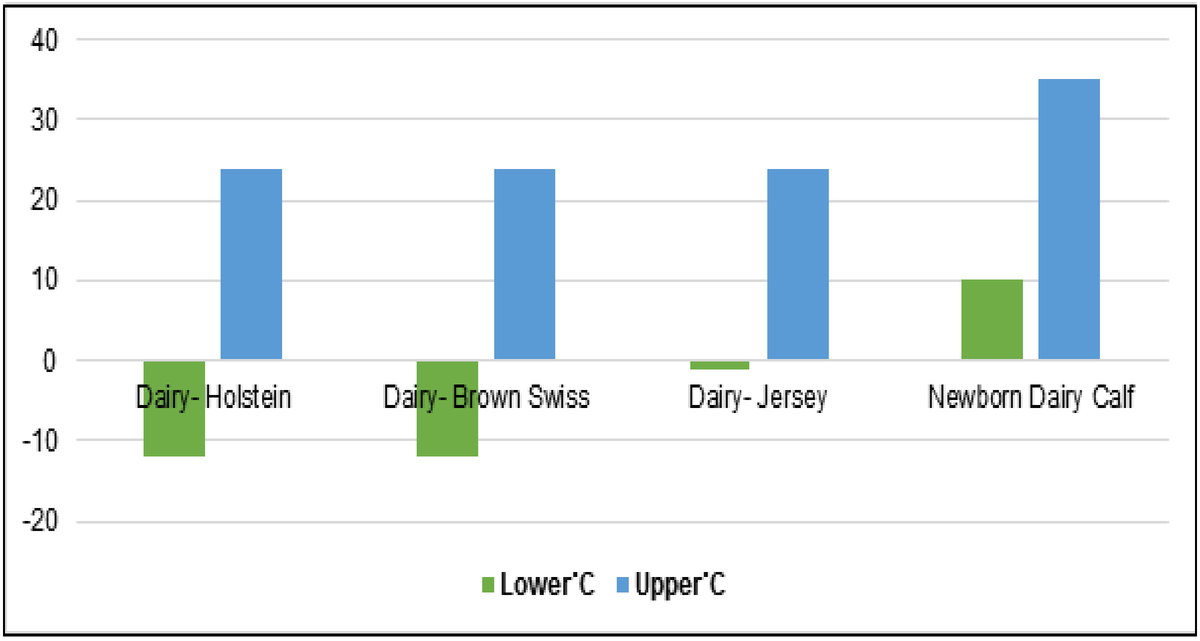

Fig. 1. Lower and upper critical temperature (˚C) of farm animals at different age (Babinszky *et al.,* 2011).

Supplementation of fat

Lipid supplementation was required for high-producing dairy cows to improve the feed's dietary energy content and meet the animals' energy demands (Haque, 2018). Furthermore, the energy augmentation in ruminant diets will shift from carbohydrate to fat, resulting in decreased fermentation and the production of CH_4. However, due to the toxic effects of fat on cellulolytic bacteria and protozoa, fat supplementation has been shown to reduce carbohydrate fermentation while leaving starch fermentation unchanged (Grainger and Beauchemin, 2011).

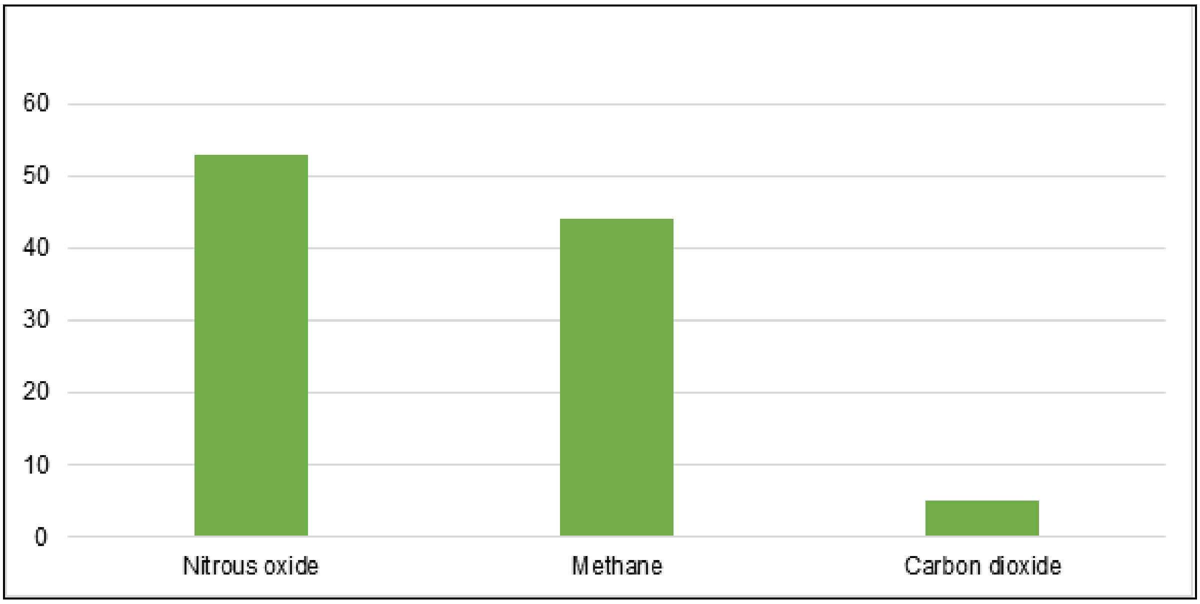

Fig. 2. Various GHG anthropogenic gases contributed by livestock (Rojas-Downing *et al.,* 2017).

The CH_4-suppressing mechanism of fat is induced by decreasing organic matter fermentation, fibre digestibility and consequently the methanogenic pathway and by the direct inhibition of methanogens in the rumen via the hydrogenation of unsaturated fatty acids (Johnson and Johnson, 1995).

Conclusion

It has been forecasted that the demand for meat and animal products is expected to rise in 2050. To address the demand, the primary goal is to increase the stocking density rate of the animals, but this will result in greenhouse gas emissions. However, the supply of animal products is not achievable due to heat stress, and it has a significant impact on animal productivity (reduction in feed intake, decreased animal activity, and increased respiratory rate). The impact of greenhouse gases such as methane and nitrous oxide in the livestock sector requires several strategies to mitigate livestock management, manure management, and animal nutrition through diet manipulation.

Competing interest

The author declared no conflict of interest.

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