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Carbon Footprints of Dairy Animals: Causes and Its Mitigation

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Abstract
Greenhouse gases are building up in the atmosphere to a larger degree leading to "global warming". The total quantity of gaseous emissions of greenhouse gases emitted by an individual in one year; directly or indirectly is measured in terms of 'carbon footprint'. Livestock play an important role for emission of greenhouse gases through various ways like rumen fermentation, manure and fodder production, milk, beef production etc. The demand for livestock products is increasing regularly and livestock products carry a high carbon footprint as compared to other products. Thus, in order to balance environmental concerns with the emergent global demand for dairy products along with economic feasibility to individual dairy producers there is need of emissions mitigation strategies. Proper management practices can lead to reduction in carbon footprints of livestock which in turn will help to minimize the negative effects of emissions on climate change.

Keywords: *Carbon footprints, greenhouse, livestock, milk*

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INTRODUCTION

The atmosphere has a natural supply of greenhouse gases that capture heat and keep the surface of the earth warm. These greenhouse gases are building up beyond the earth's capacity to remove them and creating "global warming". There is a relation between consumption of different products by human and their impact on global warming. Life-cycle assessment (LCA, also known as life-cycle analysis, eco-balance, and cradle-to-grave analysis) is a technique to assess the environmental impacts associated with all the stages of a product's life from cradle to grave (i.e., from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling). The emission of N_2O or CH_4 are often most important contributors to global warming.

In LCA, these impacts are aggregated in CO_2 equivalents which are often referred to as carbon footprints, taking into account their different contribution to global warming. In other words, 'carbon footprint' is a measure of the total quantity of gaseous emissions of greenhouse gases emitted by an individual in one year; directly or indirectly. Livestock contributes about 65% of total agricultural greenhouse gases (CO_2 equivalent), out of which enteric fermentation accounts for 90% [1]. There are three main gases that are classified as greenhouse gases: carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). By converting nitrous oxide and methane into equivalent quantities of carbon dioxide, total amount of 'carbon dioxide equivalents' produced per year can be estimated.

MEASUREMENT OF CARBON FOOTPRINTS

Carbon footprint value is the number of tonnes (1 tonne is a 1000 kilograms) of carbon dioxide equivalents generated in one year.
CO_2 equivalent is given as:
$CO_2e=CO_2\times1+CH_4\times25+N_2O\times298$

Carbon dioxide equivalents allow different GHGs to be compared relative to CO_2, using their 'global warming potential' (GWP), which accounts for their capacity to absorb radiation. The capacity of greenhouse gases to trap heat in the atmosphere is described in terms of their global warming potential (GWP), which compares their warming potency to that of CO_2 (with a GWP set at 1). The new widely accepted figure for the GWP of methane is 25 using a 100 year timeframe but it is 72 using a 20 year timeframe, which is more appropriate because of both, the large effect that methane reductions can have within 20 years and the serious climate disruption expected within 20 years if no significant reduction of GHGs is achieved. The intergovernmental panel on climate change supports using a 20 year timeframe for methane.

SOURCES OF NATURALLY OCCURING GREENHOUSE GASES

Naturally occurring greenhouse gases consist of water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). Carbon dioxide, CH_4 and N_2O have a direct global warming effect and their concentrations in the atmosphere are the result of human activities. Gases produced from industrial activities include chlorofluorocarbons and hydrochloro-fluorocarbons. There are several gases that have an indirect effect on global warming by influencing the formation or destruction of greenhouse gases, including tropospheric and stratospheric ozone. These gases include carbon monoxide (CO), oxides of nitrogen (NO_x) and non-volatile organic compounds. Aerosols, which are small particles or liquid droplets, can also affect the absorptive characteristics of the atmosphere. Major sources of human caused emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs) are oil, natural gas and mainly coal. Domesticated animals which are raised for food are generally accounted for at least 50% of all human caused GHGs but this source of GHGs emission is believed to be underestimated to a larger extent.

ROLE OF LIVESTOCK IN GHGs PRODUCTION

Livestock contributes a lot to GHG emissions worldwide. It is estimated that 7,516 million metric tons per year of CO_2 equivalents (CO_2e) or 18 percent of annual worldwide GHG emissions are contributed by cattle, buffalo, sheep, goats, camels, horses, pigs, and poultry as per the report of United Nations Food and Agriculture Organization (Livestock’s Long Shadow). According to Brighter Green, a US-based public policy action tank, livestock species, mainly cattle and buffaloes, have been identified as one of the prime contributors of greenhouse gases in India. The various ways by which livestock contributes to the production of GHGs are as follows:

Rumen Fermentation

Animals play a major role in the emission of methane; a gas with a much more lethal impact on global warming than the usual suspect carbon dioxide. Livestock is known to release a huge amount of methane through belching and flatulence, though the flatulence accounts for a smaller quantity. Cows digest their food through enteric fermentation while chewing their cud. This emits methane, a greenhouse gas that traps heat 23–25 times better than carbon dioxide. The average dairy cow belches out about 100 to 200 L of methane each day. The eructation of gases via belching is important in bloat prevention but is also the way CH_4 is emitted into the atmosphere.

Manure and Fodder Production

Cow manure also produces nitrous oxide which considered over a 100 year period, has 298 times more impact per unit weight than carbon dioxide. Producing fodder for farm animals also impacts climate as the production of chemical fertilizers and the clearing of land and forests to make way for agriculture too release significant quantities of carbon dioxide. Over a 20 year period, the methane’s impact is as much as 72 times that of carbon dioxide.

Milk Production

A study conducted by FAO (2010) revealed that a global average carbon footprint of 2.4 kg of $CO_2$was equivalent per kilogram of milk, of which 93% was emission from cradle to farm gate. It also appears that until 3,000 to 4,000 kg of milk per cow, the carbon footprint was markedly reduced with increased milk production. Generally, low feed efficiency of animals and use of larger proportion of feed for non-productive purposes like replacement stock, maintenance requirement are the main reasons for greater carbon footprint at a low yield.

Beef Production

Beef production which is one of the largest industries in the agriculture sector is a significant source of greenhouse gas (GHG) emissions. Beef, with a range of 15 to 32 kg of CO_2 eq. per kilogram of product had the largest carbon footprint followed by pork (4 to 11 kg of CO_2 eq.) and chicken (4 to 6 kg of CO_2 eq.). Milk had the smallest carbon footprint of the investigated livestock products per kilogram, but when considered per kilogram of milk protein, it was equivalent to chicken [2].

Others Sources

Carbon dioxide emissions are primarily due to the manufacturing and operation of farm machinery and vehicles, the manufacturing of fertilizers and agrochemicals as well as the manufacturing of farm buildings and electrical power generation.

MAJOR CONCERNS ABOUT LIVESTOCK CARBON FOOTPRINTS

India’s population is expected to grow further in future. As there will be no significant increase in the amount of cultivable agricultural land so food production must intensify to ensure an affordable abundant food supply. The demand for livestock products is increasing day by day and livestock products carry a high carbon footprint as compared to other products. Therefore, emissions mitigation strategies need to balance environmental concerns with the growing global demand for dairy products along with financial viability to individual dairy producers. The emissions should be reported per unit of output so that comparison of emissions can be made across diverse operations of the dairy industry. An effective way to reduce emissions per unit of milk is by improving dairy industry’s production efficiency. These improvements can be made by minimizing waste, maximizing both milk production and fraction of life of animal spent in peak milk production without compromising with animal health and well-being. The proportion of total consumed feedstuffs going towards maintenance energy costs is less in high yielding animals as compared to low yielders. With the historical advances in genetics as compared to 60 years ago, nutrition and management of dairy farms played a significant role to reduce the emissions by about 50% [3–4].

WAYS TO REDUCE CARBON FOOTPRINTS OF CATTLE

Through Heifer Management

Heifers are consuming inputs and producing both GHGs and air pollutants without contributing to the production of milk before calving. Intensified feeding programs for dairy heifers can lower the age at first calving with no reduction or even an improvement in first-lactation milk yield. Decreasing average age at first lactation and increasing first lactation milk yield could improve production efficiency and decrease emissions per kilogram of fat-corrected milk (FCM).

By Improving Herd Health

Various health problems lead to increase in mortality, loss of saleable milk, decreased reproductive performance and reduced milk production efficiency which in turn affects per unit of milk emissions. So, there are opportunities for the dairy industry to increase milk production efficiency, enhancing milk production, reproductive performance and cow longevity by improving the health of the herd. Many environment and social factors leading to stress are responsible for decreasing production efficiency. The emissions per kg of FCM can be reduced by improving cooling systems of animals in the herd during hot weather. Animals should be grouped properly according to size and age to minimize behavioral and social stress. Dry matter intake can be improved by avoiding overcrowding which further leads to increase in milk yield.

The GWP (Global Warming Potential) of milk can be reduced by decreasing the rate of sub-clinical and clinical mastitis. It is due to increased input-use efficiency, decreased losses of milk production and decrease in quantity of waste milk. In addition, lameness or injury to animals lead to decreased survivability, mortalities, selective culling in mature dairy cows, decreased milk production and poorer reproductive performance in affected cows. So, lameness or injury is a serious health concern in a herd and incidence of lameness can be potentially reduced by improved facilities, management, nutrition and genetics which will further result in decreased emissions per kilogram of FCM.

Reduction in Herd Size

The GHGs emission can be reduced by reducing the number of cows but due to increasing world population, the overall need to increase world food production limits this step. Still, as compared to larger number of low yielding cows, a smaller number of high yielding cows will produce less methane per liter of milk production.

Reduction in Number of Unproductive Animals

More profit and less emission can be achieved by reducing the number of replacement heifers and dry cows. The number of replacement heifers needed can be reduced by keeping the cows for longer periods in the herd.

Through Rumen Manipulation

Methanogens (microbes that produce methane) are a small proportion of the total rumen microbial population. Reducing the numbers of methanogens in the rumen can reduce methane production apparently without harming the digestion process. Antibiotics such as rumensin added to the diet of ruminants can reduce methane production. However the effect is not reliable, can be short lived and there is low public acceptance for routinely using antibiotics in animal production systems. In addition, biological control strategies where predators of the methanogens are introduced or encouraged are possible, but this research is only in its very early stages.

Through Animal Breeding

In future, the genetic selection of animals for breeding purposes could be based on a new criterion i.e. breeding animals for lower methane production [5]. Without compromising production whether livestock can be bred as low methane emitter is still under investigation. Currently, it is impractical to select animals directly having lower methane emissions due to lack of availability of selection index for low methane heritability. Moreover, it is difficult and costly to measure emissions.

However, it is possible to select low emissions animals indirectly via correlated traits for feed conversion efficiency. That is, some animals have been found to produce the same amount and quality of meat with a lower feed intake than less efficient animals. Theoretically, a breeding program could reduce methane emissions as heritable differences in rumen methane production between dairy cows, have been demonstrated by some studies. Though at present, bulls are not assessed for methane production and no attempts are being made to include reduced methane production in dairy breeding programs but it may be important in the prospect.

Through Improvement of Animal Survival

High mortalities of animals at birth or before maturity need to be replaced to fulfill the market needs in any dairy industry. Better survival of animals can be selected genetically through the identification of a heritable component in perinatal mortality of animals. Peri-natal mortalities can also be reduced by improving the disease resistance of animals.

Feed Related Strategies

i) Maximize diet quality/digestibility: Ruminants have an evolutionary advantage of digesting fibrous plant materials. Roughage digestion leads to production of methane which suggests that methane production is profoundly entrenched in the evolution of ruminants so may be hard to alter. Any strategy that improves diet quality will tend to reduce methane production per liter of milk such as improving pasture quality through grazing management, switching from C4 (subtropical) grasses such as paspalum or kikuyu to C3 (temperate) species such as rye grass or fescue and adding grain to a forage diet. Also forages with higher digestibility and higher rates of passage out of the rumen have the potential to reduce methane emissions for each unit of feed consumed.
ii) Feeding fats and oils: Dietary fats have the potential to reduce CH_4. This occurs through bio-hydration of unsaturated fatty acids, enhanced propionic acid production, and protozoal inhibition. The effects are variable and lipid toxicity to the rumen microbes can be a problem. This strategy can affect milk components negatively and result in reduced income for the producer.

iii) Feeding of condensed tannins: Due to direct toxic effect of condensed tannins (usually extracted from wattle bark) on methanogens, these help in reducing methane production. On contrary, even at very lower concentrations in diet, it leads to undesirable effects like suppression of voluntary feed intake and reducing digestibility of animals, which in turn leads to overall reduction in milk production.
iv) Certain feed additives have the ability to affect rumen bacteria leading to increased feed efficiency and even improved carcass quality. Examples are oils and bioactive agents such as tannic acid and ionophores.
v) The grinding and pelleting of forages can reduce emissions however the costs associated with this practice may be high.
vi) To minimize the environmental impact of the animal's excreta, there should be precision feeding of the animals. Precision feeding closely matches the nutrients needed by the animal for maintenance, growth and lactation to the supplied dietary nutrients. Nutritional models with adequate accuracy that can decrease variations in feeding system are needed for the precision feeding of the animals. Dairy producers can avoid expensive overfeeding and minimize nutrient excretion which in turn reduces emission by regularly monitoring the dry matter and nutrient composition of feedstuffs.
vii) Animals should be grouped according to size, age and stage of lactation for their proper feeding. Risk of various nutritionally influenced diseases and conditions like milk fever, ketosis, acidosis, lameness, prolonged anoestrous etc. of animals can be minimized by close monitoring and ensuring proper nutrition to the animals.

Therefore, feed and feeding programs plays a significant role to decrease the life-cycle emissions per kg of FCM by minimizing waste and at the same time it maximizes milk production to improve farm profitability.

Restoration of Reproductive Performance

The emissions per kg of FCM are affected by reproductive performance of animals to a larger extent. Feed conversion is the most efficient during peak milk production period but dairy cows having extended calving interval due to failure conception period spend more time out of this period. The emissions per kg FCM can be reduced significantly by restoring reproductive performance in addition to increased milk yield. Climate change per kg FCM is also affected by the use of sexed semen reproductive technology. In dairy cattle, selective use of sexed semen can lead to increase in rate of genetic progress. Moreover, the replacement population for dairy herd will increase in size due to use of sexed semen in all animals. To keep the population of dairy cattle at a level that does not create an oversupply of milk, the culling rate of the lactating cow must be increased. Further, a larger replacement herd size means more non-productive emissions for each kg of FCM produced.

CONCLUSION

Livestock are important to humans since only herbivores can convert fiber-rich vegetation into high quality protein sources for human consumption. But livestock contributes a significant amount of GHGs to the environment especially methane during fermentation process in rumen. It is therefore important that the livestock industry should recognize the potential negative effects of livestock on climate change due to emission of GHGs. Dairy farming is a highly managed system and has the potential to make reductions in GHG emissions intensity through increased efficiencies such as optimum animal performance and reduced inputs. So, proper management practices should be followed to mitigate the effects of GHGs emission from livestock.

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