

Review Article

Review on Methane Emission from Dairy Farms and Its Impact on Global Warming

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Methane is the main important greenhouse gas that emitted into the atmosphere by livestock during the process of enteric fermentation and manure management. Developing countries produce a large quantity of those emissions, caused mainly by inefficient animal rearing systems, feed production and manure management. Methane is emitted from livestock in developing countries and the mitigation actions that could be put in place to reduce atmospheric emissions and increase animal productivity. Developing countries are characterized by low Greenhouse gas emissions to the atmosphere and their potential impact on global climate have become important concerns world-wide. The impact of methane in industrialized countries, the situation is the opposite of developing countries. Livestock production systems, such as dairy farms, provide in both sinks and sources for greenhouse gas. Methane is produced during the anaerobic fermentation of hydrolyzed dietary carbohydrates in the rumen and represents an energy loss to the host besides contributing to emissions of greenhouse gases into the environment. The methane mitigation strategies require robust prediction of emissions from rumen. Therefore, improved feeding systems in dairy farms and provision of knowledge about methane emission transfer to dairy farmers are some of control strategies which contributes in methane gas reduction.

Keywords: Fermentation; Global Warming; Methane; Ruminant

Introduction

In eighth century Italian physicist Alessandro Volta was first identified methane as being the flammable gas in the bubbles that rise from a water logged marsh area. He could not have guessed how important this gas to human society and could not prove its use for centuries after Alessandro Volta initial identification [1]. Methane (CH₄) is a colorless, odorless, and tasteless gas that is the primary component of natural gas. It is lighter than air and has a specific gravity of 0.554; density of CH₄ is 0.717kg/m³ and its melting point is 86K while the boiling point 112K. Methane gas is poorly soluble in water, but soluble in organic solvents (has lipophilic nature) [2].

Methane is one of the three main Greenhouse Gases (GHG), together with carbon dioxide (CO₂) and nitrous Oxide (N₂O) in the environment [3]. In addition, it has global warming potential than CO₂ due the degradation of the ozone layer [4]. Methane is emitted from a variety of sources and its concentration in atmosphere has increased over the last few centuries [5]. Currently, the production of methane from livestock and its impact on climate changes are a major concern worldwide [6]. Methane is produced from enteric fermentation during the normal digestive process of ruminants [7].

The main sources of methane are classified as natural and anthropogenic in their nature. Therefore, natural sources of CH₄ emission in the atmosphere includes permafrost, termites, oceans, freshwater bodies, gas hydrates, wetlands and non-wetland soils, volcanoes, wildfires and emissions sources of methane from enteric fermentation of the domestic livestock contribute significantly to GHG [8]. Whereas, the anthropogenic sources of methane emission

includes fossil fuel production and use, animal husbandry (enteric fermentation in livestock and manure management),addy rice cultivation, biomass burning, and waste management systems [9].

Methane is important as a fuel for ovens, homes, water heaters, kilns, automobile, industrial chemical processes, transported as a refrigerated liquid liquefied natural gas and most important greenhouse gas after water vapor [10]. In addition, the principal component of natural gas used for turbines [11]. Recently, 75% of total methane emission is from livestock. The emission is expected to be increased in the next decade's emission, especially in developing countries [12]. Moreover, in the last five decades, enteric CH₄ emissions from dairy cattle grew by 12% and methane emission increases by 21% in developing countries whereas, the emission was reduced by 48% in developed nations [13].

Therefore, the objectives of this paper are:

- To high light methane emission from dairy farms.
- To review impacts of methane emission from dairy cow and measures to reduce its impact.

Methane Emission from Dairy Farms

Methane emission have multiple processes from dairy farms, including enteric fermentation in animals and microbial processes in manure [14]. Cattle release methane because of microbial fermentation, which leads to breakdown of carbohydrates in the rumen, and large intestine, contributes significantly to the greenhouse effect. Cattles produce by far the largest part of CH₄

and dairy cattle contribute greater percentage of emitted gases [15]. Recently, livestock sector of agriculture is industrialized; manure management contributes an increasingly large proportion of methane emissions to the environment. In addition, enteric CH_4 is produced in the digestive tract by Archaea microorganisms as a by-product of anaerobic fermentation (methanogens) which results in 3-14% loss in gross energy intake, which largely dependent on composition of the animals' diet and level of feed intake [16].

Furthermore, CH_4 emissions by dairy cows vary with body weight, feed intake, diet composition and milk yield. This occurs when cows are fed the same diet at the same intake; however, variation between cows leads to a variation in the amount of CH_4 emissions. The huge amount of CH_4 that is emitted from livestock originates in the fore stomach, also called the rumen and this occurs in the rumen by methanogens, which converts H_2 and carbon dioxide into CH_4 and water [17].

Methane formation in dairy farms

When carbohydrates are broken down by microorganisms into small molecules enough to be absorbed in the bloodstream, through the digestive process of enteric fermentation, it brings the formation of methane in dairy cows as a by-product [18]. Dairy cows consume fibrous feed and produced methane as a by-product of ruminant digestion produced by methanogen Archaea microorganisms in rumen through fermentation result in the form of methane production [19].

Furthermore, cellulose in the manure is degraded by microbes (methanogens) and serves as a substrate for CH_4 production [14]. Anaerobic digestion is a natural process in which the microorganisms consume organic matter under an oxygen-free environment and produce CH_4 , which is an important component of GHG. The composition of volatile solids contained in manure influence the anaerobic decomposition of organic matter and the formation of methane gas in dairy farms [20].

When, amount of feed consumed in dairy cows increases; the energy available for conversion to methane also increases. Through this enteric fermentation, animals like cows, sheep and goats are producing large amounts of CH_4 . Enteric fermentation occurs because of microorganisms in the stomach of these animals. This creates methane as a by-product that is either exhaled by the animal or released *via flatus* [21]. Methane is produced mainly in the rumen (87-90%) to a smaller extent (13-10%), in the large intestine [22]. The majority of methane emissions source in dairy farm is when animal exhaling CH_4 as a byproduct [23]. Methane forms where methanogen bacteria are present. Conditions favoring survival of methanogen bacteria are lack of oxygen, a redox potential below -200mV, neutral pH, nutrients (N, P, K, S), electron acceptors such as NO_3 and a substrate rich in organic matter.

Livestock manure contains portion of organic solids such as proteins, carbohydrates and fats that are available as food and energy for growth of anaerobic bacteria. Manure from the dairy sector is managed in liquid systems that produce greater quantities of CH_4 emissions due to the multiplication of methanogen bacteria in the chain [24,25]. The anaerobic environment is a precondition for the production of CH_4 sources *via* microbial metabolism of organic material. In anaerobic conditions, the decompositions of fecal and

bedding material produce methane after degrading of substance into volatile acids and the substances are used by bacteria to produce CH_4 [26,27].

Source of methane in dairy farms

Sources of methane emissions is injected in the soil as this creates anaerobic conditions and manure application [26].

Amount of methane produced

The amount of methane emissions produced calculated on livestock unit (LU is 500kg) from 58kg· LU in dry cows to 106 kg· LU from lactating cows. Lactating cows emit approximately twice the amount of CH_4 produced as compared to either dry cows or heifers, more amount of methane gas produced from lactating cows than dairy cows, this is largely due to their increased feed intake, although ration and animal size also have an effect. These emission factors may include emissions from feces deposited on the barn, floor, which would be much less than emissions from enteric fermentation [14].

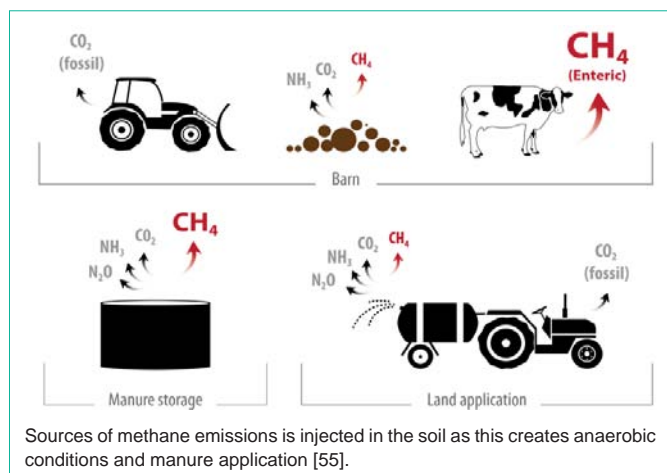
Enteric CH_4 emissions from Holstein cows by using CH_4 analyzers at robotic milking stations. This has resulted an increasingly large amount of methane, which can manipulate CH_4 production using diet, by making changes, which affect the availability of hydrogen in the rumen. Amount of methane gas emissions from handling and storage of manure depends on the amount of manure produced, its nitrogen content and the proportion that decomposes anaerobically, also temperature [28]. Moreover, if manure is kept in the animal barn, some amount of CH_4 may originate from this manure [29].

In dairy farms, the atmospheric air contains a small amount of methane gas when compared to respiration air of cattle. However, the concentration of CH_4 gas a mixture of air and excreted from the animal. Currently, the production level to decrease. increasingly large amount of methane produced by cattle which CH_4 production using diet ,and also the amount of methane production is measured by absolute as well as relative units, e.g. the ratio of emissions to the Live Weight (LW), per unit of feed intake (GE, DM), or Fat and Protein Corrected Milk (FPCM) [30]. The amount of CH_4 produced by an animal is influenced by many factors. These include dietary factors such as type of carbohydrate in the diet, level of feed intake, level of production (e.g. annual milk production in dairy), digest a passage rate, presence of ionospheres, and degree of saturation of lipids in the diet, environmental factors such as temperature, and genetic factors such as efficiency of feed conversion [31].

Condition favors production of methane gas

Rumen fermentation is one of a condition, which produces methane from anaerobic fermentation of feeds, which takes place mainly in the rumen with a minor contribution from the hindgut. No single microbial species is responsible for complete degradation of substrate in the rumen. Instead, a complex succession of organisms takes part in the cooperative catabolism of substrates and the production of methane fermentation products. The diversity, size and activity of the microbial population in the rumen are largely determined by the diet composition of methane production.

Methane gas production by two stages when breakdown of carbohydrate by rumen macrobiotic the first stage involves the hydrolysis of complex carbohydrates to glucose and performed by primary fermenters such as *Fibrobacter succinogenes* for the cell



wall carbohydrates [32]. The second stage (microbial fermentation) of carbohydrate digestion involves the conversion of pyruvate, 3-carbon simple molecule, to different fermentation products through metabolic pathways that produce metabolic hydrogen [19]. Primary and secondary fermenters are involved in the degradation of simple sugars to the main products of rumen fermentation, such as VFAs (acetate, propionate and butyrate), hydrogen gas (H_2) and CO_2 , whereas CH_4 produced in the final stage by methanogens [33].

When simple organic compounds are broken down under anaerobic conditions, CO_2 and CH_4 are produced. Where CH_4 is produced so quickly that it cannot escape by diffusion, bubbles will form and pass through overlying substrate and oxidation will not occur. This may occur in liquid manure systems where oxygen is scarce, but crusts present on liquid manure may slow the diffusion of gases and allow some oxidation [34] and also longer the manure is stored, the more CH_4 is produced. Manure from the dairy sector is managed in liquid systems that produce greater quantities of CH_4 emissions formed [24].

Mathematical models allow predicting CH_4 production from cattle without undertaking extensive and costly experiments. The models used can be classified as either statistical models, or dynamic mechanistic models. Statistical model, which relate nutrient intake to CH_4 production directly, dynamic model that estimate CH_4 production using mathematical descriptions of rumen fermentation biochemistry [35]. Methane is produced as a by-product of digestion of structural carbohydrates, due to the action of rumen microbes (bacteria, fungi and protozoa). During this digestion, monosaccharides are fermented to H_2 , CO_2 and Volatile Fatty Acids (VFAs), and as part of this stage of ruminant digestion some of the microbes (methanogens) produce CH_4 [36].

Accumulation of methane gas in the environment

Methane gas accumulate in environment at favorable freezing rates for cryogenic displacement of methane accumulation. Such conditions were found in refrozen thaw bulbs and under the active layer zone without evidence of higher substrate concentration or a favorable environment for microbial Methanogens the zones of high methane concentration accumulated must have specific conditions for the preservation of methane gas [37].

However, according to it, the freezing front displaced methane from the thawed soil when permafrost developed. It formed accumulations of methane gas in environment and in some cases the gas-hydrate in lithological rock represented by coarse-grained soils or other highly porous media, surrounded by less permeable soils (including permafrost). Similar processes of cryogenic displacement and accumulation of substances like oil contaminants or salt ions were reported earlier methane accumulation [38].

High methane fluxes accumulate observed in the places of permafrost degradation under thermos karst lakes, seawaters or the mechanical disturbance of permafrost deposits are not always associated with increased organic matter decomposition or fault/fracture zones. Methane concentration formation such accumulations depend on favorable conditions for methanogens. Especially in thaw bulbs, well pit, pump water, ground water, could create the gas-with increasing pressure and continuous methane formation [39].

Impact of Methane Accumulation on Global Warming

The major impact of methane gas accumulation that causes severe global warming in the atmosphere. Global warming becomes main issue in economics in the 21st century. Because global climate change becomes more dangerous and every nation realized due to greenhouse gas emissions accumulation effect. It is severe dangerous greenhouse gas, more global warming potential than carbon dioxide. Due to global warming the ocean levels are increasing, as a result, most of the coastal areas will submerge and some insects and animals will extinct [40]. Moreover, its effects on climate changes and atmospheric, is emitted from a variety of sources and its concentration in atmosphere has increased over the last few centuries.

One of the climate change gases, warming of earth surface is achieved by solar energy being radiated and increased global temperature concern with global environment [41]. Moreover, the gas could allow shortwave radiations to pass through the earth's atmosphere and heat the land and oceans. The long wave radiation emitted from earth surface cannot pass through atmosphere due to these greenhouse gases. Vehicular and industrial pollution is main contributor to the greenhouse gas effect and global warming [42].

Impact of methane in developing nation

Major impact of methane in developing countries are characterized by low production per animal, low feed quality, climate change, environment pollution and, consequently, high emission intensity, cause global warming, the emission of methane increase temperature of the earth, Loss of land area, including beaches and wetlands, because of sea-level rise, Loss of species and forest area, Disruption of water supplies to cities, agriculture and Increased air conditioning costs [43]. Methane gas emissions which per unit of milk produced decrease in various countries, and identified large differences in developing regions such as, In sub-Saharan Africa, South Asia, and NENA (Near East and North Africa) [44]. The emission intensity of dairy cattle in developing countries increase taking into account the limited economic and technical resources in most developing countries, developing countries produce a large quantity of those emissions, caused mainly by inefficient animal rearing systems, feed production and manure management [45].

Historic events show that droughts and large scale floods had a significant impact on the economy of developing countries where as increased air conditioning costs, Health damage and deaths from heat waves and spread of tropical diseases, Loss of agricultural output due to drought During these floods government incomes are often reduced due to a lower productivity while to increase the supply food aid and repair damaged infrastructure.

In developing countries the total CH₄ emissions impact will increase in future, mainly because of the expected rise in the number of livestock. The measure of how much heat methane gases could trap in the atmosphere in 100 years is named Global Warming Potential (GWP). These gases have high capacity to reflect infrared radiation back to earth, increase temperature on earth [46]. CH₄ emissions impact in developed nation directly from animals is not always feasible owing to high costs and need for expensive infrastructure such as respiration chambers. When the costs of genomic selection will be more affordable for breeding organizations in transition economies [47].

Impact of methane in developed nation

The impact of methane in industrialized countries, the situation is the opposite of developing countries, because productivity per animal has increased constantly in the last 30 years, owing to continues improvement in breeding, feeding, low emission intensity, high feed quantity and manage and the number of dairy cattle is decreasing [48] and its increase the global atmospheric concentration between pre-industrial times and in 2005 from approximately 0.715 parts per million (ppm) to 1.774 ppm [49]. GHG emissions methane, carbon dioxide, nitrogen dioxide were an average 7.5, 4.6, and 3.7eq/kg FPCM highly effect in developed countries at farm level respectively [50] and also the enteric fermentations process that affects ruminants in developed nation, and large molecules are broken down, causing the release of hydrogen, Carbon dioxide in atmosphere this occur when converted by methanogen *Achaeta* to methane, which is expelled through the mouth and nose emission causes global warming in developed nation [51].

Measure to Reduce Methane Accumulation in Dairy Farm

The best option measure to reduce methane accumulation emissions in dairy farm using nitrates to replace urea as a non-protein nitrogen source in the diet to meet the microbial requirements for rumen-degradable nitrogen, reduce emission from firewood and animal waste combustion. Adding sulphate to the diet of cow has been reduce CH₄ emission production [52]. On the other hand, the emissions per unit digested intake decrease and the emissions per unit of methane product most likely decrease with improved diet digestibility [53]. Moreover, different forage type increase which influences enteric CH₄ emissions in ruminant [54]. Dietary changes, direct rumen manipulation, and systematic changes. The dietary changes involve measures that enhance the efficiency of feed energy use, an area that has potential implications for forage use in the future [55]. Therefore, the efficiency of the animal digests feed is increased, the amount of methane gas by rumen can be reduced [56].

Moreover, measure to reduce methane emission in dairy farms by lowering formation in the rumen higher grain diets, grain type. Fats,

oilseeds, pasture quality and Management of herd under an intensive production system grazing high quality forage [57]. Its reduction emission by improving feed conversion efficiency and animal breeding for Residual Feed in taken improve [58]. however, reduction of CH₄ by increasing animal Productivity, diet formulation to improve rate of grain or milk, reducing numbers of replacement heifers, management of beef cattle, Better reproductive performance breeding for increased productivity and improving rumen fermentation efficiency [59].

Furthermore the main reduction of methane emission strategy is to improve rumen fermentation efficiency defined two general mechanisms by which these substances act to reduce CH emissions from farms, first by reducing the supply of metabolic H⁺ for methanogens (e.g. definition, cytotogenesis) and second by direct inhibition of methanogens (e.g. plant extracts) [60-67]. Reducing enteric methane emissions from dairy cows while maintaining levels of milk production could prove an important strategy for countries to meet reduction targets methane in global emissions [24].

Conclusion and Recommendation

In general, methane (CH₄) is a powerful greenhouse gas that through the ozone layer back to the earth and raise the temperature. It affects the earth's radiative balance by being oxidized to CO. It is also important for the atmospheric chemistry since it controls the abundance of Ozone (O₃) and the Hydroxyl radical (OH) (which in turn affects the lifetime of other greenhouse gases, CH₄ emissions from livestock and mitigation actions in developing countries. The results indicate that emission intensities from livestock are medium to high in poor countries owing to low animal productivity, low feed quality, lack of knowledge, and limited investments. There are differences among developing countries in animal gas emissions in the same continent or region, indicating that improvements are possible. The emissions of CH₄ from animal-producing farms normally result in a net GHG emission. The actual rate of methane and net GHG emission are highly dependent on the management strategies implemented on a farm. All of the important factors and measure the relevant sources of pollution in order to determine the overall environmental impact of farm production systems. This emphasizes the need for a whole-farm for evaluating mitigation strategies in farm production systems.

Therefore, based on above conclusion the following recommendation are forwarded:

- Dairy production of methane should be controlled by improving feeding systems in dairy farms.
- There should be provision of knowledge about methane emission transfer to farmers.
- There should be newly developed control strategies, which contribute in methane gas reduction.

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