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Production of Methane Emissions from Ruminant Husbandry: A Review

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Abstract

The aim of this review is to summarize the current knowledge of methane (CH_4) production from ruminants. The objectives are to identify the factors affecting CH_4 production. Methane is a potent greenhouse gas (GHG). Ruminant livestock constitute worldwide the most important source of anthropogenic emissions of methane. There are two main factors influencing global warming change, an increase in greenhouse gas emissions and depletion of the ozone layer. Methane is associated with both factors. Ruminants (dairy, beef, goats, and sheep) are the main contributors to CH_4 production. Their CH_4 production is a natural and inevitable outcome of rumen fermentation. Feed is converted into products such as milk and meat. Many factors influence ruminant CH_4 production, including level of intake, type and quality of feeds, energy consumption, animal size, growth rate, level of production, and environmental temperature. The methane emissions in dairy cows represent values from 151 to 497 g·day^{-1}. Lactating cows produced more CH_4 (354 g·day^{-1}) than dry cows (269 g·day^{-1}) and heifers (223 g·day^{-1}). Dairy ewe generates 8.4 kg·head^{-1} annually. Holstein produced more CH_4 (299 g·day^{-1}) than the Crossbred (264 g·day^{-1}). Methane emission by heifers grazing on fertilized pasture was higher (223 g·day^{-1}) than that of heifers on unfertilized pasture (179 g·day^{-1}). The average CH_4 emissions are from 161 g·day^{-1} to 323 g·day^{-1} in beef cattle. Mature beef cows emit CH_4 approximately from 240 g·day^{-1} to 396 g·day^{-1}. Suffolk sheep emit 22 - 25 g·day^{-1}. The bison's annual CH_4 emissions per year were 72 kg·head^{-1}. The CH_4 emission from manure depends on the physical form of the feces, the amount of digestible material, the climate, and the time they remained intact. The annual emissions from the pens and storage pond at dairy farm were 120 kg·cow^{-1}.

Keywords

Methane, Ruminants, Emissions, Dairy Cattle, Beef Cattle, Sheep

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1. Introduction

Agriculture is responsible for approximately 10% - 12% of global anthropogenic greenhouse gases (GHG) emissions, excluding land use change [1] [2], particularly livestock is increasingly recognized as both a potential victim of it [3] [4]. Livestock is assumed to be responsible for the largest part at nearly 80% of total agricultural GHG emissions. This is particularly due to methane (CH_4) emissions from enteric fermentation and manure handling [5]-[7].

Methane is the major GHG produced from enteric fermentation during the normal digestive process of ruminants [8] [9]. It is important to note that production of greenhouse gases from animals and their impact on climate changes are a major concern worldwide [10] [11]. Production of GHG is often recalculated to production of carbon dioxide (CO_2) as carbon dioxide equivalent (CO_2-eq), converted amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential. Cattle are considered to cause an increase in emissions with about 4.6 Gt (gigatonnes) of CO_2-eq, representing 65% of sector emissions. Average emission intensities are 2.8 kg CO_2-eq per kg of fat and protein corrected milk 12 for milk and 46.2 kg CO_2-eq per kg of carcass weight for beef [12]. However, the current review will be devoted especially only to methane emissions.

2. Generally about Methane

Methane is one of the three main greenhouse gases, together with CO_2 and nitrous oxide (N_2O), its global warming potential is 25-fold than of CO_2. CH_4 also affects the degradation of the ozone layer [3] [13]. Men are responsible for about two third of the total global CH_4 emission called total anthropogenic methane [14]. Agriculture accounts for 47% - 56% of total anthropogenic CH_4 emissions [1] [15]-[17]. Of this amount may be 12% - 37% of enteric origin [8] [10] [18] [19]. However, amount GHG percentages originating from enteric fermentation of ruminants often differ. While [20] indicated 87%, [21] inform that enteric CH_4 was the largest contributing source of GHG judging for 63% of total emissions. Study [8] indicated enteric CH_4 was 12% of the global, 19% of the anthropogenic, and 36% of the agricultural CH_4 emissions. Within the beef production cycle, the cow-calf system counted for about 80% of total GHG emissions and the feedlot system for only 20%. About 84% of enteric CH_4 was from the cow-calf herd, mostly from mature cows [21]. 10% to 15% of the total amount, which create ruminants, is formed from manure handling and storage [22]-[24].

Reference [25] reviewed literature sources and showed that the global enteric methane source was estimated in absolute values at 74 Tg (teragrams) for 1982 year of which 74% were contributed by cattle and 8% - 9% by each of buffalo and sheep. According to [25], it was 84 Tg for 1990 year, 80 Tg for 1994 year, and 71 Tg, including 44 Tg from grassland-derived feed, for 2003 year. There is a distinct difference in emission intensity between beef produced from dairy herds and from specialized beef herds. Related emissions amount to 1.1 Gt, representing 46% or 43% of the total emissions in dairy and beef supply chains, respectively [12].

Human-related methane emissions are mainly produced by domestic ruminants, rice fields, carbon mines, waste management, and natural gas usage [14]. In countries where agricultural activities are a major component of economy the contribution of CH_4 to the total anthropogenic greenhouse gases emissions is comparable to the CO_2 emissions. On the other hand, methane natural sources are mainly constituted by wetlands, including shallow marine water [26] [27]. Minor contributions come from termites and non-domestic ruminants [14]. Recent studies suggest that plants emit CH_4 directly as a consequence of metabolic processes [14] [28].

Among animals, ruminants are the primary emitters of CH_4. Their rumen, a large fore stomach, has a continuous fermentation system. The rumen occupies more than 70% of the total stomach capacity and its volume is 15 L in sheep and 100 - 150 L in cattle [15]. Methane production arises principally from microbial fermentation of hydrolyzed carbohydrates, and is considered an energy loss for the host [6] [29]. Many factors influence ruminant CH_4 production, including level of intake, type and quality of feeds, energy consumption, animal size, growth rate, level of production, genetics, and environmental temperature [15] [29]-[32].

The global atmospheric CH_4 concentration increased between pre-industrial times and 2005 from approximately 0.715 parts per million (ppm) to 1.774 ppm [23]. The 2.5 times growth in CH_4 abundance over the past 300 years is largely a result of food production, waste decomposition, and fossil-fuel mining, and makes CH_4 the second largest contributor after CO_2 to putative human-induced warming [25]. The world atmospheric load of CH_4 was 4850 Mt (megatonnes) in 1998 year, equivalent to an average concentration of 1745 parts per billion (ppb) [33]. The concentration of CH_4 in the atmosphere is thought to be increasing at a rate of 22 Mt·year^{-1}, due to the imbalance between estimated annual global emissions of 598 Mt and removals of 576 Mt [34].

3. Methane Formation

Methane is a colorless, odorless, inflammable, and tasteless gas that is the primary component of natural gas. Because CH_4 is present naturally in the atmosphere, the general public may be exposed to very low levels when breathing in air. Methane is lighter than air and has a specific gravity of 0.554. Methane gas density is 0.717 $kg \cdot m^{-3}$, melting point is −187˚C (86 K), boiling point −161˚C (112 K). This gas is only poorly soluble in water, but is soluble in organic solvents. Naturally occurring methane is mainly produced by the process of methanogenesis [35]. This multistep process is used by microorganisms as an energy source. The reaction is:

$$CO_2 + 8H^+ + 8e^- \rightarrow CH_4 + 2H_2O$$

The final step in the process is catalyzed by the enzyme methyl-coenzyme M reductase.

Methane can be released into the environment during its extraction from the earth, emissions from industries, agriculture, distribution and use in residential and commercial buildings. A large quantity of the gas is released from decaying rubbish in landfill sites [36]. Methane is also stored in sediments. These CH_4 hydrates in sediments have been studied as a possible future energy resource. Recent hydrate reserves have been estimated at approximately 10^{16} m^3 of CH_4 gas worldwide at standard temperature and pressure conditions [36]. Methane hydrates are an unusual sedimentary mineral that occurs in the continental shelf areas, permafrost regions, and marine sediments of the world. A hydrate is any chemical or mineral that contains water, bound within its chemical structure. Thus, a CH_4 hydrate is an assemblage of molecular CH_4 molecules that are bound within a crystal lattice formed by H_2O molecules [37]. Methane released into soil or water will eventually escape into the air where it will degrade slowly in the atmosphere by sunlight [33] [38].

3.1. Methane from Plants

Methane is primarily emitted through anaerobic decomposition of organic matter. Recent research indicates that plants themselves may emit small amounts of CH_4, although the mechanism is not currently known [39] [40]. This implies that croplands could provide an emission of CH_4 under certain circumstances. Soils can emit CH_4 in two ways. First, decomposition of organic matter by microorganisms in poorly aerated soils (rice paddies, wetlands) can lead to emissions of CH_4 rather than CO_2. Throughout the year, portions of agricultural fields can be saturated with water, creating anaerobic microsites. This may cause minimal amounts of CH_4 to be emitted. However, over an entire year, agricultural soils typically are well-aerated, and CH_4 is oxidized by soil microorganisms [40].

3.2. Methane from Enteric Fermentation

Interest in measuring enteric CH_4 emissions has moved from a focus on nutritional inefficiency to one of contributing to GHG concentrations in the atmosphere and climate change [29] [41]. Measurement of CH_4 emissions due to enteric fermentation must be also taken under conditions as close as possible to typical as found in farming systems.

Enteric CH_4 is a by-product of ruminant digestion produced by methanogenic microorganisms Archaea in a process called fermentation or methanogenesis. The rate and type of fermentation is influenced by animal factors such as chewing, salivation and digesta kinetics [42] [43]. Cattle produce about 7 and 9 times as much CH_4 as sheep and goats, respectively. Enteric CH_4 is produced mainly in the rumen (87% - 90%) and, to a smaller extent (13% - 10%), in the large intestine [44] [45].

Animal releases CH_4 into the atmosphere by exhaling the gas mainly through the mouth and nostrils [23]. Of the CH_4 produced by enteric fermentation in the forestomach 95% was excreted by eructation, and from CH_4 produced in the hindgut 89% was found to be excreted through the breath and only 11% through the anus [44]. Work [46] recorded 3% from the anus (from the total CH_4 enteric emissions released through mouth, nostrils, and rectum). The concentration in the breath is variable with a relatively low concentration when the breath comes from the lungs and a higher concentration when the “breath” is gases belched from the forestomachs, although breath from lungs also contain absorbed CH_4 and inhaled together with air [24]. In a barn or larger room the concentration will to a large extent be influenced by the air exchange, but the concentration of CH_4 will be a total mix of the CH_4 from breath, belch and fart [24].

The rumen ecosystem is an anaerobic environment, in which the degradation of plant material occurs in a very short time frame compared with other anaerobic ecosystems such as wetlands and estuaries, and the fermentation products are different. Some of the microbial species have coevolved with ruminants and hindgut-fermenting mammals and do not exist in any other environment (e.g., rumen protozoa) [47] [48]. Digestion of feed components by the microbiota (bacteria, protozoa, fungi) results in the production of volatile fatty acids. These acids, mainly acetate, propionate, and butyrate are used by the animal as source of energy. During the process gases are also formed and their production eliminated mainly through eructation. CO_2 and H_2 are using to form CH_4, and thus reducing the metabolic H_2 produced during microbial metabolism [4] [49]. Fermentation is an oxidative process, during which reduced cofactors (NADH, NADPH, FADH) are re-oxidized (NAD-1, NADP-1, FAD-1) through dehydrogenation reactions releasing hydrogen in the rumen. As soon as produced, hydrogen is used by methanogenic archaea, a microbial group distinct from Eubacteria, to reduce CO_2 into CH_4 [11].

Note that enteric methane produced by ruminants is a loss of feed energy from the diet and represents inefficient utilization of the feed [23]. In addition to environmental implications, ruminant methanogenesis represents a loss of 2% to 12% of the gross energy intake [29] [47] [50] [51]. However, it was found that small amounts of $CH_4$are formed also in birds. Methanobrevibacter-related phylotypes have been found to be the most prevalent methanogens in the foregut and in the hindgut of the chicken of the hoatzin (*Ophistocomushoatzin*). The hoatzin is the only bird species to have evolved a foregut fermentation system, analogous to the rumen [13].

3.3. Methane from Manure

In addition to enteric (animal-derived) CH_4, excreta are another source of CH_4, especially when stored an aerobically [52]. Methane generated from manure from ruminant and no ruminant livestock contributes 2% and 0.4% of global CH_4 and GHG emissions, respectively. In regions with low input is enteric fermentation undoubtedly the main emission source. However, in industrialized regions with high production and food processing is manure important a source of emissions [12]. Manure CH_4 emissions are a larger proportion of total farm CH_4 emissions in intensively managed dairy operations with manure storage systems, and much lower in extensive or grazing operations [48].

Manure emissions are relatively high in areas where manure from the dairy sector is managed in liquid systems that produce greater quantities of CH_4 emissions [12]. During manure storage, CH_4 is generated through a reaction similar to that of enteric fermentation. Cellulose in the manure is degraded by microbes, with products of this process serving as substrates for methanogenesis [40].

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. Obvious benefit from methane production could be the energy value of the gas itself. But the gas production from manure depends mainly upon the efficiency of operating system for it. Gas yield can be a certain amount of gas produced per unit of solids degraded by the anaerobic bacteria [53]. Anaerobic digestion is a natural process in which the microorganisms consume organic matter under an oxygen-free environment. It results in production of microbial biomass and greenhouse gases (CO_2 and CH_4). The composition of volatile solids contained in manure influence the anaerobic decomposition of organic matter and the production of CH_4. The manure volatile solids are mainly composed of fatty acids, proteins and carbohydrates of which fatty acids, proteins and a part of carbohydrates are easily biodegradable [54].

3.4. Feeding Effects on Methane

Study [55] concluded that feed intake is the superior factor of total CH_4 production. The amount of enteric CH_4 is mainly related to the type and amount of feed [15] [56]-[59]. Gross energy (GE) is negatively related to feeding level and dietary fat concentration and positively to diet digestibility, whereas dietary carbohydrate composition has only minor effects. As the daily feed intake increases, CH_4 production also generally increases [15]. Most studies agree that dry matter intake (DMI) is the main driver of daily methane output, although methane output per kilogram of DMI decreases with increasing feeding level [60], diet digestibility, and with increasing proportions of concentrates or lipids in the diet [8] [61].

There were found higher variability in the quantity of CH_4 emitted per unit of feed intake in grazing ruminants [51] [62]-[65]. The work of [66] suggests that non-grazing low forage feeding system result in the lowest enteric CH_4 emissions$\cdot kg^{-1}$ energy corrected milk, with about 13% less enteric CH_4 compared to a high forage feeding system at the same farm. Body weight and milk yield accounted for significant proportions of variation in CH_4 emissions. Both parameters were positively related to methane concentrations [67].

The composition of feed or the quality of forage influences CH_4 production in ruminants. Digestion in the rumen is dependent on the activity of microorganisms, which need energy, nitrogen and minerals [8] [15]. Therefore, the quality of forage affects the activity of rumen microbes and CH_4 production in the rumen. Forage species, forage processing, proportion of forage in the diet, and the source of the grain also influence CH_4 production in ruminants. Methane production tends to decrease as the protein content of feed increases, and increases as the fiber content of feed increases [15] [29]. CH_4 production was positively related to diet digestibility and negatively related to dietary fat concentration, whereas dietary carbohydrate composition had only minor effects [68]. Production of CH_4 has a negative impact on animal productivity, resulting in lost energy ranging from 2% to 12% of the animal's GEI [55] [69].

4. Methane Degradation

Methane is removed from the atmosphere (*i.e.*, converted to less harmful products) by a range of chemical and biological processes, which occur in different regions of the atmosphere. The degradation of CH_4 in atmosphere includes tropospheric oxidation, stratospheric oxidation and uptake by soil [70].

The oxidation of CH_4 in the troposphere is the largest CH_4 sink, removing 506 Mt of this gas per year from the global CH_4 burden. Most of the emitted methane is slowly oxidized in the troposphere through reactions with the hydroxyl OH radical, although a certain fraction escapes to the stratosphere mainly in the intertropical convergence zone. Furthermore it is transported by the Brewer-Dobson circulation and oxidized through a complex series of reactions, which play an important role in increasing the stratospheric water vapor abundance [14]. Also, a small fraction of the methane is captured and oxidized in soils [71].

Stratospheric oxidation of CH_4 consumes 40 Mt per year. Approximately 30 Mt per year of CH_4 are removed annually from the atmosphere by soil uptake. Therefore, the total sinks of CH_4 are estimated on 576 Mt per year while the overall emissions are estimated on 598 Mt of CH_4 per year. Soil is an important source of sink of CH_4, and it contains populations of methanotrophic bacteria that can oxidize CH_4, by a process known as high affinity oxidation. These bacteria convert CH_4 [4].

Although there are some differences between published estimates the average lifetime of methane in the troposphere of 9 years can be safely assumed, whereas the corresponding lifetime in the stratosphere is much shorter [14]. It has a net lifetime of about 10 years and is primarily removed by conversion to carbon dioxide and water.

5. Amount of Methane Produced

The atmospheric air contains a small concentration of methane (1.8 ppm), compared to respiration air of cattle (approximately 1000 ppm) [24]. The barn concentration of CH_4 is a mixture of air from background (outdoor concentration representing atmospheric air) and gases excreted from the animal. Moreover, if manure is kept in the animal barn, some CH_4 may originate from this manure [24]. Methane production is measured by many methods [72] in 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).

5.1. Dairy Cattle and Sheep

Authors [73] calculated enteric CH_4 emission rates using a procedure that reflects the development of the calves' rumen as well as German national animal performance data and representative diet properties. Calves (birth weight of 41 kg, final LW of 125 kg and a mean weight gain of 0.67 $kg \cdot day^{-1}$) had the emission rate of 9.4 kg CH_4 per place and year.

Methane emissions by dairy cows vary with body weight, feed intake, diet composition, and milk yield. When cows are fed the same diet at the same intake, however, variation between cows in CH_4 emissions can be substantial [74]. Study [45] estimated by using the sulfur hexafluoride tracer technique adapted to collect breath samples over 5-day periods expressed methane emission in grazing dairy cows as absolute value (368 $g \cdot day^{-1}$ or 516 $L \cdot day^{-1}$). Work [75] evaluated enteric CH_4 emissions from 1964 Holstein cows across 21 farms for at least 7 days using CH_4 analyzers at robotic milking stations. Cows were fed the same feeding systems during sampling. Methane concentrations (in milligrams per L of air sampled by the analyzer) were quantified in gas released by eructation during milking. The average CH_4 concentration across farms was 2.9 $mg \cdot L^{-1}$ which would equate to 418 $g \cdot day^{-1}$ of eructed CH_4. [67] using the relationship between CH_4 emission rate during milking and daily CH_4 emissions measured in respiration chambers observed for cows on the same dietary regimen the overall mean CH_4 emissions was 369 g·d^{-1} and the range was 278 to 456 g·day^{-1}. Reference [40] found annual CH_4 emissions calculated on livestock unit (LU is 500 kg) from 58 kg·LU^{-1} in dry cows to 106 kg·LU^{-1} for lactating cows. Lactating cows emit approximately twice the amount of CH_4 as compared to either dry cows or heifers; 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 [40]. Authors [20] recorded annual CH_4 emissions from enteric CH_4 fermentation 107 kg for dairy cow with a milk yield of 7870 kg·head^{-1}. The corresponding value for dairy ewe was 8.4 kg·head^{-1}. Study [76] evaluated dairy cows fed a diet with forage: concentrate ratio of 500:500 or 900:100 g·kg^{-1} of DM of total DMI. Mean CH_4 yields did not differ between diets, being 16.9 and 20.2 g·kg^{-1} DMI for the 500:500 and 900:100 diets, respectively. Methane productions were 267 and 339 g·day^{-1}·cow^{-1}, respectively. Article [46] found at the DMI of 17.5 kg·d^{-1} and milk yield of 22.9 kg·d^{-1} CH_4 measured by sulfur hexafluoride technique of 469 g·d^{-1} (292 - 647), and CH_4 measured by respiration chamber 422 g·d^{-1} (275 - 577). They calculated ratios during measuring by respiration chamber technique CH_4: DMI of 24.3 g·kg^{-1} (14.1 - 29.2) and CH_4: milk yield of 19.9 g·kg^{-1} (6.9 - 54.2).

The study of [77] recorded from lactating and dry cows and heifers on pasture under tropical conditions, using the tracer gas technique that Holstein produced more CH_4 (299.3 g·d^{-1}) than the Crossbred (264.2 g·d^{-1}). Lactating cows produced more CH_4 (353.8 g·d^{-1}) than dry cows (268.8 g·d^{-1}) and heifers (222.6 g·d^{-1}). Dairy cows emit approximately 430 g·d^{-1} at peak lactation down to 250 g·d^{-1} as milk yield declines [78] [79]. Holstein cows produced less CH_4 per unit of dry matter intake (19.1 g·kg^{-1}) than the Crossbred (22.0 g·kg^{-1}). Methane emission by heifers grazing fertilized pasture was higher (222.6 g·day^{-1}) than that of heifers on unfertilized pasture (179.2 g·day^{-1}) [77]. Authors [80] measured CH_4 emissions using the sulfur hexafluoride tracer technique in grazing Jersey × Friesian dairy cows in mid lactation. The average DMI was estimated to be 17.1 kg·d^{-1}. Daily CH_4 emissions ranged from 151 to 497 g·day^{-1} with an average of 311 g·day^{-1} or 18.2 g·kg^{-1} DMI.

In the [81] study, data from purebred Holstein, Simmental and Jersey cows were analyzed to test the assumption that there are genetically low methane-producing animals. Methane emission of cows offered forage *ad libitum* and some concentrate was measured in open-circuit respiration chambers The Holstein, Simmental and Jersey cows emitted on average 25 g·kg DMI^{-1}, 25 g·kg DMI^{-1}, and 26 g·kg DMI^{-1}, respectively. There was no indication of individual cows with persistently low or high CH_4 yield per kg DMI and per kg of milk. Authors [51] in an experiment involving 302 lactating dairy cows revealed that CH_4 emissions per DMI ranged from 11 to 31 g·kg^{-1} DMI, with mean CH_4 emissions from the lower and upper quartile being 16 and 23 g·kg^{-1} DMI, respectively. Reference [82] calculated 15.4 g·kg^{-1} FPCM enteric CH_4 emitted. Methane emissions expressed as absolute value are according to [45] 368 g·day^{-1} or 516 Ld^{-1}. The variation in CH_4 yield remained among the animals (26.4 ± 3.6 g·kg^{-1} DMI). The change in CH_4 yields may have resulted from lower feed intakes of lower quality pasture compared with grazing. Regression analysis showed that absolute CH_4 emission (g·day^{-1}) was best described by DMI and rumen acetate concentration [51].

Sometimes it is stated that increased production of methane causes bloating cows. Study [83] selected Friesian, Jersey, and Friesian × Jersey cross dairy cattle for high or low susceptibility to pasture bloat. They found that cattle with low or high bloat susceptibility are also differing in CH_4 emissions. So, bloat susceptibility is a genetically inherited trait. At the research of [84], the mean absolute CH_4 emissions from low bloat cows were significantly higher than from high bloat cows (144.5 vs. 107.4 g·d^{-1} and 147.9 vs. 119 g·d^{-1}) during both periods (5 or 4 consecutive measuring days). However, on per unit of LW basis, CH_4 emissions from low and high bloat animals were not different from each other either at period 1 (346 vs. 312 mg·kg·LW^{-1}) or period 2 (345 vs. 347 mg·kg·LW^{-1}).

Primary sources of CH_4 on dairy farms are not only animals but also manure storage, with smaller contributions from field-applied manure, feces deposited by grazing animals, and manure on barn floors. Reference [40] calculated in simulating representative 100-cow dairy farm annual emissions of 142 kg CH_4 per Holstein cow and 6.4 kg CH_4 per m^3 of slurry manure in storage. Feed intake was the primary predictor of total CH_4 production.

5.2. Beef Cattle and Meat Sheep

Reference [85] showed in steers of average LW 325 kg based on the animal-scale method, the average CH_4 emission rate over 9 days 161 ± 20 g·day^{-1}. There was a significant difference between two contrasting diets (Lucerne silage diet, cereal, Lucerne, and straw mixed ration) in daily CH_4 production, with mean methane production of 124.3 g·day^{-1} and 169.8 g·day^{-1} [86]. On average, mature beef cows emit CH_4 from 240 g·day^{-1} to 350 g·day^{-1} [78] [79]. Authors [14] found that the CH_4 emission rates corresponding to values of 190 g·day^{-1} per beef cattle head and [20] recorded annually 60 kg·head^{-1}. The results of [87] show that daily CH_4 emissions differed about 7% according to technique (185 vs. 199 g·day^{-1} per animal).

Average daily CH_4 emissions were 323 g·day^{-1} per animal in feedlot. Emissions from the runoff retention pond associated directly with the feedlot operation were approximately 2.7 g of the daily average feedlot emissions of CH_4 [69]. Animals kept in feedlots, as opposed to pasture, emit less CH_4 per kilogram of weight gain due to decreased forage consumption, increased grain in the diet and decreased activity [69]. Authors [88] compared CH_4 emissions from a typical feedlot in Australia and in Canada. The average CH_4 emission was 166 ± 90 and 214 ± 61 g·day^{-1} per animal for the feedlot in Queensland (AU) and in Alberta (CA), respectively. The lower CH_4 emission at the Queensland feedlot was attributed to the lighter weight of the cattle, and consequently their lower intake, and supplementation of the diet with lipids. Authors [89] studied beef feedlots in the north (Queensland) and south (Victoria) of the Australia. The data show a range of CH_4 emissions from 146 ganimal^{-1}·day^{-1} in Victoria to 166 ganimal^{-1}·day^{-1} in Queensland. Values obtained in the study of [90] on feedlot cattle included both enteric CH_4 and CH_4 derived from the manure deposited. The CH_4 emissions encompass a range from a low of 79 g·day^{-1} to a peak of 395.8 g·day^{-1} [90].

Suffolk sheep emit 22 - 25 g·day^{-1} [78] [91]. The bison's annual CH_4 emissions based on calorimeter measurements at 411 kg of LW, 3.4 t DMI per head and year were 72 kg·head^{-1} [92]. Reference [93] found in developed countries estimated CH_4 emission rate 150.7, 137, 21.9 and 13.7 (ganimal^{-1}·day^{-1}) per cattle, buffaloes, sheep, and goat, respectively.

5.3. Manure Management

Methane production from manure management was 33.2, 2.0 and 0.3 kg·head^{-1}·year^{-1} for dairy cattle, beef cattle and dairy ewes [20]. Stored liquid animal manure is an important emissions source of CH_4 globally [94]. Fluxes were measured from a circular concrete tank 11.25 m in diameter storing liquid dairy manure. Monthly average CH_4 flux ranged from 11 μgm^{-2}·s^{-1} in June after the tank had been emptied, to 153 μgm^{-2}·s^{-1} in July [94].

It was observed that the excreta of animals grazing in the morning emitted much more CH_4 than that of steers grazing in the afternoon [95]. The CH_4 emission depends on the physical form of the feces (shape, size, density, humidity), the amount of digestible material, the climate (temperature and humidity) and the time they remained intact [95]-[97]. Expected amount of excreta for steers may be around 1.5 - 2.2 kg of dry matter per day, so the measured values must be 730 kg·year^{-1}. Consequently, the total CH_4 emission can be estimated to be from 0.012 kg·head^{-1}·year^{-1} to 0.067 kg·head^{-1}·year^{-1}.

Source [2] quantified summer CH_4 emissions from wastewater lagoons of a commercial dairy farm. Methane concentrations over three lagoons (total area of 1.8 ha) and background concentrations were measured. Methane concentrations in the air over the lagoons ranged from 3 to 12 ppm, and averaged 5.6 ppm, with a background CH_4 concentration of 1.83 ppm. Methane flux density (emission rate. unit area^{-1}) ranged from 165 to 1184 g·m^{-2}·s^{-1}, with a mean daily flux density of 402 kg·ha^{-1}·d^{-1}. Methane emission rate averaged 0.211 kg·head^{-1}·day^{-1}. Reference [53] estimated the average potential CH_4 production from the livestock manure, and found the production of 692, 946, 125 and 6.4 cm^3 daily from dairy cattle (545 kg), beef cattle (450 kg), swine (68 kg) and poultry (1.8 kg), respectively.

Authors [98] measured CH_4 concentrations over the pens, wastewater storage pond, and composting area on a 700-cow open-lot dairy farm. Average CH_4 concentrations over the pens, storage pond, and composting area ranged from 2.07 to 2.80 parts per million by volume (ppmv), 1.87 to 2.15 ppmv, and 1.71 to 1.76 ppmv, respectively. Combined CH_4 emissions for the pen and storage pond areas were 0.34, 0.55, 0.21, and 0.20 kg·cow^{-1}·day^{-1} for the January, March, June, and September. The annual emissions from the pens and storage pond at this dairy operation were 120 kg·cow^{-1}.

6. Conclusions

Animal husbandry is an important contributor to global emissions of greenhouse gases, in particular of methane. Enteric fermentation from livestock ruminants is a large source of methane, which has a global warming potential 23 times that of carbon dioxide. This work summarizes the current state of knowledge on methane production relevant to environmental aspects. The methane emissions in dairy cattle represent values from 26 to 497 g·day^{-1}. The average CH_4 emissions are from 161 g·day^{-1} to 396 g·day^{-1} in beef cattle. Dairy ewe creates 8.4 kg·head^{-1} of CH_4 annually, Suffolk sheep emit 22 - 25 g·day^{-1}. The bison's annual CH_4 emissions per year were 72 kg·head^{-1}. The CH_4 emission from manure depends on more factors.

An extended review revealed that more data are needed to better quantify GHG emissions from farms of ruminants. It is necessary to obtain data on CH_4 emissions from housing systems and manure management. New research proposals which will measure emissions from agriculture are needed to establish typical emission ranges for dairy and beef farms and the effect of management factors on these emissions. Also knowledge about emissions from farm sheep and goats are insufficient.

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