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GREENHOUSE GAS EMISSIONS FROM CATTLE

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Abstract

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Cattle produce greenhouse gases (GHG) which lead to changes in the chemical composition of the atmosphere. These gases which cause greenhouse effect include: methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NO_x), sulphur dioxide (SO_2), ammonia (NH_3), dust particles and non--methane volatile organic compounds, commonly described as other than methane hydrocarbons. Fermentation processes taking place in the digestive tract produce 'digestive gases', distinguished from gases which are emitted during the decomposition of manure. Among these digestive gases methane and non-methane volatile organic compounds are of particular relevance importance. The amount of gases produced by cows can be reduced by choosing to rear animals with an improved genetically based performance. A dairy cow with higher production efficiency, producing milk with higher protein content and at the same time reduced fat content emits less GHG into the environment. Increasing the ratio of feed mixtures in a feed ration also reduces GHG emissions, especially of methane. By selection of dairy cows with higher production efficiency and appropriate nutrition, the farm's expected milk production target can be achieved while at the same time, the size of the herd is reduced, leading to a reduction of GHG emissions.

Key words: emissions, methane nitrous oxide, ammonia, nitrogen oxides, cow milk.

Introduction

World-wide energy generation and fuel consumption by combustion engines is rising yearly. While energy is an essential prerequisite for our civilisation's development, the rise in energy demand is associated with increased greenhouse gas (GHG) emissions. These have a negative impact on the environment, in particular causing the greenhouse effect, atmospheric acidification, photochemical smog and eutrophication of natural ecosystems.

An increased concentration of greenhouse gasses (CO_2, CH_4, N_2O and water vapour) in the atmosphere leads to global warming. The increased concentrations of nitrous oxide (N_2O) and methane (CH_4) are particularly dangerous as both have a much higher oxidation number and are therefore more significant in increasing the greenhouse effect than carbon dioxide. Methane is a potent greenhouse gas with a global warming potential 25 times greater than CO_2 (Van der Zaag et al., 2011).

N_2O is very high powerful greenhouse gas also its greenhouse effect is 298 times greater than that of carbon dioxide (Eckard et al., 2010). Global warming potential is used to calculate the greenhouse effect and to convert greenhouse gas emissions into a single value of CO_2-eq, i.e. carbon dioxide equivalent (Lüttich et al., 2007).

A considerable amount of GHG emissions released into the atmosphere is produced naturally during volcanic eruptions, forest fires and ocean and sea storms. These gases are also released into the air by the gas extraction and car industries with other environmentally harmful gases, such as perfluoromethane (CF_4) which has a 5700 times higher greenhouse effect than is the case of carbon dioxide, or sulphur hexafluoride (SF_6) for which the CO_{2eq} is 22,200. CFCs (CF_2Cl, $CFCl_3$, CF_3Cl) have similar effects. The presence of these substances is linked to human activity (Ehhalt et al., 2001).

With respect to atmospheric acidification, sulphur dioxide (SO_2), mono-nitrogen oxides (NO_x) and ammonia (NH_3) all play a role (Kram, 2012). Sulphur dioxide and nitrogen oxides evaporate into the atmosphere where they combine with vapour to form sulphuric acid (H_2SO_4), sulphurous acid (H_2SO_3) and nitric acid (HNO_3). Ammonia tends to act as a buffer, reacting in the atmosphere with those acids and in particular with sulphuric acid (Palkovičová et al., 2012). The overall mixture acts as an efficient regulator of the environment's acidity and air pollution (Webb et al., 2005; Maňkovská, Oszlányi, 2010).

The above mentioned compounds causing atmospheric acidification in turn contribute to the formation of acid rain. Acid rain presents serious threats to natural ecosystems (Bell et al., 2012; Chaoui et al., 2012). For example, a particular mitigation strategy could reduce the strength of the target source but this may be at the expense of increasing the strength of other non-target sources within the system or by increasing atmospheric emissions due to changes in the supply chain (Merešová et al., 2010). Such interactions ultimately reduce the overall net benefit of any mitigation strategy on a global basis.

Photochemical smog is created through the presence of methane, dust particles (particulate matter PM_{10}, $PM_{2.5}$), non-methane volatile organic compounds and mono-nitrogen oxides (NO_x) in the air under specific meteorological conditions.

Feeding, bedding and bovine hair are sources of dust (solid) particles (particulate matter PM_{10}, $PM_{2.5}$) in addition to that from combustion engines. Particulate matter is generally sized as PM_{10} and $PM_{2.5}$, the size being defined in microns (μ). $PM_{2.5}$ particles are especially dangerous and cause lung damage when inhaled (Dämmgen et al., 2007, 2009).

From the above it is clear that gas emissions result in changes to the atmosphere's chemical composition, which to a greater or lesser extent can lead to a damage of the environment. Methane and other gases are released into the atmosphere from natural and anthropogenic sources. Among these sources are volcanic eruptions, coal mining, oil and natural gas extraction, decomposition taking place on beds of oceans, seas, lakes and other water bodies, flooded areas, rice paddies, forest fires, dump sites, industry, crop plants, organic fertilisers (manure, slurry), presence of mineral fertilisers in soil, storage of fertilisers and manure from animal husbandry and wild animals, termites activity and many other sources (Chianese et al., 2009).

Gas emissions from the digestive process and from manure

Ruminants release a significantly higher amount of gas to the environment than do monogastric animals. Ruminants' digestive systems have adapted to make use of structural carbohydrates through fermentation via the activity of cellulolytic and methanogenic microorganisms. Digestion produces methane and non-methane volatile organic compounds, classified as volatile fatty acids with low molecular weight: alcohols, ethylene, bicarbonate compounds (HCO_3^-) and other compounds. The digestive tract produces several other gases as well, broadly called 'digestive gases' to distinguish them from gases produced by decaying manure (Brade et al., 2008; Brundsch et al., 2008).

Methane and non-methane volatile organic compounds are not solely produced in the digestive tract. Manure and the animals' bodies release a significant amount of these and, additionally, nitrogenous substances every day. Undigested organic matter and water contained in faeces and urine serve as an excellent source for methanogenic bacteria – these produce a high amount of methane, non-methane volatile compounds, ammonia and other nitrogen compounds (Kimberly et al., 2011).

The dry matter of slurry and manure has two main fractions: volatile parts and solids. Volatile solids are organic substances which evaporate during the process of burning process at 600–800 °C (Brade et al., 2008; Dämmgen et al., 2009). The volatile fraction is a source of carbon for various forms of carbohydrates and of nitrogen for ammonia and for forms of nitrogen compounds, such as oxides.

Animal excrements, i.e. faeces and urine, contain two fractions of nitrogen: organic nitrogen (components of undigested feed) and excretion products designed as total ammonia nitrogen (the sum of ammoniacal nitrogen and other nitrogen compounds in the form of simple compounds, such as nitrogen oxides produced by microorganisms) (Dinuccio et al., 2011; Shibata, Terada, 2010; Knížatová et al., 2010).

Decreasing enteric methane (CH_4) emissions from ruminants without altering animal production is desirable both as a strategy to reduce GHG emissions and as a means of improving feed conversion efficiency. Diet manipulation and feed additives have been identified as main avenues for the mitigation of enteric CH_4 production. Rumen digestion of feed components by the bacteria, protozoa and fungi, under anaerobic conditions, results in the production of volatile fatty acids, mainly acetate, propionate and butyrate used by the animal as source of energy, and the production of gases (CO_2 and CH_4) eliminated through eructation. Other fatty acids present in brown algae, for example, also have a negative effect on methanogenesis (Martin et al., 2010). Biopolym is a biological regenerative agent made from hydrolysed marine brown algae (*Ascophyllum nodosum)* and subsequently modified to be added to feed or feed water. It has a favourable influence on gastrointestinal micro flora, improving the efficiency of digestion in small intestine and accelerating the transfer of nutrients into the bloodstream. Thus it has a regenerative effect on the organism, improving the health and overall physical condition of animals. A side effect of Biopolym is a reduction in ammonia emissions from poultry, pig and cattle farms (Čermák et al., 2010; Petrášková et al., 2010).

Microorganisms produce ammonia (NH_3), nitrous oxide (N_2O), mono-nitrogen oxides (NO_x) and nitrogen (N) from nitrogen compounds contained in manure. Ammonia is produced mainly by the hydrolysis of urea, catalysed by the enzyme urease. Nitrous oxide and nitrogen oxides are produced in the microbial processes of nitrification and denitrification of nitrogen compounds contained in faeces.

Gas emissions by cattle

The quantity of released gases is given in kilograms from one housing place per year. This is regarded as the correct way of quantifying released gases as any given animal may change category during a year due to age, weight or physiological condition.

The amount of methane caused by cattle manure (faeces and urine) makes up 12 to 17% from the overall amount of gas in the air emitted from cattle. There is a positive correlation between dietary protein intake and the amount of methane emitted from faeces. The amount of nitrogen released from cow manure depends on the quantity of nitrogenous substances in the diet and milk production (Dämmgen et al., 2009).

During 1 year, one cow place (i.e. a single cow) produces 112 kg of methane and 40 kg of ammonia. These amounts suggest that gases released by cattle can present a threat to the environment and therefore we should try to mitigate the threat. Increasing the cattle production efficiency can reduce environmental pollution caused by their metabolites, as a reduction in manure nutrients facilitates their management. One particular problem is that a high concentration of farm animals creates a corresponding high amount of manure, mainly in the form of slurry. In volume, this may be difficult to store and use as fertiliser. In the context of environmental risk, slurry disposal does present certain opportunities that are both environmentally and economically advantageous. Slurry is a valuable source for energy generation (biogas) and an environmentally friendly organic fertiliser.

Improving the production efficiency of feed given to cattle facilitates the reduction of the amount of metabolites emissions for one production unit. Economic objectives are converging towards environmentally friendly production. Breeding efforts aiming at increasing the productivity of animals are in agreement with the efforts to reduce the negative environmental impacts by animals (Brade, Lebzien, 2008; Hegarty et al., 2007; Johnson, K.A., Johnson, D.E., 1995; Walter, 2008a,b, 2009; Zhou et al., 2009; Zijderveld et al., 2009).

Methane emissions from cows

The amount of methane produced by a cow in 1 year is in the relation to its milk yield. A cow with an annual milk yield of 4000 kg produces approximately 94 kg of methane. While further increases in milk production lead to an increase of methane emissions, the relationship is not linear: doubling the milk yield to 8000 kg leads to an increase in methane emissions of 30% and an increase of milk yield to 12,000 kg leads to 20% increase in methane emissions. Increasing the production three times from 4 to 12,000 kg leads to a net increase in methane emissions of 56%, i.e. from 94 to 147 kg per dairy cow per year (Dämmgen et al., 2007).

When considered methane production on a per 1 kg of milk, with increasing of milk yield the amount of methane expressed in g/kg of milk is reduced, i.e. with increasing milk yield methane emissions are lower. Nevertheless, regardless of the amount of cow milk produced or the level of production a certain amount of methane is always emitted from the body due to its physiological needs. A cow with milk yield of approximately 4000 kg subsists primarily on fiber; this is subject to fermentation in its gut, producing methane and other gases. However, voluminous feeds are more methanogen than only feed concentrates. Therefore, an increase of the share of feed mixtures in feed rations reduces the production of methane. A cow with a milk yield of 8000 or 10,000 kg should be given more feed mixture than a cow with milk yield of 4000 kg because the amount of methane produced on 1 kg of milk proteins is lower. A cow with higher milk yield releases less methane into the atmosphere.

As there is an influence between the methane emissions released into the atmosphere and the global milk production on a farm, it would be advantageous to adjust the number of cows fed by feed mixtures. For example a farm with a yearly milk production of 800,000 kg and cows with milk yield of 4000 kg should have 200 cows. The annual methane emissions output would then be 18.7 tons. The same volume of milk can be obtained from 100 cows with milk yield of 8000 kg, producing 12.3 tons of methane. With increased milk yield and reduced number of cows the amount of methane emissions decreases (Brade et al., 2008). Table 1 shows the amount of methane in kilogram produced by cows in some countries.

T a b l e 1. Methane emissions, average daily yield and weight of cows in some European countries, data since 2008 (Dämmgen et al., 2009)

Country	kg/CH_4/cow/year	Milk yield (kg)	Body weight (kg)
Austria	115.4	16.17	700
Belgium	116.92	16.80	600
Czech Republic	114.95	20.22	585
Denmark	126.22	23.29	575
Germany	92.45	19.19	594
Poland	94.31	11.86	500
United Kingdom	102.75	18.46	577

Considering all the above mentioned issues of milk production and methane and other gases emitted into the atmosphere, a question naturally arises: 'How should dairy cows be reared to keep GHG emissions low?' Currently, the answer is quite simple: 'Nobody knows'. This question should be answered in the next few years, as new technologies will be developed for rearing cattle focusing on reduction of the GHG.

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