Ways to reduce the environmental impact of dairy farming

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Abstract

The image of dairy farming systems is increasingly being scrutinized by welfare organizations, activist groups and the public with intensive systems getting the most attention. So-called factory farms are being regarded by the public as not ideal for the production of products like milk and meat. Dairy cows, being ruminants, contribute directly to greenhouse gas emissions (GHG) because of the way feed is digested. By comparing past to present production systems, it has been demonstrated that the efficiency of milk production has increased over the last 40 years resulted in lower GHG emissions per kg of milk produced. The best way to reduce the impact of livestock production on climate change is to improve the efficiency of production systems. This can be done by (1) higher milk yields and improved fertility in heifers and cows, (2) improving feed quality and management by reducing feed shrinkage during forage harvesting, feed delivery and storage, mixing and delivery of feeds and (3) to breed for cows producing less methane in the production of milk. Genetic gain is, however, a function of the accuracy of selection and genetic variation. Large quantities of data are required to estimate reliable genetic parameters for methane production. As the accuracy of directly measuring methane production cows would be difficult, an indirect indicator or associated trait would be required. The genetic correlation between direct methane production and the indicator trait would give an indication of such a possibility. As the amount of methane produced by cows is correlated to milk yield levels it would be possible to decrease the methane production of cows by selecting more efficient cows. The genetic variation suggests that reductions in the order of 11 to 26% in 10 years are theoretically possible.

Keywords: Efficiency, cow fertility, methane, pasture-based and total mixed ration systems

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Introduction

The image of agricultural production systems is increasingly being scrutinized by welfare organizations, activist groups and the public. Intensive systems are getting the most attention. These so-called factory farms are being regarded by the public as not ideal for the production of basic agricultural products like milk and meat. The antagonism against these systems is based on two aspects, i.e. the welfare of cows and the perceived effect of these systems on the environment. The public would prefer seeing cows producing milk from green pastures as nature intended. Although pasture-based dairying systems probably provide the best living conditions for cows, except in summer when heat stress is experienced or during winter when it rains, it might not the best for the environment.

Background

Dairy cows, being ruminants, contribute directly to greenhouse gas (GHG) emissions. This is because of their unique way of feed digestion. Through a fermentation process, anaerobic bacteria in the rumen break down fibre type products in animal feeds to various end-products that cows use to sustain themselves. Methane (CH₄) gas, a major GHG, is produced through this fermentation process. Methane is released into the atmosphere by natural processes of belching and breathing. The only way to reduce the CH₄ gas production from farm animals is to reduce their numbers as the fermentation process in the rumen cannot be stopped or altered significantly on a long term basis. It can only be slightly changed by using lower forage diets. The rumination process has evolved over millions of years. The implication therefore, is that all ruminants in the world have for all times been contributing towards GHG and thus climate change. It is only recently that their specific way of converting feedstuffs has caught the attention of activist groups and eventually the attention of the public. By consuming high forage diets which is unsuitable for human
consumption, cows produce high quality food products such as milk and meat. Activists campaigning against dairy cows have not come up with alternative foods for humans to replace the high quality protein, fat, lactose, minerals and vitamins being consumed on a daily basis through milk, milk products or beef. Furthermore, the comparative impact on the environment of the production of such alternative food sources has not been modeled by activist groups.

Comparing past and present dairy production systems

By modeling it is possibly to determine the effect of past and present farming systems on the environment. Capper et al. (2009) reported that, in 2007, the United States (US) dairy herd consisted of 9.2 million cows producing about 84 billion kg of milk. In comparison, in 1944, 53 billion kg of milk was produced by 25.6 million cows. This means that the total US milk output has increased by 58% while the number of dairy cows was reduced by 64%. This change in output can be ascribed to a combination of improved genetic merit of cows, better diet formulation, better herd health and housing management aimed at improving animal care. Although producing more milk, the smaller number of dairy cows resulted in a 77% reduced feed use, 90% less land use, 65% less water use and a 63% decrease in GHG emissions per kg of milk. To produce the same amount of milk at lower production levels, as would be expected on a high forage diet like a pasture-based system, would mean a national herd consisting of a larger number of lactating cows, more dry cows and replacement heifers. A higher milk production not only reduces the number of cows but also reduces the total feed requirement and resource use of all the animals. In this paper three ways to reduce the impact of dairy farming on the environment, regardless of farming system, are discussed. Options include improving the efficiency of production by increasing the genetic merit of cows for higher lifetime milk yields, improving feed quality and selecting cows for reduced methane output.

Improving efficiency of dairy farming

The best way to reduce the impact of livestock production on climate change is by improving the efficiency of production systems (Mitloehner, 2013). This means that more milk (and beef) must be produced from the same inputs, specifically ruminant feeds. The efficiency of energy utilization is increased with greater energy output (milk yield) by diluting the energy required for maintenance (Allen, 2013). Rodriguez et al. (2013) found that as milk production increased over time, total cost per kg of milk decreased regardless of year or breed. Feed, labour, replacement and operational costs also decline at increasing milk yield levels. The reason for this is the dilution of a dairy’s fixed costs. Larger dairy herds tend to have a lower cost of production and a larger milk net income per unit then small herds. Bannink et al. (2011), using a mechanistic model to predict the methane emission in Dutch dairies, showed that average methane emissions per cow per year increased from 110 kg in 1990 to 126 kg in 2010, but at the same time the average methane emissions decreased from 17.5 to 15 g per kg of milk.

Improved efficiency in dairy herds is not limited to higher milk yields by cows, but also includes better reproduction performance of heifers and cows. According to Berry (2013) the growing dairy heifer represents approximately 25% of the feed costs of a dairy animal’s lifetime. This means that an early age at first calving (before 24 months of age) would improve efficiency because of a reduction in total feed required during the unproductive period of a cow’s lifetime. Zehetmeier et al. (2012) showed that GHG emissions produced during the rearing phase of replacement heifers contribute up to 20% of total GHG emissions from modelled dairy farms. Weiske et al. (2006) reported a reduction in GHG emissions per kg of milk by 13% with a reduction in the replacement rate from 40% to 30%.

Cabrera (2013) found that feeding lactating cows more than one ration over the lactation period improves production efficiency as it provides closer-to-requirement nutritional density diets avoiding nutrient wastes. Multiple nutritional grouping reduces the number of over-conditioned cows and excess nutrient excretions improving income over feed costs.

Herd structure gives an indication of the fraction of animals in different parities, age, days after calving, pregnancy status, lactation status, etc. (de Vries, 2013). Grouping and feeding animals according to the herd structure would similarly improve herd efficiency as indicated previously. Feed efficiency is high before the peak in milk yield during the lactation; therefore a herd with more cows early in lactation would be more efficient, because of a higher average milk yield, than a herd with more cows in late lactation. Reproduction problems result in cows being milked longer after calving therefore increasing the average
number of days-in-milk for the herd. Better reproduction would therefore improve feed efficiency (de Vries, 2013). As the lactation milk yield of cows increases with age (or parity), a dairy herd with more old cows, as indicated by a higher average lactation number, are more feed efficient than a younger herd. As cows are culled from the herd because of various reasons and heifers are reared to replace culled cows, the annual cow cull rate and age at first calving of heifers would have a marked effect on herd efficiency. A low cull rate results in the best whole farm efficiency whereas a high cull rate resulted in the best cow efficiency but at a lower farm profit (de Vries, 2013).

For dairy cows, only 26% of feed energy results in useful end-products, i.e. milk 24% and fat storage 2% (Erdman, 2013). The remainder is lost as heat (33%), methane (5%), urine (3%) and feces (35%). In terms of heat production, a major loss is due to the cow’s maintenance requirement. This is driven by the cow’s live weight, however, the increase in maintenance requirement because of an increasing live weight, occurs at a decreasing rate (Erdman, 2013). Therefore, while increasing size increases the cow’s maintenance requirements, a smaller portion is used for maintenance allowing for a higher milk yield.

It has been pointed out that with the increase in milk yield; fewer cows are required to produce a specific amount of milk. As a considerable number of culled cows and bull calves born in dairy herds being reared for veal of beef production, end up in the beef market, an increase in the national milk yield would mean that the beef production coming from dairies would be reduced. Destaatit (2010), as cited by Zehetmeier et al. (2012), showed that the number of dairy cows in Germany decreased from approximately 6.3 to 4.2 million while the total milk output remained constant. Because of this decrease in dairy cow numbers, gross domestic beef production was reduced by 967 million kg or 44%. Zehetmeier et al. (2012) showed that increasing milk yields reduces GHG emissions per kg of milk; however, when considering the beef contribution of dairy cows, the result changed, because the shortfall in beef production from dairy cows have to be made up by more beef animals. Zehetmeier et al. (2012) also questions the ongoing specialization in both milk and beef production systems. The alternative would be to use dual-purpose breeds either as purebreds or in a crossbreeding programme with specialist dairy breeds.

The Fleckvieh, a Simmental derived breed from Germany, is one such a dual-purpose breed. Other similar Simmental derived breeds are the Montbeliarde in France and Abondance in Italy. At Elsenburg, two studies using Fleckvieh bulls on Holstein and Jersey cows are demonstrating the value of such a programme. Beef production of Fleckvieh x Jersey steers is 34% higher in comparison to Jersey steers while crossbred calves reared for veal reached marketing age 32 days earlier than purebred Jersey calves (Muller, et al., 2013a). The milk yield of crossbred cows is also 14% higher than purebred Jersey cows. Crossbreeding Holstein cows with Fleckvieh bulls resulted in a smaller increase in beef production while the fertility and milk composition of crossbred cows seems to be better (Muller, et al., 2013b). The better fertility and salvage value of crossbred cows should also have a positive effect on farm income and production efficiency.

A recent study (O’Brien et al., 2014) showed that the relative difference in the carbon footprint between average and high-performance dairy systems was likely to be greater than the relative difference between high-performing grass and confinement dairy systems. This suggests that improving the productivity of dairy systems has a greater effect on the carbon footprint of milk than converting from a confinement to an intensive grass-based dairy system.

Total milk yield of cows divided by their total feed intake, up to a specific age, could be considered as an efficiency indicator for dairy cows. This means that higher producing cows calving down early and maintaining short calving intervals would be more efficient than lower producing cows or cows calving late for the first time or having longer calving intervals. As it is not practical (or possible) to determine the total lifetime feed intake of animals as heifers and cows, total lifetime milk, fat or protein yield could be considered as an indication of dairy cow efficiency. As this is related to age or productive life, the ratio between total lifetime yield and lifetime in days could be considered as an efficiency measure.

**Improving feed quality and management**

There is a perception that low-input systems have a smaller effect on the environment than high-input large production systems. However, a low-input system is also a low-yield system. Such dairy systems operate on high forage and low concentrate intakes. However, a high-fibre diet increases the CH4 release per kg of milk in a three-fold manner: (i) by fermenting fibre, (ii) by low productivity and (iii) by low digestibility of fibre. An increase in the use of starchy concentrates (cereals etc.) reduces the production of greenhouse gases. For high forage feeding systems, the way to reduce the effect of ruminants on the

environment would be to increase the digestibility of the forage content of the diet. This implies feeding of higher digestible forages, i.e. forages harvested at an earlier growth stage.

Because of an increasing demand for milk products in the world, many pasture-based farming systems are moving towards more intensive systems. The reason for this is that the production of present day grass cultivars is not much higher than 40 years ago. This limits the milk production output from pasture-based dairy farms. To increase farm milk output, other forage crops have to be incorporated into the feeding system. A common forage crop is maize silage produced under irrigation increases the carrying capacity and milk output of a farm.

Methane gas production is positively correlated to dry matter intake (DMI) and the level of production although the percentage of dietary energy lost as methane declines with increasing DMI. A higher proportion of forage in the diet is also associated with higher enteric methane output per kg of milk compared to a more nutrient-dense (or lower forage) diet. Diets being digested faster in the rumen produce less methane gas.

Rumen distension dominates the control of feed intake in dairy cows (Allen, 2013). The filling effect of the diet, specifically the forage neutral detergent fibre (NDF) content, has a much greater effect than other fractions on feed intake. This effect varies greatly according to the digestion characteristics, fragility and particle size of the diet. The most common indicator of feed efficiency in dairy cattle is ratio of fat-corrected milk per kg of dry matter (DM) intake. In average herds this ratio is around 1.5 while reaching 1.6 in well managed herds (Erdman, 2013).

Mayor efforts have been put in reducing the loss in fecal energy by improving the digestibility of feeds. For forages this includes the stage of maturing at harvest, forage species, preservation method, feed ingredient selection and feed processing. These efforts have not resulted in improving feed digestibility, but by increasing feed intake and therefore increasing milk yield. Digestibility decreases with an increase in feed intake.

Reducing feed shrinkage has a major possibility in increasing feed efficiency in a dairy herd. Feed wastage occurs during forage harvest, feed delivery and storage, loading and mixing of diets, feeding-out and delivery of feeds (Grant, 2013). Dry matter loss from harvest to feed-out may range from 12 to 23% for maize silage. Cows that are fed for low refusals have greater eating rates resulting in a greater risk of rumen acidosis. Daily feed intake is reduced by restricting the time of feed access. An on-farm case study has shown a 3.6 kg/day higher milk yield when cows experienced 0 vs. 6 hours per day of a functionally empty feed bunk. According to Grant (2013) twice daily feeding in comparison to once daily feeding results in less sorting of feed especially against long particles during the day. However, feeding more than twice a day reduces resting time. Regular feed push-ups, especially during the hours after feeding, and consistent feed quality and quantity along the full length of the feed trough improves efficiency with less competition among cows.

Selecting for lower methane producing cows

Genetic improvement in any trait is important as it is cumulative and permanent (Berry, 2013). It would be therefore make sense to breed for cows that produce less methane to reduce environmental pollution by dairy cows. Genetic gain is, however, a function of the accuracy of selection and genetic variation. Large quantities of data are required to estimate reliable genetic parameters for methane production. It is expected that the accuracy of measuring the methane production of cows directly would be difficult (Haas et al., 2011); therefore an indirect indicator or associated trait like residual feed intake (RFI) would be required. The genetic correlation between direct methane production and an indicator trait would give an indication of such a possibility. The amount of methane produced by cows is correlated to milk yield levels making it possible to select for cows producing less methane. Predicted methane emission (PME) is 6% of gross energy intake. Estimated heritability estimates for PME and RFI were 0.35 and 0.40, respectively. The positive genetic correlation between RFI and PME indicated that cows with lower RFI have lower PME values with estimates ranging from 0.18 to 0.84. It would therefore be possible to decrease the methane production of cows by selecting more efficient cows. The genetic variation suggests that reductions in the order of 11 to 26% in 10 years are theoretically possible.

Herd et al. (2011) noted that in Australia, more than 90% of livestock GHG emissions are from cattle and sheep with beef cattle contributing the most. Little change is possible in GHG emissions by changing the diet of cattle therefore selective breeding is the most wide-reaching tool for a lasting reduction in GHG emissions.
emissions. In ruminants, there is a strong positive relationship between feed intake and methane production. This means that a breeding strategy that reduces the feed intake per unit of product production would result in a reduction in GHG emission intensity. Selecting for a lower methane production (MP), however, may result in a lower feed intake and possibly smaller or slower growing animals. Methane intensity (MI), that is methane produced per unit of bodyweight and methane yield (MY) per unit of feed intake, are two traits that measure methane output independent of cow size and feed intake (Herd et al., 2011). Preliminary results of Angus cows show large natural variation between animals in MP, MI and MY. Some animals produced significantly less methane per day, per kg of live weight and per kg of feed intake than the average for the sample group. Sire had a significant effect on MY and MI of animals. Results indicate that selection for a methane production trait may be possible.

Breeding objectives for dairy cattle have traditionally focused on production traits, but this has changed in recent years, leading to more balanced breeding objectives comprising a wider range of economically important traits. The measurement of traits related to animal welfare (hoof problems, lameness, laminitis), heat stress and methane emissions of dairy cows can all contribute to reducing the environmental and social impact of dairy production (Scholtz et al., 2013).

**Intensive vs. pasture-based feeding systems**

A big debate is ongoing on the effect of intensive vs. pasture-based systems on the sustainability and effect on the environment. Because of a growing demand for milk products some countries have experienced better on-farm milk prices. This has resulted in many pasture-based dairy farms increasingly incorporating feeding additional supplements like concentrates or forage crops as hay or silage. Supplementary feeds increases the cost of milk production which raises the demand for cows producing at higher milk yield levels.

For intensive feeding of cows, whether as a supplement to an existing pasture system or as a fully intensive feeding system, feed troughs are required. This aspect has been well researched and on-farm observation have shown that properly designed, built and maintained feed troughs would reduce the environmental impact through an improvement of feed intake and a reduction in feed wastage. This however means that cows have to spend some time on concrete to consume supplementary feeds. Although concrete is not ideal for cows, it is better than open camps that quickly become muddy with a large build-up of manure which is difficult to remove. Concreted feed lanes keep cows clean and the manure collected on them can be removed by scraping or washing into a manure holding facility where it can be used for a number of products such as compost and the generation of energy through biogas systems. In a pasture-based system only a small amount of manure, mostly around the milking parlour, can be collected. The bulk of the manure and urine is deposited on the pasture, near water troughs and on the way to the milking parlour. This creates an uneven spread of manure on the farm which in some cases could become pollution source-points.

O’Brien et al. (2014) compared the carbon footprint of the milk output from high-performing confinement and grass-based dairy farms through a life-cycle assessment. GHG emissions attributed to milk only from an Irish-type production system were 5% and 7% lower than a UK and US-type confinement systems respectively. However, without grassland carbon sequestration, all the systems had similar carbon footprints per ton of energy-corrected milk. The way emissions are estimated and the allocation of GHG emissions between milk and meat also affected the relative difference and order of carbon footprints. For instance, depending on the method chosen to allocate emissions between milk and meat, the relative difference between the carbon footprints of grass-based and confinement systems varied by 3 to 22%. However, top-performing herds have carbon footprints 27 to 32% lower than average performing dairy systems.

**Conclusion**

As dairy farmers rely on the public as consumers of the end-products of milk being produced on farms, some effort should be put into improving the image of farming systems. At the same time, farmers should demonstrate their commitment towards reducing the effect of dairying on the environment. Improving the efficiency of milk production is the best way to reduce the effect of dairy cows on the environment. This means a high milk yield for cows and good reproduction management with regards to age at first calving for heifers, short calving intervals and low culling rates of cows. The breeding of cows to produce less methane gas is a future possibility. Using diets containing higher concentrate levels and highly digestible forages

would also reduce methane production. Dairy cows produce a large amount of waste products as manure and urine. Manure has been in the past been converted into compost for the improvement of soil quality. It was only through the development of easily available, cheap sources of fertilizers as waste products from the fuel industry, that farmers have stopped using manure as natural fertilizers. In the past, the methane production potential of household waste has been used to produce heat. This was later replaced by cheap electricity. Currently developments are underway again to produce electricity from manure through bio-digesters. Generally, more electricity than is required could be produced on intensive dairy farms. Unfortunately at present there is a limited market for excess on-farm-produced electricity while the cost of setting up such a unit is very high. The size of a bio-digester is determined by the amount of manure produced on a farm. Farms in close proximity to each other could share an anaerobic digester to reduce construction costs.

References
Berry, D., 2013. Genetics of feed efficiency; what we know in dairy and what we have learnt from other industries. 26th ADSA Discover Conference on Food Animal Agriculture: Dairy Feed Efficiency. 23-26 September 2013. Northern Illinois University Conference Center. Naperville Illinois, USA.


