Improved production efficiency in cattle to reduce their carbon footprint for beef production

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Abstract

The FAO publication, Livestock's Long Shadow, indicated that livestock is responsible for 18% of the world's greenhouse gas production thereby creating the perception that livestock is a major cause of global warming. Methane (CH_4) makes up 16% of total world gas emissions and is the second most important greenhouse gas (GHG) after carbon dioxide (CO_2). Ruminants are important to mankind since most of the world's vegetation biomass is rich in fibre and only ruminants can convert this vegetation into high quality protein sources for human consumption. In spite of this important role of livestock, it is singled out as producing large quantities of GHG that contribute to climate change, since enteric fermentation is responsible for 28% of global CH_4 emissions. However, the net effect from livestock is only a 4.5% contribution to GHG. The livestock industry should be aware of the effect of livestock on climate change and therefore it is important that mechanisms are put in place to mitigate this effect. The improvement of production efficiency through increased production per constant unit, crossbreeding and genetic improvement may be a cost effective and permanent way of reducing the carbon footprint of beef cattle.

Introduction

Since 1980, scientific evidence of human interference on the climate placed the question of climate change and its environmental consequences on the world's political agenda. After various discussions, the Kyoto Protocol, adopted in December 1997 in Japan, officially established goals for emission of greenhouse gas (GHG) for industrialized nations (UNFCCC, 2007). This was followed by the United Nations Climate Change Conference in December 2009, known as the Copenhagen Summit, where a framework for climate change mitigation beyond 2012 was developed. The document recognized that climate change is one of the greatest challenges and that actions should be taken to keep global temperature increases as a result of GHG's to below 2°C by the end of the century. However, the document was not accepted unanimously.

It is estimated that more than 60% of global methane emissions are related to human activities (IPCC, 2007) and that enteric fermentation is responsible for 28% of global methane emissions. Human-related activities producing methane include fossil fuel production, animal husbandry (enteric fermentation in livestock and manure management), rice cultivation, biomass burning, and waste management. Natural sources of methane include wetlands, gas hydrates, permafrost, termites, oceans, freshwater bodies, non-wetland soils, wild ruminants (game) and other sources such as wild fires. The Food and Agricultural Organization (FAO) of the United Nations published Livestock's Long Shadow (Steinfeld *et al.*, 2006), in which ruminants are accused of producing 18% of the greenhouse gas that cause global warming, thereby creating the perception that livestock is a major cause of global warming. From all methane emission sources, agriculture is by far the most important source in South Africa. Enteric fermentation in ruminants accounts for 90% of the agricultural sector's methane emissions (Blignaut *et al.*, 2005). It is important to

note, though, that if enteric fermentation is responsible for 28% of global methane emissions, and methane makes up 16% of total world GHG emissions, the net contribution of enteric fermentation to GHG's is only 4.5% (28 % of 16% = 4.5%).

Some studies have shown that the exclusive use of tanninferous legumes, or in combination with grasses in pastures for ruminant feeds, may reduce enteric methane emissions per unit of dry matter consumed (g CH_4/Kg DMC) without affecting production performance (Pinares-Patino *et al.*, 2003). Most research has focused on manipulating animal diet in an effort to inhibit a rumen environment favourable for methane production. Other options to combat enteric fermentation, such as genetic engineering and the use of additives, may be options (Beauchemin *et al.*, 2008), but need further research.

The aim of this paper is to describe possible breeding technologies by which production efficiency in cattle can be improved in an attempt to reduce the carbon footprint of beef. These technologies include improved production per constant unit, crossbreeding and selection for residual feed intake.

Discussion

In ruminants, methane is produced by a specific group of bacteria, called methanogens (Moss, 1993), and protozoas, which may account for up to 20% of methanogenic microorganisms. As methane cannot be metabolized by the animal or microorganisms, it is partly absorbed by the ruminal wall and enters in the bloodstream where it is removed from the body during respiration or by eructation with carbon dioxide (CO_2) (Kozloski, 2002). Factors that influence enteric methane production in livestock are level of feed intake, diet composition, digestibility and quality of roughage, forage species, C3 versus C4 grasses, cultivar and variation between animals. From a nutritional point of view, methane represents a potential loss of energy by the animal of between 6 and 10%; this is not converted to a product (meat, milk, wool).

Variations in methane production between animals, breeds, and across time have been reported and provide the potential for improvement through selection (Wall *et al.*, 2009). Ways to improve efficiency through genetics include choice of breed, the use of crossbreeding and selection within breeds (Herd *et al.*, 2003).

The emission of GHG from livestock is measured either in terms of kg CO_2 equivalent per kg of meat or milk available for consumption, or per area of land used. In the case of ruminants, extensive systems are usually found to have a lower per-area footprint than intensive grain-fed systems, but a higher footprint if expressed in terms of kg/product (Garnett, 2010). Improved production per unit can thus reduce the carbon footprint of beef.

Improved production per constant unit

Most measurements for beef improvement in South Africa and the world are expressed per individual, for example weaning weight, calving interval and average daily gain (ADG). Although breeding values are estimated for traits such as feedlot profit and cow efficiency in the Bonsmara, breeding values are still only estimated once or twice a year. Until breeding values are estimated more frequently and breeding values for cow efficiency for all breeds are available in South Africa, farmers will need a measurement that can be available immediately (as is the case with weaning weight) after measurement that can be used in selection. It is therefore essential that a measurement is developed that can express performance in a per constant unit base, e. g. kg calf weaned per Large Stock Unit. It should also be investigated whether it will be possible to convert such a measure into kg calf produced per kg CO_2 equivalent (CH_4 can be converted to a CO_2 equivalent) by adjusting it for half-life and heating potential.

Crossbreeding

The advantages of terminal crossbreeding to improve efficiency do not lie in the higher growth rates or better feed conversion ratio (FCR) of the crossbred progeny *per se*, but rather depends on the extent to which the weight of the slaughter animal can be increased relative to that of the dam or breeding cow. This advantage follows since any system with large slaughter animals from small breeding cows must be more efficient than one with slaughter animals and breeding animals of equivalent size, simply because small dams eat less than large ones. Another advantage of crossbreeding arises from a potential increase in weaning weight of up to 26% per cow exposed to mating, while the feed energy requirement only increases by 1% (MacNeil, 2005; MacNeil *et al.*, 1991; MacNeil *et al.*, 2007).

Maternal heterosis is also of major importance in reproductive traits, making crossbred dams desirable in crossbreeding systems. Cundiff *et al*. (1974) obtained 14.8% more calf weight per cow exposed in crossbred cows compared to purebred cows, both producing crossbred calves with equal individual heterozygosity and additive genetic composition, illustrating the importance of the crossbred dam. Miller (2010) claims that heterosis in a sound crossbreeding programme can increase productivity in the beef cow herd by 20% to 25% over a comparable straight breeding programme.

Residual feed intake

A possible trait to improve production through selection within breeds is residual feed intake (RFI). In beef cattle, the concept RFI, also referred to as net feed intake, was proposed by Koch *et al*. (1963) and is defined as the difference between actual and predicted feed intake required for the observed rate of gain and body weight. A low RFI value indicates a more efficient animal and many studies have found heritability estimates varying from 0.28 to 0.58 (e.g. Crews *et al.*, 2003). Possible genetic markers for RFI have been investigated but the success rate has been low (Moore *et al*., 2009).

In selection for low RFI animals, methane production and energy lost as methane was 28% lower in low RFI steers compared to high RFI steers, resulting in approximately 16 100 litres less methane produced per year from such steers (Nkrumah *et al*., 2006). In another study a 13.38 g/d reduction in methane emission was associated with a 1 kg/d reduction in an EBV for RFI and low RFI steers emitted 25% less methane daily (Hegarty *et al*., 2007). The difference in methane production in high and low RFI animals cannot be explained by the difference in feed intake alone. Possible reasons could be differences in metabolism and possible individual animal differences in methane production (Nkrumah *et al.*, 2006). There seems to be a genetic component influencing the types of methanogenic bacteria present and their hosts (Hackstein *et al*., 1996).

The common measure of efficiency is feed conversion ratio (FCR). However, FCR is highly associated with growth rate (Koots *et al*., 1994), leading to an increase in mature size, which in turn increases the maintenance cost of the breeding herd (Liu *et al*., 2000). It has been shown that RFI is independent from mature weight and ADG, while being highly correlated to feed intake and FCR, leading to the reduction of feed intake without affecting growth performance or cow size (Nkrumah *et al*., 2007). Studies have shown that low RFI cattle have less whole-body chemical fat and more whole-body chemical protein than high RFI cattle (Richardson *et al*., 2001). Even with the decrease in body fat, low RFI animals still meet market specifications in respect of fat content for feedlot animals (Nkrumah *et al*., 2004).

Conclusion

Ruminants are important to mankind since most of the world's vegetation biomass is rich in fibre. Only herbivores can convert this fibre-rich vegetation into high quality protein sources for human consumption. In spite of this important role of livestock, it is specifically being singled out as producing large quantities of GHG that contribute to climate change. The popular press is fuelling these sentiments with slogans telling consumers to eat less meat. It is therefore important that the livestock industry should recognise the potential negative effects of livestock on climate change. It is also important that mechanisms are put in place to mitigate this effect, and since genetic improvement is permanent, it may be a cost effective approach.

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