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Technical options for reducing enteric methane emissions from livestock production[1]

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Executive summary

- A wide range of mitigation options have been surveyed, with varying degrees of effectiveness at mitigating methane emissions
- For Chinese livestock production, where poor quality forage is commonly fed, improving grazing management can reduce methane emissions by 11% on average and improving diet quality can significantly reduce methane emissions by 5% on average.
- Dietary supplements can reduce methane emissions further, with the addition of tannins or saponins reducing methane emissions by 11% on average and the addition of lipids giving an average reduction of 15%.
- The greatest mitigation potential is seen from adding chemical inhibitors to the rumen, with an average reduction of 31%. However, these are potentially toxic chemicals which raises conserns for food safety.

Introduction

Greenhouse gas emissions from livestock production is on the increase across Asia, mainly due to an increase in ruminant production. This increase is most marked in China, due to a rapid increase in population growth of both livestock and people (Yamaji et al. 2003). In recent years, there has been a continual increase in agricultural emissions. Most of this increase has come from an increase in livestock production, while emissions from rice production have decreased over the same period (Fu & Yu, 2010). The livestock sector is already a significant source of greenhouse gas emissions, with enteric emissions constituting a 3rd of the total methane emissions in China, and is expected to soon surpass rice production in terms of methane emissions (Dong et al. 2004).

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There are two major sources of greenhouse gas emissions from livestock, enteric emissions from microbial fermentation in the gut and manure emissions from microbial fermentation of manure during storage. Fermentation of manure can provide a significant source of energy, if the fermentation gases are harnessed through biogas digesters. The use of biomass energy, including biogas, accounts for a significant proportion (>70%) of rural energy consuption in place of fossil fuels (Ma et al. 2009). China now has official policies for increasing the use of renewable energy sources, including biogas (Ma et al. 2009). The focus for manure management is therefore shifting from mitigating emissions to harnessing emissions. Hence the focus for this policy report will be on the mitigation of enteric emissions, which are predominantly in the form of methane.

Globally, there is a large body of reasearch building up on methods for mitigating enteric methane emissions from livestock production, however data specifically from Chinese production systems are scarce. A global review has been conducted of the many mitigation options available, along with an effort to estimate the techincal potential for mitigation under Chinese production conditions using a meta-analytica approach. Enteric emissions from monogastric animals are negligible, and so the focus of the review has been on ruminant animals who account for nearly 90% of enteric livestock emissions in China.

Mitigation options for ruminants can be separated into 3 broad approaches; animal manipulations, diet manipulations and rumen manipulations as reviewed by Eckard et al. (2010). This policy report will discuss the technical potential of each of these different mitigation options. The economic cost or potential and barriers to adoption has been discussed in SAIN Policy Brief No. 8.

Animal manipulation

Breeding

Animal breeding is a key component in improving both the efficiency of production and quality of product produced. Comparisons of breeds, or of individual animals over time, show no clear patterns in methane emissions suggesting little genetic control over this trait (Münger & Kreuzer 2008). Though breeding specifically for reduced methane may not be a viable approach, there is some evidence that breeding for improved efficiency, for instance through improved residual feed intake, can reduce emissions both per unit product (Wall et al. 2010) and per head of animal (Alford et al. 2006). Breeding for improved feed conversion rates or improved productivity in general is likely to be of benefit to Chinese livestock systems as Chinese systems may still have a fairly low production efficiency. However, work to date shows only a small reduction in methane emissions on a per head basis as the result of breeding efforts (figure 1).

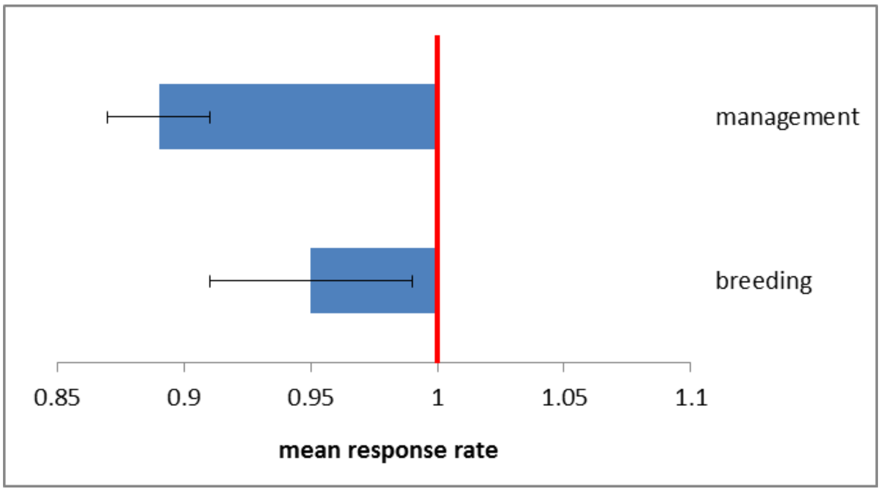

Figure 1: mean (±95% CI) response rate (treatment emissions as proportion of control emissions) based on a large scale meta-analysis of available data on animal manipulation approaches to methane mitigation. Results for management are based on 22 comparisons from 9 published papers. Results for breeding are based on 15 comparisons from 10 published papers.

Management

Herd management can give significant improvements in terms of reducing methane emissions per unit product, either through reducing the number of unproductive animals on the farm or through encouraging faster growth rates so animals reach slaughter weight earlier thereby reducing lifetime emissions per animal (Eckard et al. 2010). Increasing the total feed intake or energy intake of animals from a restricted to an *ad-libitum* intake will not only allow for a faster growth rate, but also potentially reduce the daily methane emissions per head of animal by as much as 11% (figure 1).

Diet manipulation

Forage quality

Improving diet quality is expected to have significant impacts on the methane emissions of ruminants. The substrate being fermented in the rumen influences the rate of methane production, with cellulose having the slowest fermentation rate and hence the highest methane emission rate per unit digested. Higher quality forages are also more palatable, increasing feed intake rates. A high feed intake rate, and a faster fermentation rate, will reduce the retention time in the rumen. This in turn will in theory reduce the proportion of feed energy converted to methane through fermentation. Similarly, the addition of concentrate can improve rumen fermentation efficency, and also reduce increase the propionate production with in turn reduces the amount of H_2 available for CH_4 production (Patra 2012). Chinese ruminants are typically fed a low digestibility diet high in cellulose and hemicellulose. Improving the digestiblity of such diets, through ensiling or other means, does not appear to have a great effect on the methane emissions per animal (figure 2). However, reducing the amount of roughage in the diet and replacing it with some form of concentrate does seem to improve methane emissions significantly (figure 2).

Dietary supplements

There are a host of different dietary supplements available, some of which have been proven to have a positive effect on methane emissions and others with no demonstrated effect. Most lipid supplements reduce methane emissions to some degree, with predicted mean reductions of 15% (figure 2). The effects, however, are highly variable depending on the concentration given, the type of fatty acids included or the background diet of the animal (Eugène et al. 2008). Addition of probiotics such as yeast are assumed to reduce methane production either by altering VFA profiles, reducing protozoal numbers, or promoting acetogenesis (Iqbal et al. 2008). Direct measures of the effectiveness of probiotics for reducing methane are few, but probiotic supplements appear to have no beneficial effect on methane production (figure 2). Dicarboxylic acids include the addition of nitrates or fumarate to the diet. These compounds stimulate the synthesis of propionate at the expense of CH_4, thus reducing the overall CH_4 emissions (Iqbal et al. 2008). This has proven to be very effective as a method of reducing methane in all ruminants (figure 2), though less effective in small ruminants than in cattle. All dietary strategies are most likely applied to intensive production systems which account for only a small proportion of Chinese livestock production. Though effective in most cases, they are therefore not widely applicable in China and data specifically from Chinese systems are not available. One exception is the supplementation with tea saponins which has received a great deal of attention within the Chinese research community. China is the largest producer of tea in the world. A byproduct of tea production is tea seed meal which contains a very high concentration of tea saponin (Wang et al. 2012). Tannins in general, including saponins, are assumed to reduce methane production through their anti-protozoal properties (Wange et al. 2012) and have been shown to be very effective in reducing the methane emissions from all groups of ruminants (figure 2).

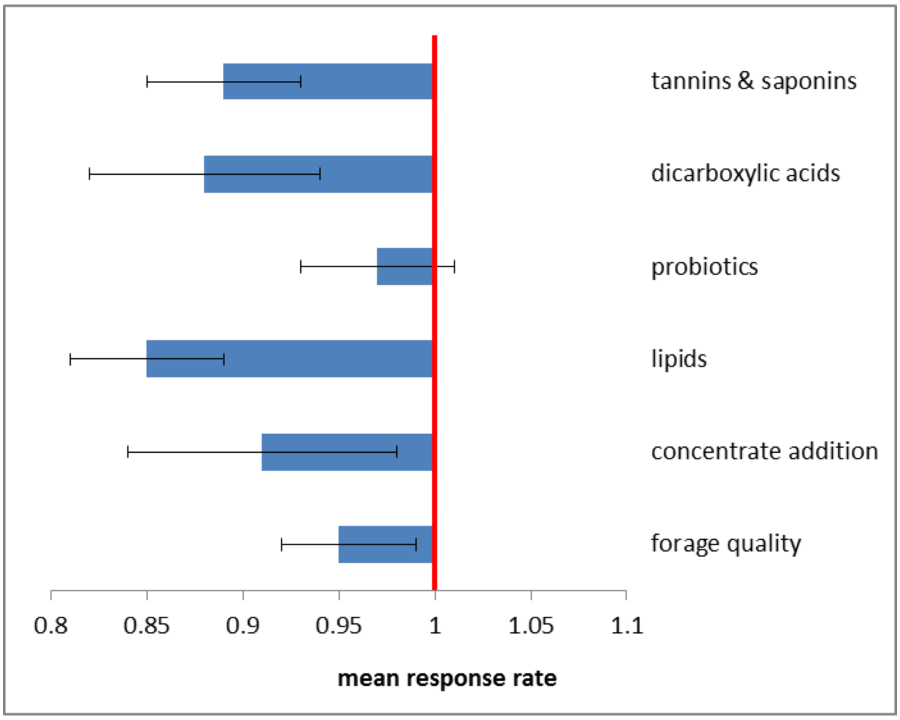

Figure 2: mean (±95% CI) response rate (treatment emissions as proportion of control emissions) based on a large scale meta-analysis of available data on nutritional approaches to manipulating enteric methane emissions. Results for forage quality are based on 55 comparisons from 24 published papers. Results for concentration addition are based on 33 comparisons from 17 published papers. Results for lipids are based on 55 comparisions from 20 published papers. Results for probiotics are based on 11 comparisions from 5 published papers. Results for dicarboxylic acids are based on 17 comparisons from 11 published papers. Results for tannins and saponins are based on 47 comparisons from 22 published papers.

Rumen manipulation

Chemical inhibitors

Halogenated analogues such as bromochloromethane and chloroform are highly effective at reducing methane production, though methanogen species differ in their responsiveness (McAllister & Newbold 2008). Though these compounds can be highly effective (figure 3), the effect of these chemicals is transitory with no significant long-term reduction in methane production (McAllister & Newbold 2008). These are also potentially highly toxic chemicals which are unlikely to be found acceptable in food production systems.

Ionophores

Ionophores such as monensin are antibiotic compounds which specifically targets bacteria producing H_2 and formate. This reduces the amount of H_2 available for methanogenic bacteria and thereby reduces the production of methane during fermentation (Russel & Strobel 1989). Though proven to be effective in the short term, the mean effectiveness of ionophores is small (figure 3). There are also concerns over the excessive use of antibiotics in animal production systems with such compounds being banned in other parts of the world. Ionophores are threfore not a mitigation strategy likely to be widely adopted by the Chinese livestock industry.

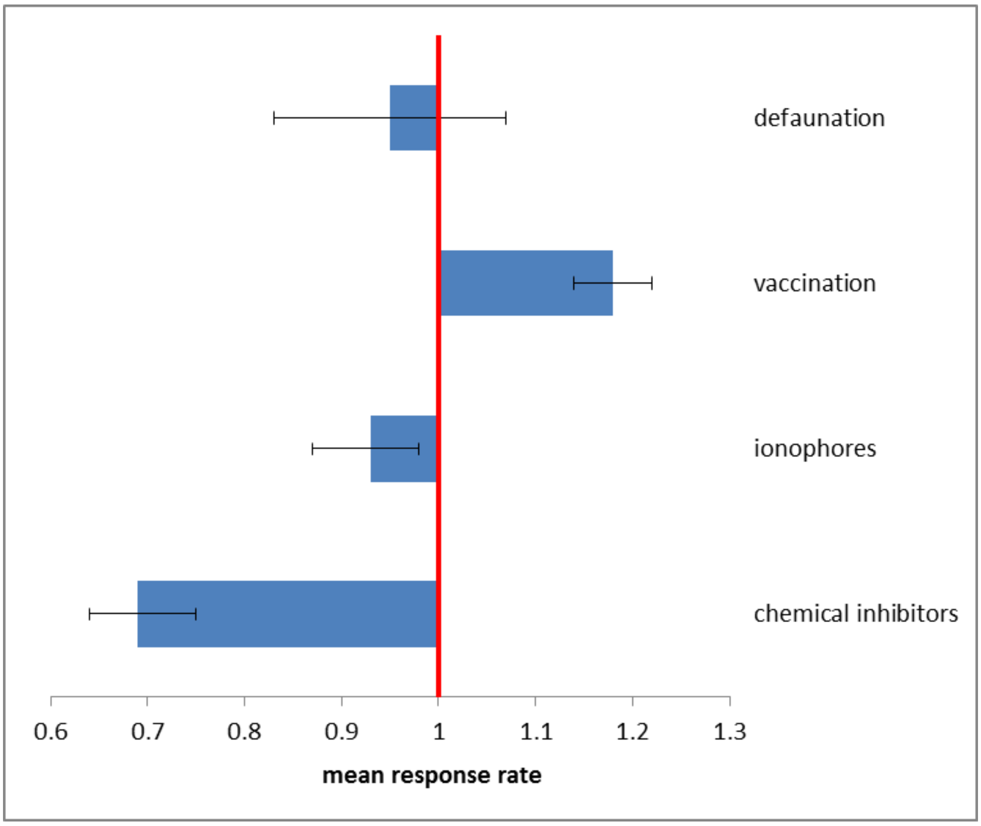

Figure 3: mean (±95% CI) response rate (treatment emissions as proportion of control emissions) based on a large scale meta-analysis of available data on rumen manipulation approaches to manipulating enteric methane emissions. Results for chemical inhibitors are based on 6 comparisons from 4 published papers. Results for ionophores are based on 16 comparisons from 10 published papers. Results for vaccination are based on 6 comparisions from 2 published papers. Results for defaunation are based on 6 comparisions from 3 published papers.

Defaunation or vaccination

Defaunation of the rumen, the removal of ciliate protozoa from the rumen ecosystem, is thought to significantly alter fermentation patterns and improve nutrient use (Eugène et al. 2004). This in turn is expected to result in a reduced production of methan during fermentation. Research has begun into the potential for vaccines against rumen methanogens, with the aim to reduce the production of methane during fermentation (Williams et al. 2009) . Efforts to permanently defaunate animals or to develop a vaccine against methanogenic bacteria are still in the early stages of research, with research only available from sheep. So far, these strategies have not proven to be very successful (figure 3).

Conclusions

There are many mitigation strategies available, with a proven effectiveness for reducing enteric methane emissions from ruminants. Breeding for reduced methane production may not be effective, but appropriate feeding management can be effective either through improving feeding practice or through improving diets. Chinese livestock are often fed on low quality forage, high in fibre and low in nutrients. Improving diet quality can therefore have positive benefits not only on greenhouse gas emissions, but also on productivity. A wide range of dietary additives or rumen manipulators have been investigated for their potential to reduce methane emissions, and found to be of varying effectiveness. Some, such as the ionophores and chemical inhibitors, though effective, have safety concerns and are therefore not likely candidates for widespread adoption. Of the remaining strategies, supplementation with tea saponins is the most promising for Chinese production systems as these compounds are readily available as industry by-products with a proven effectiveness.

The results presented so far only discuss the technical potential of the different mitigation options. A policy brief describing the economic potentials and barriers to adoption has already been published (SAIN Policy Brief No. 8).

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Appendix 1: Table shows mean potential emission savings in tonnes of CO_2-equivalents per year and the 95% confidence interval for those means. The mitigation results are based on a global meta-analysis of published research data on methane mitigation. Emission savings are calculated based on IPCC emission factors for ruminant livestock and 2010 census data for livestock populations and assume the mitigation strategy in question is applied to all ruminants.

Mitigation strategy		**% reduction in CH_4 emissions**			**maximum emission savings (tCO_2-eq/year)**		
		Mean	**95% lower**	**95% upper**	**Mean**	**95% lower**	**95% upper**
Animal manipulation							
	Breeding	5	9	1	680	1224	136
	Management	11	13	8	1495	1767	1088
Diet manipulation							
	Forage quality	5	9	2	680	1224	272
	Concentrate addition	9	16	2	1224	2175	272
	Lipid supplements	15	19	11	2039	2583	1495
	Probiotics	3	7	-1	408	952	-136
	Dicarboxylic acids	12	18	6	1631	2447	816
	Tannins and saponins	11	15	7	1495	2039	952
Rumen manipulation							
	Chemical inhibitors	31	36	25	4214	4894	3399
	Ionophores	7	13	2	952	1767	272
	Vaccination	-18	-14	-22	-2447	-1903	-2991
	Defaunation	5	17	-7	680	2311	-952