

Feeding Strategies to Reduce Greenhouse Gas Emissions from Pigs

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■ Introduction

Greenhouse gases and the Kyoto Agreement have been front-page news for months. Despite all the rhetoric on all sides we have heard very little about the potential impact on animal agriculture, and specifically the pork industry. The objectives of this paper are to first describe the potential impact on pork production in Canada and to discuss some of the current research we are conducting to find ways for pork producers to reduce greenhouse gas (GHG) emissions from the pig.

■ How will Kyoto affect pork producers?

In our report 'Feeding Strategies for Mitigating Greenhouse Gas Emissions from Domestic Animals' (Mathison, Ball, Möhn and Buchanan-Smith, 1999), we estimated the GHG emissions from all livestock species in Canada. This document included a detailed analysis of the estimated GHG emissions from swine in Canada and a prediction of the emissions for 2010, the date by which the Kyoto agreement requires a reduction in GHG emissions to 6 % below 1990 levels, and a series of potential feedings strategies for reducing GHG emissions. We did not consider GHG emissions from manure storage and treatment because this was the subject of a separate report. See the paper by Claude Laguë in these proceedings for a discussion of the effects of alternative manure management on GHG.

In 1990, Canada produced 15.6 million slaughter pigs. Using a combination of data from Statistics Canada and Agriculture and Agri-Food Canada, pig production in Canada and the main pig producing regions were estimated for 2010 and 2025. To extrapolate to future animal numbers, 5 and 3 year rolling

averages within regions were used and projected assuming the same rate of increase as that which occurred between 1980 and 1997. These calculations predicted 23.5 million pigs marketed per year in 2010. However, in 2002 the Canadian production was already at 26.0 million pigs. If this trend continues, we could expect a production of almost 35 million pigs by 2010.

Key animal performance characteristics that influence GHG emissions were also calculated and predicted into the future. These included: pigs marketed per sow per year, rate of weight gain, feed efficiency, protein and lipid deposition rates, slaughter weight, and carcass lean yield.

Data from the published scientific literature were used for calculation of GHG emissions by each class of pig including: methane (CH₄) production, nitrogen excretion, and N₂O emissions from manure. Carbon dioxide (CO₂) production was not included in these numbers, because it was assumed, based upon the literature available, that CO₂ production by pigs could not be influenced. We now know from our current research that this is incorrect and that CO₂ can be manipulated. We also know from our recent research that the literature values used in this document substantially underestimated the CH₄ production by pigs.

Calculated GHG emissions by Canadian pigs for 1990 were 414,886 tonnes of CO₂ equivalent, assuming 0.5% of the excreted N is transformed to N₂O (Misselbrook et al, 1998). Our calculations predicted that by 2010 there would be an increase in GHG emissions from 23.5 million pigs to 555,834 tonnes CO₂ equivalents per year. This represents an increase of 34%. For a production level of 26 million and 35 million pigs/year the predicted GHG emissions would be 614,965 and 827,838 tonnes/year respectively; increases of 48% and 100%, respectively.

Benchmark GHG emissions from pigs

However, we need to correct these previous emission estimates based upon our recent research. This requires addition of the CO₂ emissions, increased CH₄ emissions and a higher value (to 30% of excreted N) for potential N₂O emissions. This brings the calculated 1990 CO₂ equivalent emissions to 11.6 million tonnes/year for 15.6 million pigs slaughtered. This should be regarded as our current best estimate of benchmark emission levels from Canadian pig production. The predicted CO₂ equivalent emissions for 23.5, 26 and 35 million pigs would be 14.6, 16.1 and 21.7 million tonnes/year, respectively. These are equivalent to 126, 139 and 187% of 1990, respectively. These predicted emissions already assume 15% improvement in animal performance, as described below.

We do not know the implications for the pork industry, regarding GHG emissions, of the increase in exports of live pigs to the USA and elsewhere. In

1990 Canada exported about 868,000 pigs whereas in 2001 more than 5.3 million were exported, mainly as feeder pigs. How these pigs will be attributed for GHG emissions needs to be determined. Because of the very large number of pigs involved this could have a significant impact on the calculated GHG emissions

■ **The Worst Case Scenario**

Given that Canada produced 15.6 million pigs per year in 1990, if we made no improvements in animal performance and did not apply feeding and manure management strategies to reduce GHG emissions, then we would need to reduce the current Canadian pig production to 6% below the 1990 level by 2010. This is equal to producing 14.66 million pigs by 2010, about the same number of pigs that Canada produced in 1980. This represents a decrease of 11.34 million from the 2001 production of 26.0 million pigs or 56 % of current production. At this level of production we would not even be producing enough pigs for domestic consumption in 2010, and Canada would no longer be the top pork exporting country in the world. Clearly, such a restriction on the pig industry would be devastating. The economic impact would be far reaching, including the crop production industry, the animal feed industry, packing plants, meat processors, rural communities, balance of trade, etc.

■ **A More Realistic Scenario**

However, it is more reasonable to presume that improvements in pig performance, including, genetics, nutrition, reproduction and management, will occur in the future. However, we are also producing more pigs every year and this trend appears set to continue, despite recent setbacks due to low market prices. We predicted an overall improvement in efficiency and performance by 2010 of about 15% from 1990 levels.

If we apply the assumption of a 15% improvement in performance due to a better feed efficiency and growth rate and also assume that we choose to achieve the target of 6% below 1990 levels only by reducing the number of pig produced this would require a reduction in pig production to approximately 17.0 million pigs per year. This is 9 million fewer pigs than Canada produced in 2001. There is no question that this level of reduction would have major economic impacts on Canada and the major pork producing regions of Quebec, Ontario and the Prairie Provinces.

■ A Better Case Scenario

Meeting GHG reduction targets only by reducing the number of pigs produced is clearly not a viable economic goal. Therefore other means of reducing GHG emissions must be considered. Obviously, new and affordable technologies to reduce GHG emissions must be developed and applied if the Canadian pork industry is to continue to thrive and successfully compete on the world market.

We identified several feeding strategies that could potentially reduce GHG emissions, so that producers would not need to substantially reduce the number of pigs sold, simply to meet targets for GHG emissions. Our goal was to develop feeding strategies and dietary interventions which, when combined with improved practices for manure handling and treatment, would enable the Canadian pork industry to remain competitive and continue to grow.

Potential feeding strategies to reduce GHG emissions from pigs

We identified a reduction of dietary protein content in swine rations, using supplementation of synthetic amino acids, as the single most effective strategy. The effects of dietary protein reduction on N-excretion are well documented. For example, Möhn and Susenbeth (1995) showed that a 20% reduction in dietary protein can reduce nitrogen excretion by as much as 35%, provided that the low protein diets offer adequate amino acid concentration. Similarly, the use of low protein diets for sows also shows promise. The reduction of nitrogen excretion by the animals appears to lead to a reduction in N₂O emissions from manure (Misselbrook et al., 1998). We are currently studying this aspect in collaboration with Drs. Feddes and Leonard from the University of Alberta. A secondary benefit of reduced dietary protein contents may be a reduction in the animals' CO₂ emissions as a result of an improved utilisation of dietary energy (Möhn and Susenbeth, 1995). Feeding of low-protein diets can be implemented immediately for grower and finisher pigs, while for sows there are still constraints related to uncertainties in some amino acid requirements (Möhn et al., 2000, McMillan et al., 2002).

Phytase addition to feed, although marketed primarily to reduce phosphorus excretion, has been shown to increase protein digestibility (for summary see NRC, 1998). Ketaren et al. (1991) estimated that phytase addition improved growth and protein deposition by 15% while feed efficiency was improved by 10%; this could lead to a decrease in N₂O and possibly CO₂ emissions as outlined above. However, to our knowledge, phytase addition to diets has not been studied as a means of reducing GHG emissions, therefore no data about its effectiveness or optimal inclusion in diets for this purpose is available.

Addition of cellulases and hemicellulases may improve animal performance by degrading non-starch polysaccharides (NSPs) that may interfere with digestion

of other nutrients (Li et al., 1995). This improvement does not necessarily occur (Thacker and Baas, 1996), especially in diets based on corn and soybean meal (NRC, 1998). A further beneficial effect of the addition of these enzymes may be a reduction in methane production by intestinal microbes, which appears linearly related to the ingestion of NSPs (Jensen, 1996). The use of these enzymes to reduce methane production is likely to be most effective in diets based on barley, wheat and canola because of the higher content of NSPs in these diets compared to corn and soybean meal diets.

How much can GHG emissions be reduced by implementing new feeding strategies?

Our review of the literature indicated that there were currently no data available to assess the effectiveness of enzymes for reducing CH₄ emissions nor about the necessary inclusion levels to achieve that goal. Direct measurements of the effectiveness of reduced dietary protein on CO₂ emissions were also not available. Similarly, possible effects of a reduction of dietary protein intake on CH₄ emissions had not been studied. Therefore we began a series of experiments to determine whether GHG emission could be reduced by these feeding strategies, and by how much.

The data presented in this section can be found in more detail in several abstracts in the current Banff Pork Seminar proceedings (Advances in Pork Production vol. 14: abstracts # 16, 17; vol. 13: abstracts #12, 13, 14.) We assessed the impact of these diet interventions by measuring CO₂-, CH₄- and heat production, and O₂ consumption using an open-circuit respiration system. We also measured nitrogen excretion. This research shows that low protein diets can reduce GHG emissions from growing pigs by 25 to 30% and from sows by 10-15%. Research is currently underway or planned on the use of phytase and NSP enzymes.

Effect of low protein diets in GHG emissions by finishing pigs.

Our objective was to study the effect of decreasing dietary protein intake on GHG production by finisher pigs (Atakora et al., 2003b), while maintaining growth performance.

Finisher pigs (68 kg, SE 2) were fed conventional 19.3% (HP) or protein-reduced (16.0%), amino acid supplemented diets (LP) based on wheat, barley and soybean meal in a cross-over design. The diets were equalized for the first four limiting amino acids. Daily gain (784 g/d), nutrient digestibility and protein retention (182g/d) were not affected ($P > 0.2$) by diet. N excretion was lower ($P = 0.001$) by 22% in LP due to a 29% reduction ($p = 0.001$) in urinary N excretion. CO₂ production and O₂ consumption were reduced in LP by 4% and 7.0%, respectively. CH₄ production was lower in LP by 27.3% (**Table 1**).

Assuming the excreted N is fully converted to N₂O, the reduction in N excretion would reduce the CO₂ equivalent by 19.9% ($p = 0.001$) when feeding the LP diet. The conversion of excreted N to N₂O is dependent, however, on manure properties and treatment. Therefore the N₂O generated may vary between 0% and 30% of the N content of slurry (Béline et al., 1999); the 30% value is for manure that is mixed and aerated and then spread on the land. At these extremes of conversion, the reduction of CO₂ equivalents amount to 10.4% and 17.4% by feeding the amino acid supplemented low protein diet. Clearly, more research is urgently needed to assess the effect of diets on the emission of CO₂ equivalents, particularly N₂O emission from manure of pigs fed LP diets.

Table 1. CO₂, CH₄ production and N excretion and CO₂ equivalents produced by finishing pigs fed barley- based diets at two protein levels (n = 12/group).

	High protein	Low protein	SEM	P =
CO ₂ , g/d ¹	2229	2145	101	0.69
Relative	100	96		
CH ₄ , g/d	15.0	10.9	1.1	0.05
Relative	100	73		
N excretion, g/d	35.0	27.4	1.1	0.001
Relative	100	78		
CO ₂ equivalents, g/d ²	8209	6784	233	0.001
Relative	100	83		

¹: observed means.

²: Assuming 30% of the excreted N is converted to N₂O.

Research is currently underway to compare corn-based diets to barley based diets and to evaluate addition of phytase and enzymes that degrade NSPs to grower pig diets. We expect to find that these enzymes will have positive and significant effects on GHG emissions from pigs.

Effect of low protein diets on GHG emissions by sows.

Our objective was to reduce the GHG production by sows by decreasing their protein intake. We have conducted experiments in non-pregnant (Atakora et al 2003a), gestating (Atakora et al 2002) and lactating sows (Atakora et al 2002) using both barley-based and corn-based diets.

In non-pregnant sows (Atakora et al 2003a), the CO₂ production was 5% lower for corn-based diets than for barley-based diets (**Table 2**). CH₄ production was greater for the barley-based diets than for the corn-based diets. By reducing the protein content of the barley diet, the methane production decreased by 57% from 21.6 g/d to 9.3 g/d. Reducing the protein content of the corn-based diets did not affect methane production, probably due to the lower content of NSPs in these diets compared to barley based diets. Low protein diets based on both corn and barley reduced N-excretion, which may result in a proportional decrease in N₂O production. Applying the conversion factors of 23 and 310, respectively, the reduced CH₄ production and N excretion lowers GHG production, in CO₂ equivalents, by sows by about 17%.

Table 2. CO₂, CH₄ and CO₂ equivalents produced by non-pregnant sows fed barley- or corn-based diets at two protein levels.

	Barley-based diets		Corn-based diets	
	HP	LP	HP	LP
CO ₂ , g/d ¹	3169 ^{ab2}	3341 ^a	3020 ^b	3095 ^{ab}
SE	152	162	148	162
Relative	100	105	100	102
CH ₄ , g/d ³	21.6 ^a	9.3 ^b	8.8 ^b	11.8 ^b
SE	1.4	1.9	1.4	1.4
Relative	100	43	100	134
CO ₂ equivalents, g/d ⁴	13307 ^a	10987 ^b	10524 ^b	8874 ^c
SE	261	348	258	280
Relative	100	83	100	84

¹: observed means.

²: different letters within a row indicate differences at P < 0.05.

³: Least square means.

⁴: Assuming sows are at N-equilibrium, and 30% of the excreted N is converted to N₂O.

In gestating sows and lactating sows, CO₂ production was reduced by 5% and 7% respectively, by feeding low protein barley based diets (Atakora et al 2002). CH₄ was not measured in this earlier experiment.

■ The Best Case Scenario

The best case scenario is that we can combine the diet interventions described above and that the effects will be additive. If we only consider the use of low protein diets we may be able to achieve about a 15-20% reduction in GHG emissions (in CO₂ equivalents). Because of our increase in pig production, this is not enough to meet the requirement of reduction of GHG to 6% below 1990 levels. This will require about at least 25 % reduction below the projected emissions for 2010, assuming we only produce to 23.5 million pigs in 2010. If more pigs are produced then this obviously requires a greater reduction per animal. If we continue to produce 26 million pigs, the GHG reduction required will be at least 32 %. However, if addition of phytase and carbohydrases can reduce emissions by at least 10%, then this may make the goal of reduction to 6% below 1990 levels achievable. In addition, there are many improvements in manure handling and management that could also reduce GHG emissions from pig production.

■ Will it be economical to reduce GHG emissions in pigs?

We are currently adding simple economic evaluation to our data. We previously calculated that the cost of feeding low protein diets for sows was an additional \$3.23/sow (Möhn et al 2002). This was due to the slightly lower number of weaned pigs produced; this should be remedied by better knowledge of the amino acid requirements of sows. For growing pigs, many diets already contain lysine, methionine is commonly used and threonine will be more often used in the future as the price declines due to increased production capability. These amino acids are priced by the industry to result in their economical inclusion in pig diets. This means that the relative cost of low protein diets for growing pigs could be similar to diets that are not supplemented with amino acids. Therefore, we predict that producers will be able to feed low protein, amino acid supplemented diets at similar costs to high protein diets.

An economic evaluation of the addition of enzymes to diets for the purpose of reducing GHG is not possible at this time. We do not yet have the data to determine the effects these may have on GHG emissions and the levels of inclusion (i.e. costs) required to achieve benefits.

Integrated research with economic evaluation is required. We must follow the effect of changes in pig diets upon the manure characteristics and the resulting GHG emissions from manure during storage, composting, biogas generation and land application. To our knowledge this research has not been conducted. We have recently formed a consortium amongst researchers from the University of Alberta, Alberta Agriculture, Food and Rural Development, and

Prairie Swine Centre with the goal of conducting this integrated research. We are currently seeking funding for this research program.

Finally, we need to consider the possibility that pork producers could sell their reductions in GHG emissions as GHG credits to organizations that are not able to reduce their own emissions adequately. If all the possible strategies are implemented, including: diet interventions, targeted manure management, and improved animal performance, it may be possible to reduce GHG emissions by more than the 30-50% required to meet the Kyoto targets. Carbon credits are currently valued at \$15-\$60 per Tonne. In our research, finisher pigs excreted 35.0 g N /d, 15.0 CH₄/d and 2230 g CO₂/d when fed conventional diets. This equals a total emission of 8,200 g/d in CO₂ equivalents, assuming 30% of the N excreted is converted to N₂O. By reducing the greenhouse gas emissions by 30% or about 2,500 g/d, using the technologies described above, a reduction of 1 Tonne in CO₂ equivalents could be achieved every day with 400 pigs.

■ Conclusion

It may be feasible for pork producers to achieve a reduction in GHG emissions from swine production. This will require the implementation of a combination of strategies, including: diet interventions, alternative manure management and increased animal performance. There is insufficient research at the present time to determine if the combination of these factors will meet the total GHG reduction that is required, however there are some reasons to be optimistic. If these combined strategies can reduce GHG emissions more than required, then there may be an economic opportunity for pork producers to improve their income by reducing GHG emissions and selling these credits to other industries. The actual cost to pork producers of implementing all the necessary strategies cannot be determined at this time due to insufficient research data.

Finally, the most important factor is the number of pigs produced per year. At the current production of 26 million pigs, a reduction of 32% is required, which only appears to be achievable if all the strategies are employed by all producers with 100% effectiveness. However, for a production of 30 million pigs, a reduction of GHG emission of 45% from baseline would be required. Even if all current and projected technologies are applied with 100% effectiveness, this does not seem readily achievable. New and innovative technologies and interventions will be required to achieve this goal.

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