EFFECT OF ADDING FIBRE SOURCES TO PIG DIETS ON VOLATILISATION AND METHANE PRODCUTION FROM MANURE

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1 INTRODUCTION

Pig production in Europe is concentrated in specific areas, which has an economic advantage but also causes environmental damages dealing with local surplus of slurry. Slurry from livestock farms is the principal source of ammonia (NH_3) emission (ECETOC, 1994) and it contributes to methane (CH_4) emissions due to the anaerobic digestion of organic matter during storage (Hashimoto et al., 1981). Many studies have attempted to reduce such gaseous emissions through diet modifications. Reducing crude protein content, associated with a supplement in amino acids, or the addition of fibres to the diet, achieve a reduced N excretion and subsequent ammonia emission (Canh et al., 1997). The modification of the diets could also influences the production of methane from the slurry, but very few studies were carried out on this subject. Zeeman (1991) and Velthof et al. (2005) showed that a decrease in protein content of the diet reduced the production of methane, while the addition of fermentable fibres increased it.

The recent peak in the price of cereals has highlighted the competition between animal feed and human food demands. In this context, others raw materials are encouraged as an alternative to cereals in animal diets. Among the reasons leading to this competition the government policy to incorporate biofuel (up to 5.75% in Europe by 2010, European Directive 2003/30/CE) plays a major role. Such policies lead to the developpement of a biofuel processing industry which produces co-products, rich in fibre as wheat distillers dried grains with solubles (DDGS) or sugar beet pulp in the case of production of ethanol, and oilseed meal in case of production of biodiesel. The recycling of such co-products in animal feed represents an economically sound alternative. There is a wide variation in the process of quality of these co-products according to the raw material and the technology. For economic reasons, some farmers process their own biodiesel from rapeseed, leading to a high fat rapeseed meal (up to 15 % crude fat compared to about 2 % crude fat for an industrial process). The influence of European biofuel processing coproducts incorporated as pig diets and their subsequent manure 'environmental' impacts remains to be addressed.

In this context the aim of the present study is to investigate the effects of different biofuel co-products (DDGS, sugar beet pulp and high fat level rapeseed meal) in pig diet on (i) excretory patterns of N and C and (ii) ammonia and methane emission.

2 MATERIALS AND METHODS

Twenty Piétrain x (Landrace x Large White) castrated male pigs, with an average initial body weight of 50 (± 3) kg, were housed individually in metabolism cages. The pigs were assigned to five dietary treatments according to a complete randomized block design (based on initial age and body weight). The 23-day experimental period consisted of a 13-day adaptation period to allow the pigs to accustom to the cage and the diet and a 10-day period during which urine and faeces were collected.

Five experimental diets mainly based on wheat and soybean meal were formulated: two control diets, a control high protein (CHP) level with 17.5 % of crude protein (CP) and a control low protein (CLP) level with 14.0 % of CP and three experimental diets with 20 % of (i) dried distiller's grain with solubles (DDGS), (ii) sugar beet pulp (SBP) or (iii) fatty rapeseed meal (FRM). Feeding level was from 2 to 2.2 kg day^{-1} during the collection period.

The pigs received their diet in mash form (2 L water / kg feed) in two equal meals. Five litres of additional water were also provided each day.

Ammonia emission measurements were done on slurry produced through a pilot scale system developed by Portejoie et al. (2004). Two measurements were made per diet. Ammonia emissions were determined for a period of 16 days. Samples of 5 kg slurry were placed in each measurement unit. Ammonia emissions were trapped daily in 50 ml H_2SO_4 (2N) and ammonia concentration and mass of acid were determined.

For the estimation of CH_4 emissions, the International Panel on Climate Change (IPCC, 1997) proposes a procedure based on the maximum methane producing capacity (B_0) of the waste. This procedure was developed by Vedrenne et al. (2007) and modified further for this study to reflect the characteristics of the slurry used as follows. B_0 was determined for the slurry from each dietary treatment and achieved in batch assays in triplicates using 330 ml glass bottles (liquid volume 120 ml) at 38°C with an OMinoculum/OMsubstrate ratio of 0.1. Inoculum (2.4 g, corresponding to 80 mg OM) and corresponding amounts of slurry were weighed to the bottles, after which water was added to reach the 120 ml liquid volume. From this point the procedure follows that developed by Vedrenne et al. (2007).

3 RESULTS AND DISCUSSION

3.1 N and C balances

The amount of N ingested was significantly lower for the CLP diet (Table 1). This resulted in a lower N excretion for CLP treatment than for the other treatments which did not differ among each other. The addition of DDGS, SBP and FRM increased significantly the amount of N excreted per pig and per day, compared to the CHP diet, by 23%, 10% and 20%, respectively. The partition of N excreted among urine and faeces was also affected by dietary treatments. A higher proportion of N was excreted in faeces for the three high fibre diets (32%) whereas the lowest proportion of N excreted in faeces (18%) was measured for the CHP diet. The excretory route of N was modified in pigs fed co-products compared to the control diets. Fibre increases the flow of fermentative energy substrate and N (of both exogenous and endogenous origin) into the large intestines. Under fermentation conditions (as with higher dietary intake), ammonia is partially derived from the bloodstream and used by the microflora for the new synthesis of bacterial proteins which are excreted in the faeces (Low, 1985).

Daily C excretion was significantly ($P<0.05$) increased by the addition of co-products, compared to the CHP diet (Table 1), by 72 %, 32% and 63%, respectively. However the partition of C excretion between urine and faeces did not differ between treatments, with about 80% of C excreted in faeces. Very few studies have evaluated the effect of dietary fibre sources incorporation on excretory C patterns. C excretion in faeces increases as a consequence of the low digestibility of nutrients but according to our results this has only limited effects on the partition of excreted C between urine and faeces, faeces being the major route of C excretion in all situations. A second explanation as for N excretion could be found in a higher bacterial activity in the tract and especially in the intestine and possibly a higher bacterial excretion in faeces.

3.2 Ammonia volatilisation test and B_0, ultimate methane production potential

The volatilisation of ammonia and the production of methane were significantly ($P<0.05$) affected by the dietary treatments. The addition of fibre sources to the diets and the lowering of CP content (CLP diet) reduced significantly ($P<0.05$) the cumulated N-NH_3 volatilised from slurry by 31% to 49% and the rate of ammonia volatilisation by 12% to 32% (Table 2) compared to the CHP diet. The ammoniacal N content in slurry from diets with added fibre sources, with about 17.5% CP, is almost equivalent to that of the slurry from the CLP diet with 14% of CP. Canh et al. (1997) reported that the addition of fermentable fibre in the diet will most likely lead to higher VFA production in the large intestine, thus resulting in a lower slurry pH which has been shown to diminish ammonia emissions. In our study the pH of slurry from diets rich in fibre was reduced in agreement with these results. In agreement with the results of Portejoie et al. (2004) the decrease of dietary CP from 17.5 to 14.0% resulted in about 30% reduction in ammonia volatilisation. The incorporation of fibre sources to the diet, without reducing CP content, resulted in about 40% reduction in ammonia emission compared to the control high protein diet, which is in line with the results obtained by Cahn et al. (1997).

Compared to CHP diet, the addition of DDGS and SBP reduced significantly B_0 by 9 and 4%, respectively; whereas B_0 increased by 3% with de addition of FRM to the diet. The reduction of CP content in CLP diet also reduced B_0 by 5% compared to the CHP diet. In contrast, because of the difference in the daily amount of OM excreted per pig, the addition of fibre sources affected significantly on the amount of methane emitted per pig and per day. Indeed, compared to the two control diets, the addition of DDGS, SBP and FRM increased the amount of methane emitted by 73%, 37% and 84%, respectively. In the literature the B_0 of pig slurry vary between 290 and 480 ml CH_4 / g OM. Our results are within this range (428 to 484). This effect is likely due to low levels of VFA in slurry during the anaerobic digestion (Zeeman, 1991; Velthof et al., 2005). Our results are consistent with the results of these authors. However, it is interesting to note that the B_0 of the slurry from DGGS treatment is the lowest although protein and fermentable fibres contents are similar to those of slurry from SBP and FRM treatment. This could be explained by the fact that the manufacturing process of DDGS requires heating steps that may be causing reactions between protein and others molecules, such as lignin, resulting in products hardly degradable by the bacteria associated with anaerobic digestion. The increased B_0 measured for the slurry from FRM diet could be due to the higher fat content. When the potential methane production is expressed per pig and per day differences among treatments are much more marked. This is mainly related to the difference in excretion of OM. When the production of CH_4 is not controlled, which is often the case when slurry is stored in the piggery or outside, most often over long periods of time, this will result in increased CH_4 emissions to the atmosphere with harmful effect on the environment. Conversely, in the case of anaerobic treatment, the increased CH_4 production will contribute to increased energy production as heat and/or electricity, which has a positive environmental impact.

TABLE 1 **Excretory patterns of N and C***

	CHP	CLP	DDGS	SBP	FRM	RR†	Significance
Ingested nitrogen (g/pig/day)	58.6c	47.0d	61.5a	59.0b	58.9b	0.11	***
N excretion (g/pig/day)	27.1ab	21.1b	33.4a	29.7a	32.6a	3.24	***
- in faeces (%)	18c	22bc	34a	33a	30ab	4.1	***
- in urine (%)	82a	78ab	66c	67c	70bc	4.1	***
N excreted/N ingested (%)	46	45	56	50	55	5.6	t
Ingested carbon (g/pig/day)	797b	790c	822a	798b	822a	1.6	***
C excretion (g/pig/day)	107c	103c	183a	141b	174a	10.6	***
- in faeces (%)	76	80	82	81	83	5.7	
- in urine (%)	24	20	18	19	17	5.7	
C excreted/C ingested (%)	13c	13c	22a	18b	21a	1.3	***

* Abbreviations are: CHP = control high protein, CLP = control low protein, DDGS = dry distiller's grain with solubles, SBP = sugar beet pulp, FRM = fatty rapeseed meal.

[a, b, c] Values with different superscripts differ significantly, effect of diet (P< 0.05).

[†] Residual error.

TABLE 2 **Effect of dietary treatments ammonia volatilisation and ultimate methane production ***

	CHP	CLP	DDGS	SBP	FRM	Rsd†	Significance
Cumulated N-NH3 volatilised (g)	5.53a	3.72bc	3.82b	2.83d	3.29dc	0.12	***
Rate of N-NH3 volatilisation (%)	14.5a	12.7b	9.6c	10.0c	11.9b	0.41	***
B0 (L CH4/kg OM)	471ab	449c	428d	453bc	484a	6.8	***
Level of CH4 in biogas (%)	82a	67c	65d	68c	70b	0.2	***
Ultimate daily CH4 production (L/pig)	70d	69d	120b	95c	128a	4.9	***

* Abbreviations are: CHP = control high protein, CLP = control low protein, DDGS = dry distiller's grain with solubles, SBP = sugar beet pulp, FRM = fatty rapeseed meal.

[a, b, c] Values with different superscripts differ significantly, effect of diet (P< 0.05).

[†] Residual standard deviation

4 CONCLUSION

This study has shown that adding biofuel co-products, rich in fibre, to pig diets results in a shift of nitrogen excretion from urine to faeces, a decrease of slurry pH and an increase in the amount of slurry C, OM and VFA. This results in a decrease in the rate of volatilization of ammonia during storage and in an increase in the production of methane. Thus, the composition of the diet and its effect on the quantity and the characteristics of effluent should be considered in the context of optimizing collection procedure and waste treatment to minimize uncontrolled emissions of ammonia and methane, or in some situations, to maximize the controlled emission of methane.

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