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Original article

Effects of a reduction of diet crude protein content on gaseous emissions from deep-litter pens for fattening pigs

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Abstract – Two successive batches of 32 fattening pigs per batch were each divided into 2 homogenous groups of 16 pigs fed either a high crude protein (CP) level diet (HP-groups) or a low crude protein level diet balanced with synthetic amino acids (LP-groups). Pigs were raised on straw-based deep litters in separate rooms according to diets. Once a month, the emissions of ammonia (NH_3), nitrous oxide (N_2O), methane (CH_4), carbon dioxide (CO_2) and water vapour (H_2O) were measured continuously for 6 days consecutively. The mean nitrogen (N) intakes of pigs from HP-groups and LP-groups were 6.83 kg and 5.78 kg per pig respectively with mean initial and final pig body weights of 26.6 and 111.4 kg. There was no significant difference between the daily weight gains with regards to the diet CP content. At the end of the fattening periods, the N-contents of the litters were on average 1.84 kg per pig for the HP-groups and 1.56 kg per pig for the LP-groups. Gaseous emissions in the room with LP-groups were, compared with the emissions in the room with HP-groups, 26.1% lower for NH_3 (10.60 vs. 14.35 g per pig per day), 12.8% lower for CH_4 (13.12 vs. 15.04 g per pig per day) and 2 times higher for N_2O (1.02 vs. 0.52 g per pig per day). The emissions of CO_2 and H_2O were not significantly different according to the diet CP level.

fattening pig / crude protein / ammonia / nitrous oxide / methane

Résumé – Effets d'une réduction de la teneur en protéine brute de l'aliment sur les émissions de gaz associées à l'élevage de porcs charcutiers sur litières accumulées. Deux lots successifs de 32 porcs charcutiers par lot ont été chacun subdivisés en 2 groupes de 16 nourris soit avec un aliment à haute teneur en protéine brute (groupes HP) ou un aliment à faible teneur en protéine brute complémenté avec des acides aminés synthétiques (groupes FP). Les porcs ont été hébergés sur des litières accumulées de paille, dans des locaux distincts en fonction de l'aliment reçu. Une fois par mois, les émissions d'ammoniac (NH_3), de protoxyde d'azote (N_2O), de méthane (CH_4), de dioxyde de carbone (CO_2) et de vapeur d'eau (H_2O) ont été mesurées en continu durant 6 jours consécutifs.

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Les consommations moyennes d'azote (N) des porcs des groupes HP et FP ont été respectivement de 6,83 kg et 5,78 kg par animal, pour des poids moyens des porcs en début et fin d'engraissement de 26,6 et 111,4 kg. Les gains moyens quotidiens n'ont pas été significativement différents en fonction de la teneur en protéine brute des aliments. A la fin des périodes d'engraissement, les contenus en azote des litières accumulées des groupes HP et FP ont été respectivement de 1,84 kg et 1,56 kg par porc. Les émissions de gaz au sein du local hébergeant les groupes FP ont été, comparées à celles relevées dans le local hébergeant les groupes HP, inférieures de 26,1 % pour NH_3 (10,60 vs. 14,35 g par porc par jour), inférieures de 12,8 % pour CH_4 (13,12 vs. 15,04 g par porc par jour) et 2 fois plus élevées pour N_2O (1,02 vs. 0,52 g par porc par jour). Les émissions de CO_2 et d'H_2O n'ont pas été significativement différentes en fonction de la teneur en protéine brute des aliments.

porc charcutier / protéine brute / ammoniac / protoxyde d'azote / méthane

1. INTRODUCTION

Livestock productions contribute to pollutant gaseous emissions [3, 5]. There are ammonia (NH_3) emissions that contribute to soil and water acidifications [6, 18, 19, 22]. In addition, ammonia is well known as a toxic gas irritating the respiratory tract [19] at concentrations exceeding 15 p.p.m. There are also emissions of greenhouse gases like carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) [5, 13, 18]. These three gases do not have the same warming potential, which is for CH_4 and N_2O respectively 23 and 296 times that of CO_2 [9]. N_2O also contributes to the destruction of ozone. In France, it is estimated that 80% of NH_3-emissions, 76% of N_2O-emissions, 70% of CH_4-emissions and 14% of CO_2-emissions come from agriculture [3]. For CO_2 however, agriculture is also a consumer via plant photosynthesis.

The principal source of ammonia results from the degradation of urea by urease, an enzyme produced by micro-organisms that are commonly present in manure. N_2O is produced during nitrification – denitrification reactions in manure when optimal conditions are not met for a complete N-reduction to N_2. The transformation of organic material in manure is also accompanied by the release of carbon in the form of CO_2 and CH_4. These two gases also originate respectively from the respiratory tract and the enteric tract of pigs [13].

Many factors can influence NH_3-emissions. Among these, the N content of the manure is one of the more important. It is principally a function of diet crude protein (CP) content and animal capacity to use it. It has already been shown that lowering the CP content of diets balanced with industrial amino acids (AA) to maintain performance, decreased the manure N-content and in consequence the NH_3-emissions. Canh et al. [2] obtained a 30% reduction of manure-N (7.65 versus 11.13 g N·100 g^{-1} dry matter) and a 50% reduction of NH_3-emissions (4.79 versus 9.44 g per pig per day) by lowering CP content from 16.5 to 12.5% with pigs reared on partially slatted floor. Experiments conducted by Hayes et al. [8] on partially slatted floor showed 60% reduction of NH_3-emissions (3.11 versus 8.27 g per pig per day) by lowering the CP content from 20.9 to 13.2%. In metabolic cages, with diets containing 20% and 12% CP, Portejoie et al. [20] obtained 56% reduction of manure N-content and 76% reduction of NH_3-emissions. In all these experiments, essential AA levels were balanced to meet pig requirement and performances were maintained between animals fed with different N-content diet.

Almost all of the research on this topic was done in fattening units with pigs kept on slatted floors and manure handled in the form of slurry. Furthermore, the potential effects of lowering the CP content of the diet on other gaseous emissions, especially N_2O, were not studied simultaneously. The aims of this research were to study the effect of a CP reduction of the diet on manure-N content and on gaseous emissions when fattening pigs were kept on deep litter.

2. MATERIALS AND METHODS

2.1. Animals

Two successive batches of 32 Belgian Landrace-type pigs per batch were each divided into 2 homogenous groups of 16 pigs according to sex and weight, the HP-groups fed a high CP level diet and the LP-groups fed a low CP level diet.

During the fattening of the second batch in the HP-group, one loss occurred after 1 week and one loss 16 days before the end of the experiment but after the last series of gaseous emissions measurements. After the first loss, a same-weight pig was added to the group with the objective to keep the same floor area per pig in the 2 experimental rooms. However, since this pig never grew like the others its performance was not taken into account to calculate the mean daily weight gain of the group.

2.2. Experimental rooms

Pigs were housed in two identical rooms, one for the HP-groups and another one for the LP-groups. The rooms had a 30 m^2 horizontal area and a volume of 103 m^3. They were arranged to keep pigs in a pen on a straw deep litter with an available floor space of 1.35 m^2 per animal. The same amount of straw was used for each batch and each group, i.e. about 47 kg of straw per pig. Ventilation was provided using an exhaust fan in each room and the ventilation rates were adapted automatically to maintain a constant ambient temperature. The air inlet was an opening of 0.34 m^2 connected to a service corridor of the building.

2.3. Feeding

Pigs were fed ad libitum either a high CP level diet (HP-diet) or a low CP level diet (LP-diet). Each group received a grower meal for about 40 days, followed by a finishing meal. Table I shows composition and characteristics of each of the four meals. The grower and the finishing meals fed to the HP-groups contained respectively 18.1% and 17.5% CP and the two meals fed to the LP-groups 15.5% and 14.0% CP. The four diets contained 10000 I.U. vitamin A, 2000 I.U. vitamin D_3 and 80 mg vitamin E per kg. Meals were supplemented and balanced with AA to meet pig requirements in agreement with the recommendations of the National Research Council (NRC), both for the growing period (body weight 20–50 kg) and the finishing period (body weight 50–120 kg). Requirements were assumed both in terms of % of essential AA in the diets and on the ratios of other essential AA to lysine [12]. Table I shows that the essential AA contents of the HP-diet and LP-diet were very similar.

The feeding equipment was composed of two single-spaced feeders per pen with an integrated watering nipple. Meters (Wateau®, EEC approval No. B02 314.29) were used to determine the water consumption per pen. Feed and water intakes and feed conversion ratio were determined per group.

2.4. Measurement of gas emissions

The gas concentrations in the air of the experimental rooms and of the corridor providing fresh air were measured with a 1312 Photoacoustic Multi-gas Monitor (Innova Air Tech Instruments) equipped to measure NH_3, N_2O, CH_4, CO_2 and H_2O. During the raising of each batch, four measurement series of six consecutive days were conducted with a 1-month interval

Table I. Content and characteristics of the high crude protein level diets ('HP-diet') and the low crude protein level diets ('LP-diet').

	HP-diet		LP-diet	
	Grower meal	Finishing meal	Grower meal	Finishing meal
Composition (%)				
Humidity	12.5	11.9	12.2	12.3
Crude protein	18.1	17.5	15.5	14.0
Ether extract	4.7	3.8	4.1	2.8
Ash	5.3	4.7	5.2	4.1
Crude cellulose	5.0	6.0	4.8	5.2
Minerals				
Calcium	0.73	0.57	0.90	0.56
Phosphorus	0.45	0.37	0.44	0.34
Digestible amino acids				
Lysine	0.85	0.74	0.85	0.75
Methionine	0.27	0.23	0.28	0.25
Cystine	0.24	0.23	0.22	0.20
Tryptophan	0.17	0.16	0.15	0.13
Threonine	0.50	0.46	0.49	0.47
Raw materials (%)				
Cereals	62.2	66.5	77.1	81.1
Soybean meal	24.8	21.3	17.5	9.4
Palmist schilfers	/	4.0	/	2.5
Other components	12.9	8.1	4.9	6.4
Supplemented amino acids				
L-Lysine HCL	0.11	0.07	0.37	0.40
L-Threonine	/	/	0.09	0.15
DL-Methionine	0.06	0.02	0.09	0.08
L-Tryptophan	/	/	0.01	0.01
Net energy ($kcal{\cdot}kg^{-1}$)	2230	2190	2230	2190

between the series. The first series began 3 weeks after the arrival of the pigs. The sampling of the air in the rooms was performed above the exhaust fan, and that of the air of the corridor at about 1 m from the air inlets. The air was analysed every hour.

The ventilation rates were continuously measured by an electronic device (Ex-avent, Fancom®) and the hourly means were recorded.

Emissions (E), expressed as $mg{\cdot}h^{-1}$ were calculated according to the following formula:

$$E = D \times (C_i - C_e),$$

with D, the hourly mass flow (kg air per h); C_i and C_e, respectively the concentrations of gas in the air of the room and corridor ($mg{\cdot}kg^{-1}$ dry air).

Hourly data were used for the statistical analyses.

The cumulative emission of nitrogen (N_c) in the form of NH_3 and N_2O was determined using the relation:

$$N_c = (14/17) \times NH_3\text{-emission} + (28/44) \times N_2O\text{-emission}.$$

N_2-N emissions from deep litters were estimated as:

$$N_2 - N = (\text{litter-N} + \text{feed-N}) - (\text{retained-N} + \text{deep litter-N} + N_c\text{-N}).$$

The N retained in animal products (N_r) was estimated by the following equation established by CORPEN [4]:

$$N_r(\text{kg per pig}) = e^{(-0.9385-0.0145\times LY)} \times \left(0.915\ WG^{1.009}\right)^{(0.7364+0.0044\times LY)} / 6.25,$$

LY is the lean yield of carcass (%) and WG the weight gain (kg).

The deep-litter nitrogen content was calculated knowing the amount of deep litter produced and its nitrogen content determined by the Kjeldahl method.

2.5. Statistical analyses

For each batch and each gas, the differences of the emissions with regards to the diet CP level (HP-diet or LP-diet) were tested in the form of a mixed model for repeated measurements with two criteria (SAS® software, proc MIXED) [21]: diet CP content (1 d.f.), period of measurements (3 d.f.) and interaction between diet CP content and period of measurement, four replicates per diet (periods) and 144 (24 h × 6 days) successive measurements per replicate. Residuals were assumed normally distributed, with a null expectation. Correlation between successive measurements was modelled using a type 1-autoregressive structure.

The combined data obtained with the two batches were treated in the same way as for the previous analyses.

3. RESUTS

3.1. Climatic characteristics of the rooms

The mean air temperatures were 21.2 °C (s.d. 0.29) in the room with the HP-groups, 21.8 °C (s.d. 0.39) in the room with the LP-groups and 17.9 °C (s.d. 0.99) in the corridor providing fresh air (s.d. between batches). The mean ventilation rates were 1319 (s.d. 265) and 1529 $m^3 \cdot h^{-1}$ (s.d. 245) for the two rooms respectively (s.d. between batches).

3.2. Performance of the animals

The average initial body-weights for the HP-group and the LP-group were respectively 24.7 ± 3.2 kg and 24.6 ± 3.5 kg for the first batch and 28.4 ± 4.0 and 28.8 ± 4.2 kg for the second batch. Pigs fed the HP-diet eat on average 63.3 kg per pig of the grower meal (18.1% CP) and 178.9 kg per pig of the finishing meal (17.5% CP) and pigs fed the LP-diet eat 63.3 kg per pig (15.5% CP) and 188.3 kg per pig (14.0% CP) of the two meals respectively. The mean CP contents of the diets fed to the two groups were 17.64% and 14.37% and the mean N intakes of the HP-groups and the LP-groups were thus 6.83 kg and 5.78 kg per pig respectively, i.e. a difference of 15.4%.

Table II shows the performance of the animals. Feed conversion ratios were corrected with coefficients of standardization for fattening pigs from 30 to 115 kg [1]. There was no significant difference between the daily weight gains of the pigs fed the HP-diet and those fed the LP-diet.

3.3. Characteristics of the deep litters

Table III shows the compositions of the deep litters for the two batches at the end

Table II. Performance of the pigs (mean ± s.d.) fed with a high crude protein level diet ('HP-group') or a low crude protein level diet ('LP-group').

	Batch 1		Batch 2	
	HP-group	LP-group	HP-group	LP-group
Number of pigs	16	16	16	16
Initial weight (kg)	24.7 ± 3.2	24.6 ± 3.5	28.4 ± 4.0	28.8 ± 4.2
Final weight (kg)	106.3 ± 10.3	108.3 ± 10.9	111.9 ± 12.9	118.9 ± 10.8
Lean yield (%)	59.8 ± 5.0	58.3 ± 2.7	60.2 ± 5.2	59.1 ± 3.0
Losses (number)	0	0	2	0
Duration (days)	118	118	118	118
Daily weight gain (g)	692 ± 84	710 ± 88	708 ± 89	764 ± 74
Daily feed intake (kg per day)	2.0	2.1	2.2	2.2
Feed conversion ratio (kg/kg)	2.93	2.95	3.10	2.92
Feed conversion ratio standardized (kg/kg)*	3.07	3.07	3.14	2.9
Price (€ per kg BW)	0.91 ± 0.10	0.87 ± 0.15	1.14 ± 0.12	1.15 ± 0.08
Water drunk (L)				
Per pig per day	4.26	4.26	4.51	4.44
Per kg of food	2.10	2.04	2.15	2.05

* According to the coefficients of standardization established by Aubry et al. [1] for fattening pigs from 30 to 115 kg.

Table III. Composition of straw deep litters at the end of the fattening of each batch of pigs fed with a high crude protein level diet ('HP-group') or a low crude protein level diet ('LP-group').

		Amount removed (kg per pig)	DM ($g \cdot kg^{-1}$)	pH	C/N	Kjeldahl-N ($g \cdot kg^{-1}$ DM)	NH_4^+-N ($g \cdot kg^{-1}$ N)	K_2O ($g \cdot kg^{-1}$DM)	P_2O_5 ($g \cdot kg^{-1}$ DM)
Batch 1	HP-group	205	340	8.12	15.94	30.0	366	34.1	9.2
	LP-group	146	360	8.51	14.08	34.1	245	30.6	13.5
Batch 2	HP-group	165	287	8.78	14.05	33.0	302	35.6	10.1
	LP-group	153	383	8.26	20.74	22.3	176	32.8	13.2

DM: dry matter; C/N: carbon-nitrogen ratio.

of the fattening periods. The amounts of straw manure produced by the HP-groups and the LP-groups were respectively 185 and 149 kg per pig. The N-contents of the litters were 1.83 kg per pig for the HP-groups and 1.55 kg per pig for the LP-groups with a NH_4^+-N content of 334 and 210 $g \cdot kg^{-1}$ N, respectively.

3.4. Gas emissions

The mean gas emissions for each batch are presented in Table IV. Figure 1 shows the evolution of the emissions from the beginning to the end of each fattening period. Over the 2 fattening periods altogether, gaseous emissions in the room where pigs

Table IV. Gas emissions (per pig and per day) during the raising of two batches of fattening pigs on a straw deep litter and fed with a high crude protein level diet ('HP-group') or a low crude protein level diet ('LP-group').

		HP-group	LP-group	s.e.	Significance
Batch 1	NH_3 (g)	17.14	13.46	0.823	*
	N_2O (g)	0.41	0.58	0.010	**
	N_c (g)	14.37	11.45	0.679	NS
	CH_4 (g)	13.94	10.93	0.253	**
	CO_2 (kg)	1.98	2.16	0.036	*
	H_2O (kg)	3.67	3.83	0.098	NS
Batch 2	NH_3 (g)	11.56	7.74	0.585	*
	N_2O (g)	0.63	1.45	0.153	*
	N_c (g)	9.91	7.30	0.487	*
	CH_4 (g)	16.14	15.32	0.209	NS
	CO_2 (kg)	1.85	1.80	0.029	NS
	H_2O (kg)	3.19	2.93	0.077	NS
Batches 1 and 2	NH_3 (g)	14.35	10.60	0.650	**
	N_2O (g)	0.52	1.02	0.113	*
	N_c (g)	12.14	9.37	0.520	**
	CH_4 (g)	15.04	13.12	0.210	***
	CO_2 (kg)	1.92	1.98	0.029	NS
	H_2O (kg)	3.43	3.38	0.080	NS

s.e.: Standard error of least squares means; significance: NS: $P > 0.05$; *: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$; N_c: cumulative emissions of nitrogen in the form of ammonia and nitrous oxide (NH_3-N + N_2O-N).

were fed the LP-diet, compared to pigs fed the HP-diet, were 26.1% lower for NH_3 ($P < 0.01$), 12.8% lower for CH_4 ($P < 0.001$) and 2.0 times higher for N_2O ($P < 0.05$). The emissions of CO_2 and H_2O were not significantly different according to the diet CP level. Whatever the diet and the batch, NH_3, CH_4, CO_2 and H_2O emissions increased regularly during the fattening periods. On average, the NH_3 emissions were 4.2 times higher at the end compared with the beginning, those of methane, 4.7 times, those of CO_2 and H_2O, 2.3 times.

3.5. Nitrogen balance

Over the two fattening periods altogether, the feed-N supply was 6.83 kg per pig with the HP-diet and 5.78 kg per pig with the LP-diet. From these quantities, the proportions retained by the pigs were respectively 30.2% (2.06 kg) with the HP-diet and 37.4% (2.16 kg) with the LP-diet. So, the amounts of feed-N excreted were 4.77 and 3.62 kg per pig respectively.

Table V presents the nitrogen excreted by pigs (wastes-N). The manure-N represents the quantity of nitrogen in the litter apart from the straw-N supply, which was of 0.29 kg per pig. The manure N-content of the deep litter was on average 1.54 kg per pig when they were fed the HP-diet and 1.26 kg per pig with the LP-diet. However, the ratios manure-N/feed-N were similar with the two diets (22.6 and 21.9%). Whatever the diet, about 66% of the N excreted by the pigs was recovered in the gas form with 29% in the form of NH_3, 1% of N_2O and 36% in the form of N_2.

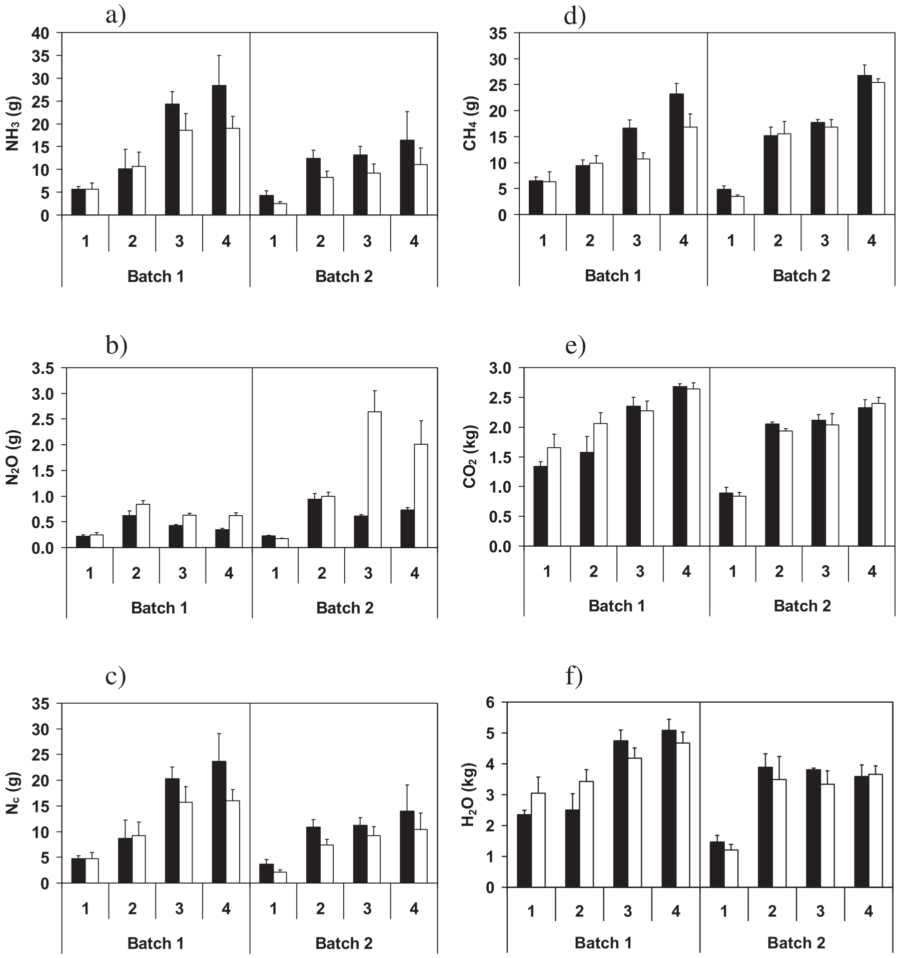

Figure 1. Evolution of gas emissions of ammonia (a), nitrous oxide (b), cumulative nitrogen (Nc) in the form of ammonia and nitrous oxide (c), methane (d), carbon dioxide (e) and water vapor (f), expressed per pig and per day, for four series of measurements (mean ± s.d.), at one month interval, with 6 days of measurements per series during the raising of two batches of fattening pigs on straw deep litter and fed with a high crude protein level diet (closed bars) or a low crude protein level diet (open bars).

4. DISCUSSION

The mean daily weight gain of pigs was no significantly different between the HP-diet and the AA supplemented LP-diet. This was in agreement with several authors when comparing diets with high or low protein contents but balanced in essential AA [2, 8, 10, 11, 16, 20, 24–26].

The estimated nitrogen (N_r) was 23.6% higher for the LP-groups compared with the HP-groups (37.4% versus 30.2%), expressed in percentage of feed-N. While the mean CP content of the two diets were 17.64% and 14.37%, the N_r increased

Table V. N excreted by pigs (wastes-N) during the fattening period for each batch, with regards to diet fed (‘HP-group’ for pigs fed with a high crude protein level diet and ‘LP-group’ for the pigs fed with a low crude protein level diet), expressed in kg per pig and in percentage of wastes-N.

	Batch 1				Batch 2			
	kg per pig		% of wastes-N		kg per pig		% of wastes-N	
	HP-group	LP-group	HP-group	LP-group	HP-group	LP-group	HP-group	LP-group
Manure-N	1.81	1.51	38.4	42.0	1.28	1.01	26.5	27.8
NH_3-N	1.67	1.31	35.4	36.3	1.17	0.78	24.3	21.5
N_2O-N	0.03	0.04	0.6	1.2	0.05	0.11	1.0	3.1
N_2-N	1.21	0.74	25.6	20.5	2.33	1.73	48.2	47.7
Total excreted-N	4.71	3.60	100	100	4.83	3.64	100	100

of +7.2% for each percentage reduction of diet CP level. Such an improvement has been observed by several authors with values between +1.7% and +5.8% for each percentage reduction of diet CP level [2, 16, 20, 25, 26]. However, Otto et al. [17] mentioned that reducing dietary CP below a certain concentration may impair gut functions and as such affect whole body N retention.

As expected, the total nitrogen excreted per pig was 24.1% lower with the LP-diet compared with the HP-diet. This N-excreted decrease amounted to 7.4% per each percentage reduction of diet CP content. This is on a scale of results from other authors [2, 16, 17, 20, 25, 26] according to whom N-excreted decreased by about 8% per each percentage reduction of diet CP content.

The N-contents of manure were, on average for two batches, 1.54 kg per pig with the HP-diet and 1.26 kg with the LP-diet. Both values were in accordance with results from a previous experiment (1.47 kg per pig) [14] and confirm that the N content of deep litter is much lower than the N content of slurry which is about 2.7 to 3.25 kg per pig [4].

The NH_3-emissions related to the HP-diet, on average 14.4 g per pig per day or 29.8% of wastes-N, were in agreement with a previous experiment with the same housing conditions and a similar diet, i.e. 13.61 g per pig per day or 27.6% of wastes-N [14]. Feeding the LP-diet allowed to reduce the emissions of 3.75 g per pig per day, i.e. of 26.1% or around 8% per each percentage reduction of diet CP content. Studies about NH_3-emissions from slurry showed reductions varying from 8.1 to 13.3% per diet CP percentage unit decrease [2, 8, 17, 20].

The nitrous oxide emissions were on average 0.52 and 1.02 g per pig per day for the HP-groups and the LP-groups respectively, representing 0.8% and 2.1% of total N-excreted. N_2O emissions from deep litters are very variable. Hassouna et al. [7] estimated between 4 and 12% the N_2O-emissions from straw-based deep litters with less than 2 m^2 floor space per pig. But a negligible value (0.15%) was observed by Nicks et al. [14]. Obviously other factors than the CP content of the diets are more important in regards with N_2O emissions, like the oxygenation level of the litter and the surface of the dunging area.

The total gaseous nitrogen emissions represented 68% and 65% of the total N excreted with the ‘HP-group’ and the ‘LP-group’ respectively. These high levels, compared with N-emissions from slurry estimated at 25% [4], were in agreement with other data [4, 14] and are in relation with the N_2-emissions from deep-litters.

CH_4-emissions were 15.04 and 13.12 g per pig per day with the 'HP-group' and 'LP-group', respectively. In an experiment with the fattening of three successive batches on deep litter without changing the litter between batches, the mean CH_4-emissions observed during the stay of the three batches were respectively 3.25, 6.25 and 12.67 g per pig per day [14]. These data show that the variation observed in regards with the CP content is small compared with other sources of variation as the oxygenation level of the litter, the temperature of the litter and the surface of the dunging area.

CO_2-emissions were not significantly different between the 2 groups with a mean of 1.95 kg per pig per day. Since the CO_2 produced with the respiration of the animals is estimated at about 1.56 kg per pig per day [23], the contribution of the deep litter to the total emission is relatively low.

Water vapour emissions were not significantly different with regards to the diet CP content, with an average of 3.4 kg per pig per day. This production level was higher than that observed when pigs are kept on slatted floors for the high temperatures in the litter, above 30 °C [15], favouring water evaporation.

In conclusion, when pigs are kept on straw-based deep litter, the decrease of the CP content of the diet, gives the same advantages as those observed when pigs are kept on slatted floors with manure handled in the form of slurry, i.e. a decrease of the N content of the manure and of NH_3-emissions. Other differences were observed in this study, a decrease in CH_4-emissions and an increase in N_2O emissions but these differences are small compared with those that could be attributed to other factors.

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