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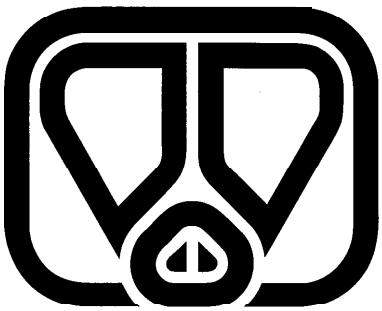
Influence of benzoic acid in the diet on performance and urine pH of growing/ finishing pigs



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SUMMARY

Ammonia emission from pig houses can considerably be reduced by a combination of housing and feeding measures. Research at the Experimental Farm for Pig Husbandry at Raalte showed that adding an acidic mixture containing 70% of benzoic acid reduced ammonia emission to a level of 1.22 kg ammonia per pig place per year. Up to now benzoic acid has not been allowed yet in pig feed. As part of the registration procedure of benzoic acid, an experiment was conducted to examine the effect of benzoic acid in the diet on the performance and health of growing/finishing pigs and on the pH of urine and slurry.

Three experimental treatments were compared comprising in total 60 individually housed growing/finishing pigs:

1 *0% of benzoic acid*: *sows* and barrows were fed a starter diet and a growing/finishing diet with 0% of benzoic acid;
2 1% *of benzoic acid*: *sows* and barrows were fed a starter diet and a growing/finishing diet with 1% of benzoic acid;
3 2% *of benzoic acid*: *sows* and barrows were fed a starter diet and a growing/finishing diet with 2% of benzoic acid.

All pigs were fed twice a day. Water was supplied four times a day.

The most important results and conclusions are:

- Pigs fed diets containing 1% of benzoic acid grew faster and had a better feed conversion ratio than pigs fed diets with 0% or 2% of benzoic acid. The growth rate was 40 g/day higher and the feed conversion ratio was 0.1 better. Pigs fed diets containing 0% and 2% of benzoic acid showed the same performance.
- Pigs fed diets containing 1% or 2% of benzoic acid had less diarrhoea problems than pigs fed diets with 0% of benzoic acid.
- Gross margin per pig place per year was highest when pigs were fed diets containing 1% of benzoic acid. The difference between pigs fed diets with 0% and 2% of benzoic acid was Dfl 1 0.- and Dfl 14.80 respectively.
- The pH of the urine and slurry was influenced by the percentage of benzoic acid in the diet: the higher the percentage of benzoic acid in the diet, the lower the pH of the urine (7.52, 6.45 and 5.59 respectively) and slurry (8.18, 7.76 and 7.26 respectively).
- When the pH of the slurry is lower, there is more nitrogen in the form of ammonium nitrogen in the slurry.

1 INTRODUCTION

Ammonia emission can considerably be reduced by housing measures, feeding measures or by a combination of both. The feeding measures have received a lot of attention lately, since the emission problem is tackled at the source and since the cost of feeding measures is usually lower than the fairly far-reaching housing measures. Early 1997 a research project was finished, in which both feèding (acidic mixture) and housing (convex floor, narrow slurry channel at the front, wide slurry channel at the back, manure split, metal tribar slats) measures were studied to reduce ammonia emission (Den Brok et al., 1999). One percent of acidic mixture was added to starter feed and 2% to growing/finishing feed. The mixture contained 70% of benzoic acid, by which the pH of the urine was clearly reduced, and hence ammonia emission was reduced by 40%. Ammonia emission (together with improved pen design) dropped below the Green Label threshold level of 1.5 kg ammonia per pig place per year. Feed conversion was significantly better when acidic mixture was added to the diet. Benzoic acid is likely to be the component in the mixture that is responsible for this reduction in ammonia emission. This was confirmed by research by Canh et al. (1996).

Up to now benzoic acid has not been approved by the Product Board of Animal Feed yet to be added to pig feed, which means that benzoic acid cannot be acknowledged as an emission-poor system by the Foundation of Green Label. Until benzoic acid is approved as an additive to growing/finishing feed, a record should be made first for the Product Board of Animal Feed with data on the effect of benzoic acid in feed on performance and animal health. To this end, research was done at the Experimental Farm for Pig Husbandry at Raalte on the effect of different concentrations of benzoic acid in feed on performance, slaughter quality, health, urinary pH (indicator of ammonia emission) and slurry composition of individually housed growing/finishing pigs. The Product Board has granted an exemption for this experiment, which was conducted in cooperation with DSM Special Products.

2 MATERIAL AND METHODS

2.1 Experimental animals and size of experiment

The study was carried out at the Experimental Farm for Pig Husbandry "North- and East-Netherlands" at Raalte with barrows and sows of crossbred Gy_s-boar x (Gy, x NL)-sow. At an average weight of 24.3 kg the piglets entered the experiment, all at the same day. At an average liveweight of 108.9 kg the pigs were delivered to the slaughterhouse, all at the same time. The growing/finishing pigs were individually housed. The study comprised one fattening period with 60 animals from February to May 1998.

2.2 Experimental treatments

Three experimental treatments were compared:

1 0% of *benzoic acid*: sows and barrows were fed a starter diet and a growing/finishing diet with 0% of benzoic acid;
2 1% *of benzoic acid*: sows and barrows were fed a starter diet and a growing/finishing diet with 1% of benzoic acid;
3 2% *of benzoic acid*: sows and barrows were fed a starter diet and a growing/finishing diet with 2% of benzoic acid.

The ingredients and the calculated chemical composition of the feeds are presented in appendix 1. Benzoic acid was not calculated nutritionally. Starter feed with 1% of benzoic acid was not prepared separately, but obtained by mixing starter feed without benzoic acid and with 2% at a 1 : 1 ratio.

2.3 Experimental design

In this experiment block distribution has been applied. The animals in the pens within one block were similar as much as possible as to crossbreed, weight and age. Each block had three barrows or three sows. Within one block the animals were assigned to one particular treatment. The twenty blocks were randomly divided among the compartments.

2.4 Feed and drinking water

The barrows and sows were fed twice a day during the entire fattening period. The feeding was done by hand and at different feeding schemes (appendix 2). The first four weeks after starting all animals received starter feed. In week 5 the feed was gradually changed to growing/finishing feed, which the pigs received until delivering. All feeds were prepared at the same time from the same batches of ingredients.
The pigs received limited drinking water via a nipple in the trough. The water dose was operated by a timer. The animals were able to drink from 7.30 to 8.15 am (after feeding), from noon to a quarter past 12, from 3 to 3.45 pm (after feeding) and from 9 to 9.30 pm.

2.5 Housing and climate

The experiment was carried out in a 60-pen compartment for individually housed growing/finishing pigs. The pens were 1 m wide and 2 m long, with a 1 m long solid floor and with a tribar-slatted grid of 1 m. Underneath each pen was a separate slurry pit (0.91 m wide, 1.35 m long and 0.40 m deep), provided with a drain plug. The grid at the back of the pen was a swing grid, so that slurry samples could be taken in an easy way.
Fresh air came directly from outside through valves in the side wall. Removal of air took place through two ventilation shafts. On the starting day the compartment temperature was set at 24°C, dropping to 22°C 15 days after starting and to 20°C 30 days after starting. From 30 days after starting until the end of the fattening period the compartment temperature was set at 19°C. The minimum and maximum ventilation settings were 10 and 100 m^3 respectively per pig per hour. The range varied from 3 - 5°C, depending on the outside temperature.

2.6 Observations

2.6.1 Feed samples

Before starting the experiment, samples

were taken from the starter feeds with 0% and 2% benzoic acid and from the three growing/finishing feeds to determine the concentration of benzoic acid. During the experiment collective samples were taken from all feeds. These collective samples were made by collecting a small amount of feed (100 g) each week. These six samples (one of each feed and one of the mixture of starter feed without benzoic acid and with 2% of benzoic acid) were analysed as to contents of dry matter, crude protein, crude fat, crude fibre, ash and calcium. Moreover, pH and buffer capacity were determined. Feed pH was determined by dissolving 20 g of feed in 100 ml of water, and to leave it for 30 minutes. After that the pH was measured. The buffer capacity was determined by incubating 5 g of feed with 50 ml of 0.1 molar HCl at 37°C for 1 hour. The acid was partly absorbed by the feed. Excess acid was determined by backtitration with 0.1 molar NaOH to a pH of 4. From this mixture, the amount of absorbed acid was determined.

2.6.2 Performance

All pigs were weighed at the start, 26 days after starting and at delivery. The amount of feed supplied was recorded at in-between weighing, at disposal and delivery. On the basis of these data the following production characteristics were calculated: growth per day, feed intake per day and feed conversion. The following data were collected on the pigs slaughtered: slaughter weight, dressing percentage, meat percentage HGP, fat layer, type judgment and lung and liver examinations. Occurrence of diseases and/or lesions and their treatments were recorded for each animal. If the pig was disposed of, date, weight and reason were recorded.

2.6.3 Urine and slurty

Each three weeks (once during the starter feed period) urine was collected in tins on a long stick of as many pigs as possible (approximately 13 pigs per treatment) during one day (between 8 and 12 am and

Individually housed growing/finishing pigs at the Experimental Farm at Raalte

between 1 and 2 pm). The urinary pH was measured immediately. If more samples could be taken from one pig, pH was an average of the total amount of the day concerned. The pH of the top layer of the slurry was measured for 5 pigs per treatment each week. Slurry pH was measured of the same animals over and over again. Slurry in the pits did not prove to be mixed homogeneously. The thick slurry (mainly faeces) was mainly at the front of the pit, while thin slurry (especially urine) was distributed over the entire slurry pit. That is why pH was measured at two places in the slurry pit. In the analysis these values are average ones. After finishing the fattening period the slurry was homogenized in all pens. Then the level of the slurry was measured and a slurry sample was taken. The pH of the homogeneous slurry was measured on the spot. The samples were analysed at the IMAG-DL0 Environmental Laboratory at Wageningen as to pH, ash, total nitrogen, ammonium nitrogen, total phosphorus and dry matter.

2.7 Data processing

The parameters growth, feed intake, feed conversion, meat percentage, fat layer, dressing percentage (= slaughter weight/ end weight weighed x 100%) and gross margin per growing/finishing pig delivered were analysed by means of variance analysis (SAS, 1990) to determine whether differences were coincidental or not. Disposed pigs were not taken into account. The model, in which the individual animal is the smallest unit, was as follows:

$$y = \mu + \text{block} + \text{treatment} + \text{rest}.$$

By means of the chi-square test it was studied whether there were differences between the treatments as to number of disposed pigs, number of veterinary treatments and the number of pigs with lung and/or liver abnormalities. The number of pigs per type class (AA, A, B/C) was analysed by using the threshold model of McCullagh (Oude Voshaar, 1994).
Data on urinary pH, slurry pH and composition were also analysed by variance analysis (SAS, 1990) according to the following model:

$$y = \mu + \text{number of days after starting} + \text{sex} + \text{treatment} + \text{sex} * \text{treatment} + \text{rest}.$$

3 RESULTS

3.1 Composition of experimental feeds

The results of the chemical analyses of the experimental feeds are presented in table 1.

From table 1 can be seen that the planned and actual amounts of benzoic acid in the different feeds were fairly similar. The crude protein contents analysed were somewhat higher than those calculated in advance in all feeds (appendix 1). The crude fat contents in the starter feed and growing/finishing feed without benzoic acid analysed and previously calculated were almost the same. In the feeds with benzoic acid, the crude fat contents analysed were higher than those calculated earlier. This is a result of the analysis method applied for determining the crude fat content, with which benzoic acid is partly or entirely analysed as crude fat (Den Brok et al., 1999). In the starter feeds, the calcium analysed was 1.8 to 2.3 g/kg higher than calculated earlier. In the growing/finishing feeds the calcium contents analysed

Table 1: Chemical composition of the experimental feeds (g/kg) analysed

	starter feed			growing/finishing feed		
	0%	1%	2%	0%	1%	2%
benzoic acid	< 1	n.d.[1]	19	< 1	10	20
dry matter	879	883	881	886	888	891
crude protein	184	180	179	163	165	161
crude fat	40	46	50	52	60	63
crude fi bre	46	42	40	67	67	68
ash	63	63	60	59	57	58
calcium	9.3	9.0	8.8	5.0	5.2	4.8
pH	5.6	5.2	5.0	5.8	5.3	5.0
buffer capacity (mEq/kg)	555	535	469	415	398	359

[1]n.d. = not determined

Table 2: Fattening results of growing/finishing pigs fed with feed containing 0%, 1% or 2% of benzoic acid from start to finish

	0% benz. acid	1% benz. acid	2% benz. acid	SEM[1]	significance[2]
number of animals	20	19	20		
weight at start (kg)	24.2	24.3	24.3		
end weight (kg)	107.3	111.6	107.7		
days	97	97	97		
growth (g/day)	857[a]	898[b]	858[a]	10.4	*
feed intake (kg/day)	2.23[a]	2.26[b]	2.24[ab]	0.010	*
feed conversion	2.61[a]	2.52[b]	2.62[a]	0.029	*

[1] SEM = pooled standard error of the mean (is indication of the accuracy of the estimate of the variable measured)

[2] significance: * = ($p \leq 0.05$)

[a,b] averages with a different letter within a row are different

and previously calculated are almost the same. The buffer capacity in the starter feed was higher than in the growing/finishing feed. This buffer capacity decreases with an increasing percentage of benzoic acid in the feed.

3.2 Fattening results and slaughter quality

Table 2 shows the fattening results from start to finish per treatment. End weight is live end weight.
From table 2 can be seen that the growing/finishing pigs that received 1% of benzoic acid in their feed, clearly grew faster, had an improved feed conversion and feed intake than those that did not receive any or 2% of benzoic acid. Between the pigs that received 0% or 2% of benzoic acid in their feed no differences could be found in performance.

In table 3 the fattening results from start to a weight of approximately 43 kg are presented.

Table 3 shows that from start to a weight of approximately 43 kg there are no significant differences in fattening results among pigs that received different amounts of benzoic acid.

In table 4 the fattening results from approximately 43 kg to delivery are presented.

From table 4 can be seen that the growing/finishing pigs that received 1% of benzoic acid in the feed clearly grew faster, had an

Table 3: Fattening results of growing/finishing pigs that received 0%, 1% or 2% of benzoic acid in their feed from starting to a weight of approximately 43 kg

	0% benz. acid	1% benz.acid	2% benz. acid	SEM[1]	significance[2]
number of animals	20	19	20		
weight at start (kg)	24.2	24.3	24.3		
in-between weight (kg)	42.7	43.1	42.5		
growth (g/day)	712	724	699	10.8	n.s.
feed intake (kg/day)	1.42	1.43	1.42	0.003	n.s.
feed conversion	2.01	1.98	2.05	0.030	n.s.

[1] SEM = pooled standard error of the mean (is indication of the accuracy of the estimate of the variable measured)
[2] significance: n.s. = not significant

Table 4: Fattening results of growing/finishing pigs that received 0%, 1% or 2% of benzoic acid in their feed from a weight of approximately 43 kg to delivery

	0% benz. acid	1% benz. acid	2% benz. acid	SEM[1]	significance[2]
number of animals	20	19	20		
in-between weight (kg)	42.7	43.1	42.5		
end weight (kg)	107.3	111.6	107.7		
growth (g/day)	910[a]	962[b]	917[a]	12.7	*
feed intake (kg/day)	2.52[a]	2.57[b]	2.55[ab]	0.013	*
feed conversion	2.78[a]	2.67[b]	2.78[a]	0.035	*

[1] SEM = pooled standard error of the mean (is indication of the accuracy of the estimate of the variable measured)
[2] significance: * = ($p \leq 0.05$)
[a,b] averages with a different letter within a row are different

improved feed conversion and had a slightly better feed intake than those that received 0% or 2% of benzoic acid in the feed. Among the pigs that received 0% or 2% of benzoic acid in the feed, no differences could be found in performance.

Table 5 presents the results of the slaughter quality of the pigs slaughtered.

Table 5 shows that there are no differences as to dressing percentage, meat percentage, fat layer and type judgment among pigs that received different amounts of benzoic acid in their feed.

3.3 Disposal and health

Table 6 presents the number of pigs disposed of and those that have had a veterinary treatment. Also the reasons for treatment are shown.

From table 6 can be seen that there is not any difference in number of pigs disposed of among the three experimental treatments. There is a difference, however, in the number of pigs treated for health problems. More pigs from the non-benzoic acid group were treated for diarrhoea than from the other groups. As to results of lung and liver exami-

Table 5: Slaughter quality of growing/finishing pigs that received 0%, 1% or 2% of benzoic acid in the feed

	0% benz. acid	1% benz. acid	2% benz. acid	SEM[1]	significance[2]
number of animals	20	19	20		
slaughter weight (kg)	84.0	88.2	85.1		
dressing percentage	78.6	78.6	79.1	0.44	n.s.
meat percentage	54.1	54.7	54.4	0.48	n.s.
fat layer (mm)	18.4	17.4	17.7	0.63	n.s.
% pigs with AA type	15.0	15.8	5.0		
% pigs with A type	75.0	73.7	85.0		n.s.
% pigs with B type	10.0	10.5	10.0		

[1] SEM = pooled standard error of the mean (is indication of the accuracy of the estimate of the variable measured)
[2] significance: n.s. = not significant

Table 6: Disposal and veterinaty treatments of growing/finishing pigs that received 0%, 1% or 2% of benzoic acid in their feed

	0% benz. acid	1% benz. acid	2% benz. acid	significance[1]
number of pigs started with	20	20	20	
number of pigs disposed	0	1	0	n.s.
number of pigs treated	10[a]	1[b]	3[b]	**
reason for treatment:				
- diarrhoea	7[a]	1[b]	2[ab]	*
- lung disorder	3	0	0	
- other	0	0	1	

[1] significance: n.s. = not significant; * = (p 50.05); ** = ($p \leq 0.01$)
[a,b] averages with a different letter within a row are different

nations, no differences could be found among pigs that received different amounts of benzoic acid in their feed. Of the 59 pigs that were examined, 56 did not have affected lungs or liver.

3.4 Urinaty pH, slurty pH and composition of the slurty

Table 7 presents the average urinary pH of the three experimental treatments.

From table 7 can be seen that urinary pH is significantly influenced by percentage of benzoic acid in feed. Moreover, the number of days after starting appears to have a clear influence on urinary pH. The pH was higher at the beginning of the fattening period (the period with starter feed) than in the remainder of this period. In the final stage the urinary pH consolidated in all three treatments. The course of the urinary pH during the fattening period is presented in figure 1 for the different treatments.

Table 8 presents the average slurry pH determined each week during the fattening period. The first pH measurement was done on day 26 after start. Due to the low level of slurry in the pits it was not possible to determine a reliable pH at an earlier stage.

From table 8 can be seen that there is a significant effect of the amount of benzoic acid on slurry pH. Due to the buffering capacity of organic matter in the faeces, the pH values were higher than of the urine (table 7). Also the differences in pH of the slurry

Table 7: Urinaty pH of growing/finishing pigs that received 0%, 1% or 2% of benzoic acid in the feed

	0% benz. acid	1% benz. acid	2% benz. acid	SEM[1]	significance[2]
number of samples	63	66	69		
urinary pH	7.52[a]	6.45[b]	5.59[c]	0.071	***

1 SEM = pooled standard error of the mean (is indication of the accuracy of the estimate of the variable measured)

2 significance: *** = (p **50.001)**

a,b,c averages with a different letter within a row are different

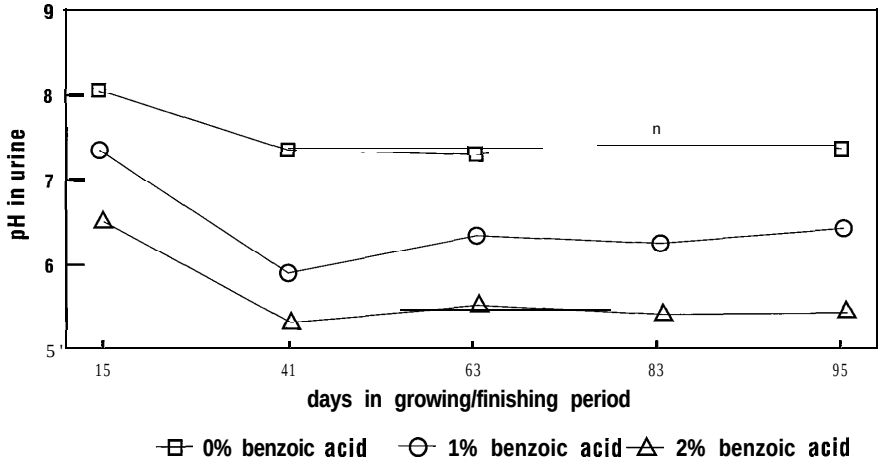

Figure 1: Course of the urinary pH of growing/finishing pigs that received 0%, 1% or 2% of benzoic acid in the feed during the fattening period

among the treatments proved to be smaller than the differences in urinary pH. Moreover, pH of the slurry is influenced by the number of days after starting ($p < 0.01$). Figure 2 presents the course of slurry pH during the fattening period for the different treatments.

Figure 2 shows that the slurry pH of pigs receiving 1% or 2% benzoic acid in their feed decreased at the beginning of the fattening period, but consolidated after that. Slurry pH of pigs receiving 0% benzoic acid in feed showed a decreasing course over the entire period. At the end of the fattening period the pH of the slurry of pigs receiving 0% benzoic acid in feed was almost equal to that of the pigs receiving 1%.

Table 9 presents the composition of the slurry as measured after the pigs having been delivered. They concern averages of samples taken from the homogenized slurry. The slurry pH was determined immediately after homogenizing and in the laboratory. In the 1% benzoic acid group two pens were not taken into account, due to a leaking slurry pit in one pen and because the pig was disposed of for another.

From table 9 can be seen that there are no differences in slurry pH among the pigs that received 0% or 1% of benzoic acid. The slurry pH of pigs receiving 2% benzoic acid in feed was considerably lower. This effect was already apparent in figure 2 at the end

Table 8: Slurty pH of growing/finishing pigs that received 0%, 1% or 2% of benzoic acid in the feed

	0% benz. acid	1% benz. acid	2% benz. acid	SEM[1]	significance[2]
number of observations	55	55	55		
slurry pH	8.18[a]	7.76[b]	7.26[c]	0.060	***

1 SEM = pooled standard error of the mean (is indication of the accuracy of the estimate of the variable measured)

2 significance: *** = ($p \leq 0.001$)

[a,b,c] averages with a different letter within a row are different

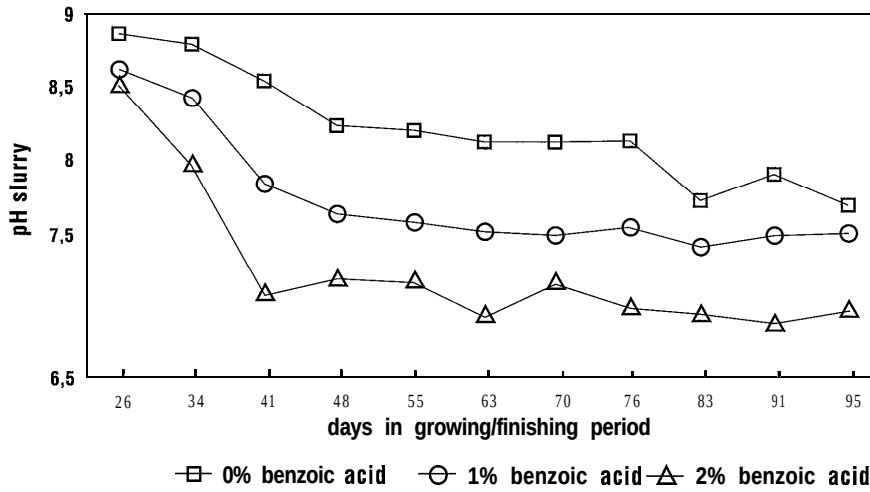

Figure 2: Course of the slurty pH of growing/finishing pigs that received 0%, 1% or 2% of benzoic acid in the feed during the fattening period

of the fattening period, when slurry pH was clearly lower in the group with 2% of benzoic acid in feed than in both other groups. The differences in slurry pH among the three treatments, as measured after delivery, correspond to the differences in slurry pH on day 95 (figure 2). The pH determined in the laboratory is slightly lower than that determined in the pig house in all cases.

There are no significant differences in excreta production per animal (in volume and kg of dry matter) and the dry matter percentage of the slurry among the animals of the three experimental treatments. Excreta production per pig shows a large distribution, however, which reveals itself in the dry matter percentage of the slurry (from 5 to 23%).

The pigs in the 2% group had higher contents of total nitrogen and ammonium nitrogen in the dry matter of the slurry than pigs of the other treatments. Also the total nitrogen and the ammonium nitrogen excretion per animal were higher with the 2% group. Ammonium nitrogen in the slurry (expressed as a percentage of total nitrogen) was significantly higher with animals that received 2% benzoic acid in their feed than with pigs without any benzoic acid in their feed.

The pigs that received 2% of benzoic acid in the feed had less phosphorus in the slurry. Total P loss per pig was, however, not significantly different in pigs from the three treatments. Ash content in the dry matter of the slurry was lower in pigs receiving 2% benzoic acid in the feed.

3.5 Economic results

Table 10 presents the results of the economic calculation. The following assumptions were considered:

- selling price per kg (excluding quality bonus):
  Dfl 3.01
- piglet price at 25 kg (including transportation costs):
  Dfl 99.-

Table 9: Excreta production (excluding cleaning water) per pig and composition of slurry of growing/finishing pigs that received 0%, 1% or 2% of benzoic acid in the feed

	0% benz. acid	1% benz. acid	2% benz. acid	SEM[1]	significance[2]
number of samples	20	18	20		
pH on farm	7.46[a]	7.56[a]	7.00[b]	0.08	***
pH in laboratory	6.89[a]	6.95[a]	6.71[b]	0.06	*
excreta prod. (l/pig)	212	189	234	16.9	n.s.
dm (%)	15.2	15.8	13.2	0.97	n.s.
dm (kg/pig)	29.0	27.7	28.5	1.04	n.s.
total N (g/kg)	9.47	9.84	9.22	0.50	n.s.
total N (g/kg dm)	64.5[a]	63.2[a]	71.4[b]	1.74	**
total N (kg/pig)	1.86[ab]	1.76[a]	2.03[b]	0.08	
NH_4-N (g/kg)	5.22	5.60	5.44	0.24	n.s.
NH_4-N (g/kg dm)	36.5[a]	36.3[a]	42.8[b]	1.60	**
NH_4-N (kg/pig)	1.05[a]	1.01[a]	1.22[b]	0.05	
% NH_4-N	56.0[a]	57.3[ab]	59.6[b]	0.85	*
total P (g/kg)	2.44[a]	2.57[a]	1.93[b]	0.16	
total P (g/kg dm)	16.0[a]	16.2[a]	14.6[b]	0.23	***
total P (kg/pig)	0.46	0.45	0.42	0.02	n.s.
ash (% of dm)	28.0[a]	27.2[ab]	26.6[b]	0.30	**

[1] SEM = pooled standard error of the mean (is indication of the accuracy of the estimate of the variable measured)

[2] significance: n.s. = not significant; * = ($p \leq 0.05$); ** = ($p \leq 0.01$); *** = ($p \leq 0.001$)

[a,b,c] averages with a different letter within a row are different

- feed costs:
  starter feed with 0% of benzoic acid:
  Dfl 44.60/100 kg
  starter feed with 1% of benzoic acid:
  Dfl 46.35/100 kg
  starter feed with 2% of benzoic acid:
  Dfl 48.10/100 kg
  growing/finishing feed with 0% of benzoic acid:
  Dfl 38.00/100 kg
  growing/finishing feed with 1% of benzoic acid:
  Dfl 39.75/100 kg
  growing/finishing feed with 2% of benzoic acid:
  Dfl 41.50/100 kg
- interest liquid capital:
  Dfl 3.31
- costs of health care:
  Dfl 1.59 per percentage of animals treated
  Dfl 4.- per growing/finishing pig delivered
  (Huiskes et al., 1997)
- costs of disposal:
  Dfl 3.73
- other costs:
  Dfl 5.30

Prices (excluding feed prices) are based on KWIN-V (1997). The price of benzoic acid is Dfl 1.75/kg.

Table 10 shows a clearly higher gross margin per pig delivered for pigs with 1% of benzoic acid in the feed than pigs that received none or 2% of benzoic acid in their feed.

Table 10: Gross margin per growing/finishing pig delivered for growing/finishing pigs that received 0%, 1% or 2% of benzoic acid in feed

	0% benz. acid	1% benz. acid	2% benz. acid	SEM[1]	significance[2]
yield	Dfl 247.57[a]	Dfl 262.14"	Dfl 250.46[a]	3.51	*
piglet costs	Dfl 97.32	Dfl 97.32	Dfl 97.32		
feed costs	Dfl 85.06[a]	Dfl 90.21[b]	Dfl 93.35[c]	0.38	x*x
other costs[3]	Dfl 17.13	Dfl 16.51	Dfl 16.50		
gross margin per growing/finishing pig delivered	Dfl 48.06[a]	Dfl 58.10[b]	Dfl 43.29[a]	3.48	*

1 SEM = pooled standard error of the mean (is indication of the accuracy of the estimate of the variable measured)
2 significance: * = ($p \leq 0.05$); *** = ($p \leq 0.001$)
3 other costs = interest liquid capital + health costs + costs of disposal + other costs
[a,b,c] averages with a different letter within a row are different

4 DISCUSSION AND CONCLUSIONS

4.1 Fattening results and slaughter quality

In this research the effect of 1% or 2% of benzoic acid in feed on performance and health of individually housed growing/finishing pigs was studied. The results showed a faster growth of 40 g/day and a 0.09 improved feed conversion for growing/finishing pigs that received 1% of benzoic acid in their feed than for pigs receiving no benzoic acid. They had also fewer health problems (particularly diarrhoea).

Providing feed with 2% of benzoic acid did not lead to more improvement in performance, but to a worsening of the results. Pigs that received 2% of benzoic acid in feed had comparable results of performance as pigs without benzoic acid in feed.

Adding benzoic acid to feed has in first instance a positive effect on the performance and health of growing/finishing pigs. If, however, a certain optimum is exceeded, performance is decreasing.

Other acids showed similar effects. Eckel et al. (1992) have conducted research in which piglets received feed, containing 0%, 0.6%, 1.2%, 1.8% or 2.4% of formic acid. The piglets that received 0.6% and 1.2% of formic acid had a better feed intake, grew faster and had a better feed conversion than piglets without any formic acid in feed. Piglets receiving 1.8% of formic acid in feed showed comparable technical results as the control group. The piglets that received 2.4% of formic acid in feed had a considerably worse performance than the animals in the control group. Eckel et al. (1992) assumed that a decrease in performance with high doses of formic acid might be a result of disturbance of the acid-base balance of the animal resulting from too much acid. This may also be true for higher doses of benzoic acid.

Relatively little research has been done on the effect of benzoic acid on performance of growing/finishing pigs. Den Brok et al. (1999) have carried out an experiment in which growing/finishing pigs received feeds containing 1% and 2% of an acidic mixture respectively. This mixture contained 70% benzoic acid. The pigs receiving the acidic mixture had a 0.08 better feed conversion than those pigs that received feed without this mixture. The results of Den Brok et al. (1999) correspond to the results of this research. The better performance with feed containing benzoic acid can possibly be explained by a better digestibility of the amino acids. Research by Mroz et al (1997) showed that by replacing calcium carbonate with 2.4% calcium benzoate, the digestibility of the different essential amino acids is improved by 1.6 to 3 percentage points and of the different non-essential amino acids by 2 to 11.2 percentage points. The improved health of animals that received benzoic acid in feed may result from the bacteriostatic effect of acids. Various researchers have indicated that acids reduce the pH in the gastrointestinal tract, due to which proliferation of harmful bacteria can be curbed (Kirchgessner and Roth, 1988; Gabert and Sauer, 1994).

4.2 Urinary and slurry pH

Urinary and slurry pHs are both influenced by the amount of benzoic acid in feed. Animals that received 2% of benzoic acid had the lowest pH, while those receiving no benzoic acid had the highest pH. Similar results have been found by Canh et al. (1996) and Den Brok et al. (1999). Slurry pH was higher than the urinary pH. This can be explained by the buffering effect of the organic matter in faeces.

In all treatments urinary and slurry pH values were highest in the first fattening stage, when the animals received starter feed. Protein content in starter feed was approximately 20 g/kg higher than in growing/finishing feed. Research by Canh et al. (1998) has proved that urinary and slurry pH values are influenced by the protein content in feed. They have found a higher urinary and slurry pH at higher protein contents and a lower pH at lower protein contents in the feed. The lower ammonium concentration in the slurry at lower protein contents in the feed is likely

to be the reason for the lower pH (Sommer and Husted, 1995 [a,b]; Canh et al., 1998). The higher urinary and slurry pH values during the starter feed period in this research are most likely to have been caused by the higher contents of protein in the starter feeds as compared to growing/finishing feed.

The course of the slurry pH of pigs that received 1% or 2% of benzoic acid in the feed was flat during the period in which growing/finishing feed was given. The slurry pH in the control group (0% benzoic acid) showed a slightly decreasing course. This slight decrease has also been found by Muck and Steenhuis (1982) during slurry storage in a storage facility. The decreasing course is possibly caused by the conversion processes in the slurry, particularly emission of CO_2 (Anderson et al., 1987) and the forming of volatile fatty acids. These processes will also have occurred in both other treatments, but their effect may be better revealed in slurry with a higher pH at the start.

In figure 2 a drop is shown in pH at measuring on day 83 in the group with 0% benzoic acid. Studying these observations have revealed a clear drop in three slurry pits and a slight drop in two slurry pits on this day. The cause cannot be explained easily. Because this drop was not observed in both other treatments, it is not likely a result of the setting or calibration of the equipment.

At the end of the fattening period the pH of the slurry in the group without benzoic acid was more or less equal to the pH of the 1% benzoic acid group. In the homogenized slurry pit there proved to be no difference in pH of the slurry between animals that received 0% and 1% benzoic acid in the feed. This is rather a result from the reduction in pH of the slurry in the control group than that the slurry pH of pigs receiving 1% of benzoic acid in their feed would not remain at a sufficiently low level.

During the fattening period the pH in the top layer of the slurry was measured. After closing the fattening period the pH was measured again in the homogenized slurry. The pH values after finishing the experiment were lower than during the fattening period. The pH values at the laboratory (about one to two weeks after finishing the experiment) proved to be lower still than those measured immediately after the fattening period. The latter may be caused by a different method of measuring at the laboratory, but the most plausible explanation for this decrease in pH is the conversion process in slurry, where volatile fatty acids are formed and CO, is emitted from the slurry.

4.3 Excreta production and composition of slurty

The growing/finishing pigs of the three experimental treatments produced, on average, 0.22 m^3 of slurry per growing/finishing pig. The number of fattening periods per year in this experiment was 3.65. This means that the average excreta production per pig present was 0.80 m^3 per year (excluding cleaning water), which is fairly low. As part of the study "Practical Data on Excreta Production Pig Husbandry" (LAMI, 1994), excreta production (including cleaning water) and water usage were measured at 25 fattening farms, where the trough nipple was applied to water the animals. The average excreta production on these farms was 1.11 m^3 per growing/finishing pig present per year. Excreta production of the 25% of farms with the lowest excreta production was, however, 0.88 m^3 per growing/finishing pig per year. Of all the water used at these farms, 4% was cleaning water. The cleaning water was entirely added to the slurry. If this 4% is added to the 0.80 m^3 that was found in this experiment, excreta production is 0.83 m^3 per growing/finishing pig present per year (including cleaning water). In this experiment the surface of the slurry pits was approximately three times as large as in practice, which means that more water can evaporate from the slurry. According to Van Wagenberg (1998) the extra water evaporation is approximately 0.1 m^3 per growing/finishing pig per year. Taking this into account, the excreta production found in this experiment is comparable to the excreta production of the 25% farms with the lowest excreta production in the LAMI study (1994). Although significant differences in total P per kg of slurry have been found (due to the difference in dry matter percentage), total

P excretion per pig was not substantially different among the three experimental treatments. Phosphate excretion (= P x 2.29) for the three treatments was 1.05, 1.03 and 0.96 kg respectively per growingfinishing pig delivered. Van Wagenberg and Backus (1997) have developed a calculation model with which phosphate loss per animal can be calculated, depending on, among other things, performance. If the following assumptions were applied in the program:
- growth of 900 grams per day,
- feed intake of 2.25 kg per day,
- ratio starter and growing/finishing feed 20/80,
- P-content in starter and growingfinishing feed 4.8 and 4.2 g/kg respectively,

the phosphate excretion per growing/finishing pig delivered was 1.14 kg. The values calculated and actually measured were fairly similar.

Ammonia is mainly formed by urea in urine, catalysed by the enzyme urease from faeces according to the formula:

$$CO(NH_2)_2 + H_2O \xrightarrow{\text{urease}} 2\,NH_4^+ + CO, \qquad (1)$$

Subsequently, in the aqueous environment a balance is realized between non-volatile ammonium and volatile ammonia.
In formula:

$$NH_4^+ + OH^- \Longleftrightarrow NH, + H_2O \qquad (2)$$

This ammonia in the slurry forms a balance with the ammonia in the air, according to:

$$NH_3 \text{ (liquid)} \Longleftrightarrow NH, \text{ (gas)} \qquad (3)$$

The slurry of pigs receiving 2% of benzoic acid in their feed had more total N per kg of dry matter and more kg of total N per pig. This also held for NH_4-N. The share of ammonium nitrogen (expressed as a percentage of total nitrogen) in the slurry was significantly higher in the slurry of pigs that received 2% of benzoic acid in their feed than of pigs receiving 0% of benzoic acid. If more acid is added to feed (and thus reducing the pH of the slurry), more nitrogen, particularly NH_4-N, is likely to be left in the slurry. This indicates that the forming of ammonium from urea continued in all treatments (formula 1), but that with a higher dose of benzoic acid the conversion of ammonium to ammonia (formula 2) and thus the volatilization of ammonia (formula 3) was restrained.

The above chemical equations can be closer quantified by means of physical-chemical patterns (Verdoes, 1992; Elzing et al., 1992; Aarnink, 1997). If the pH values of the slurry (table 8) are included in the calculations by Verdoes (1992), the level of ammonia emission in the three experimental treatments is 100%, 39% and 12% respectively. A slurry temperature of 20°C, an average ventilation flow of 80 m^3/hour/pig, an emitting surface in the slurry pit of 0.4 m^2 and an ammonium nitrogen concentration of 5 g/litre of slurry are assumed. This only concerns emission from the slurry pit, where it is assumed that the pH values of the top layer of the slurry (approximately the topmost 5 cm) determine emission. It is likely that the topmost millimetres of the slurry layer determine emission even stronger. Moreover, ammonia emission from the pig house is strongly determined by foul pens and animals, which has not been taken into account in these calculations. Although there are many uncertainties in these calculations, ammonia emission is supposed to be substantially reduced with the reductions in urinary and slurry pH measured.

4.4 Conclusions

- Growing/finishing pigs fed diets containing 1% of benzoic acid grew faster, had a better feed conversion ratio and a better feed intake than pigs fed diets with 0% or 2% of benzoic acid. Pigs fed diets containing 0% and 2% of benzoic acid showed the same performance.
- Gross margin per pig place per year for pigs fed diets containing 1% of benzoic acid was Dfl 10.- and Dfl 14.80 higher respectively than for pigs fed diets with 0% and 2% of benzoic acid.
- The pH of the urine and slurry was clearly influenced by the percentage of benzoic acid in the diet: the higher the percentage of benzoic acid in the diet, the lower the

pH of the urine and slurry.
- When the pH of the slurry is lower, more nitrogen in the form of ammonium nitrogen is left in the slurry.

4.5 Practica1 implications

To sufficiently reduce ammonia emission, it is necessary that the pH of the top layer of the slurry is sufficiently Iow during the fattening period. This top layer consists mainly of urine. In view of the results of this experiment, benzoic acid in feed is expected to have a clear effect on ammonia emission. This means that if benzoic acid is approved as an additive to growing/finishing feed, ammonia emission can be reduced in a relatively simple and cheap way.

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APPENDICES

Appendix 1: Ingredients and the calculated chemical composition of the experimental feeds (g/kg)

	starter feed		growing/finishing feed		
	0%	2%	0%	1%	2%
barley	200	200	---	---	---
wheat	100	100	100	100	100
triticale	100	100	25	25	25
peas	50	50	75	75	75
tapioca	196.6	196.6	385.0	374.8	379.2
rape seed extracted 00	—	—	100	99.1	80.4
soya beans extracted	132.5	134.4	92.7	87.2	101.2
sunflower seed extracted	40	33.6	75	75	70
wheat middlings	25	25	39.6	49.2	41.7
cane molasses	60	40	48.4	40	40
meat and bone meal	56.2	60	12.7	16.1	18.7
animal fat	19.3	20.6	35.3	37.5	37.8
dl-methionine	0.76	0.76	0.17	0.16	0.28
1-threonine	0.43	0.39	—	—	—
liquid lysine	2.37	2.17	1.41	1.44	1.25
calprona p	7.47	7.47		—	—
benzoic acid	—	20	---	10	20
calcium carbonate	---	---	2	2	2
monocalcium phosphate	2.23	2.22	—	—	—
salt	1.97	1.50	2.55	2.27	2.25
premix	5.0	5.0	5.0	5.0	5.0
p hytase	0.22	0.20	0.23	0.20	0.20
ME (MJ)	13.55	13.55	13.43	13.43	13.43
water	128	122	123	121	119
crude protein	175	175	157	157	156
crude fat	41	42	49	51	51
crude fibre	44	43	63	63	60
ash	55	52	59	57	57
starc h	387	387	377	372	373
ileal digestible lysine	8.4	8.4	7.0	7.0	7.0
ileal digestible meth. + cyst.	5.0	5.0	4.3	4.3	4.3
calcium	7.0	7.0	5.0	5.0	5.0
phosphorus	4.8	4.8	4.2	4.3	4.1
digestible phosphorus	2.8	2.8	1.8	1.8	1.8
sodium	1.4	1.2	1.4	1.3	1.3
potassium	9.9	9.3	10.5	10.2	10.2
tylosine (mg/kg)	40	40	20	20	20

Appendix 2: Feeding schemes for barrows and sows

	barrows		sows	
week	starter feed (kg/day)	growing/finishing feed (kg/day)	starter feed (kg/day)	growing/finishing feed (kg/day)
	1.10		1.05	
2	1.20		1.15	
3	1.40		1.30	
4	1.65		1.55	
5	1.00	0.90	1.00	0.80
6		2.10		2.00
7		2.30		2.20
8		2.40		2.30
9		2.60		2.50
10		2.70		2.60
11		2.80		2.70
12		2.90		2.75
13		3.10		2.95
14		3.10		2.95
15		3.10		2.95
16		3.10		2.95

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