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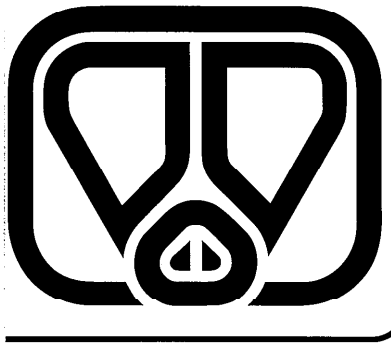
Urinary pH, ammonia emission and performance of growing/finishing pigs after the addition of a mixture of organic acids, mainly benzoic acid, to the feed



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SUMMARY

Reducing ammonia emission from animal housing is possible using technical solutions (scraper systems, flushing systems) or by improving pen design. This improved pen design is based on reducing the slurry surface area in the slurry pit and reducing the surface area covered in slurry in the pen. Currently more research is being carried out on the possibilities of applying feeding measures, possibly in combination with housing adjustments, to reduce ammonia emission. One such measure is adding acid salts to feed in order to lower the pH of the urine and slurry. Preliminary research on this subject has learned that in this way a 30 - 54% reduction in ammonia emission is possible (Canh et al., 1996).

Therefore, a study was conducted at the Experimental Farm for Pig Husbandry at Raalte to examine the effect of improved pen design in combination with adding a mixture of several organic acids to feed of growing/finishing pigs on the pH of the urine and slurry, ammonia emission and performance of pigs.

The research was conducted in three compartments during three fattening periods. Each compartment had 6 pens, containing 66 animals. In the two identical compartments 1 and 2, all pigs were fed either control feed or acidified (experimental) feed. After each period the treatments were changed over. The improved pen design in the two compartments consisted of a narrow slurry channel (50 cm) with concrete slats at the front of the pen, a convex solid floor (1.85 m) and a wide slurry channel with tribar metal slats and a sewage pipe system underneath at the back of the pen (1.60 m including manure split). In these two compartments the pH of the urine and slurry and the ammonia emission were measured. In the third compartment, pigs in three pens were fed control feed and pigs in the other three pens experimental feed. In this compartment the effect of the experimental feed on performance and meat quality was examined. All pigs were fed by using a dry-wet feeder and were fed with a starter feed during the first four weeks. After this period, the starter feed was replaced by growing/finishing feed over a period of five days. The experimental starter feed and growing/finishing feed contained no $CaCO_3$, but did contain a mixture of acid salts comprising 1% and 2% of the feed respectively. The mixture consisted of 70% benzoic acid, 16.5% calcium salts, 6.5% formic acid and 7.0% propionic acid (experimental starter feed and growing/finishing feed contained 0.7% and 1.4% benzoic acid respectively). The energy and crude protein content of both control and experimental feed were equal.

The most important results and conclusions are:

- The average pH of the urine of growing/finishing pigs fed with control and acidified starter feed was 7.50 and 5.69 respectively (difference is 1.81). For growing/finishing pigs fed with growing/finishing feed the pH of the urine was 7.48 and 5.02 respectively (difference is 2.46).
- The average pH of the top layer of the slurry of growing/finishing pigs fed with control and acidified feed was 7.76 and 7.28 respectively (difference is 0.48). For growing/finishing pigs fed with growing/finishing feed the pH of the top layer was 7.82 and 7.04 respectively (difference is 0.78).
- The improved pen in this study resulted in an ammonia emission of 2.04 kg per pig place per year (standard is 2.5 kg per pig place per year for traditional pen design). The combination of improved pen design and acidified feed resulted in an ammonia emission of 1.22 kg per pig place per year, a reduction of 40%. The ammonia emission rate calculated was not corrected for the ammonia concentration of surrounding air (in similar research the corrected ammonia emission was about 0 - 5% lower than the emission not corrected).
- Feeding acidified feed to growing/finishing pigs in this research did not influence meat quality.
- Feeding acidified feed to growing/finishing pigs in this research improved the feed conversion by 0.08 (2.64 instead of 2.72).

There was no influence on mortality rate.

- The additional feeding costs of using acidified feed in this research were calculated to be Dfl 17.60 per pig place per year. Because of a better feed conversion the gross margin in this research decreased by only Dfl 5.66 per pig place per year. Together with the extra annual costs of Dfl 9.90 per pig place for the improved pen design compared to a traditional housing system, the total extra annual costs were Dfl 5.66 + Dfl 9.90 = Dfl 15.56 per pig place (see table 1).

Table 1: Extra annual costs of improved pen design compared to a traditional housing system, with or without using acidified feed

	ammonia emission (kg/ppl/y)	extra investment costs (Dfl/ppl)[1]	extra annual costs (Dfl/ppl/y)
traditional housing (concrete slats)	2.5[2]	-	-
improved pen design (metal slats)	2.0	42.00	9.90
improved pen design and acidified feed	1.2	42.00	15.56

[1] Dfl/ppl = Dutch guilders per pig place

[2] 2.5 kg/ppl/y = ammonia emission standard for a traditional housing system for growing/finishing pigs with a partly slatted floor and concrete slats

1 INTRODUCTION

In the 1980s and early 1990s research on reducing ammonia emission from pig houses was mainly aimed at finding technical solutions. Examples are slurry scrapers, flushing systems, aerating and acidifying of slurry. For a large number of the technical solutions developed, considerable investments and maintenance are necessary and are, therefore, less suitable or are hardly applied in practice. The ammonia research has, however, also resulted in a few simple and cheap emission-poor systems. These systems with mainly constructional adjustments are aimed at diminishing the slurry surface area in the slurry pit and reducing the slurry surface area covered in slurry in the pen (animals, floors and pen walls) as much as possible in order to reduce ammonia emission. As to growing/finishing pigs, one can think of improving the passing of the slurry through the slats by applying metal tribar slats instead of concrete slats. The slurry pit can be reduced by partly applying a convex solid concrete floor. Moreover, narrow deep pens instead of wide short pens can influence the defecating behaviour of the pigs. Research by Van der Peet-Schwering et al. (1996) has shown that these simple technical applications result in a 34% reduction in ammonia emission compared with current housing systems for growing/finishing pigs with dry-wet feed. This research has shown that the combination of improved pen design with multi-phase feeding leads to an additional reduction in ammonia emission of another 11%. The same effect of multi-phase feeding on ammonia emission was found with dry feeding (Van der Peet-Schwering et al., 1997).

Theoretically there is an exponential relation between the slurry pH and ammonia emission (figure 1). Research by Hendriks and Vrielink (1996 a and b) has shown that acidifying slurry in the slurry pit can lead to a reduction in ammonia emission. The slurry was acidified by organic acids, such as acetic acid and MMDBA (a mixture of organic acids that are released at production of acetic acid), or by adding micro-organisms that produce the necessary acids. With the acidifying systems studied, the acidified slurry was mixed regularly. This was necessary to prevent that on top of the acidified slurry, a layer of fresh non-acidified slurry caused by excreta production would accumulate. Mixing the slurry and the concomitant expensive technicál adjustments are not necessary if pH-reduction in urine and/or slurry can be realized in pigs directly through feeding measures. Acidified feed can possibly also lead to improvement in performance, which cannot be realized with acidifying slurry.
Elzing and Aarnink (1996) have shown that urinary pH influences ammonia emission from the slatted floor area and slurry pit. On the basis of their results a maximum reduction of 13% at most in ammonia emission is possible, if the pH of urine is reduced from 7 to 6. Research by Canh et al. (1996) has shown that the pH of urine and slurry is influenced by the calcium level applied and the kind of calcium salt. During that research urine and faeces of growing/finishing pigs in metabolism cages were mixed to slurry. Ammonia emission from the various kinds of slurry was measured in a laboratory setting. On average, a reduction of 30%, 54% and 33% was realized, when replacing calcium carbonate with calcium sulphate, calcium benzoate and calcium chloride respectively. Moreover, emission proved to increase with a higher level of calcium carbonate and to decrease with a higher level of other salts in the diet.

The results of research by Hendriks and Vrielink (1996a and b), Elzing and Aarnink (1996) and Canh et al. (1996) have induced the Experimental Farm for Pig Husbandry in Raalte to carry out an experiment in growing/finishing pigs with acidified feed in combination with simple housing measures. Aim of this research was to determine the effect of adding a mixture of organic acids, particularly benzoic acid, to compound feed on urinary pH, ammonia emission and performance of growing/finishing pigs.

This research was done by order of Verdugt bv at Tiel, the Netherlands.

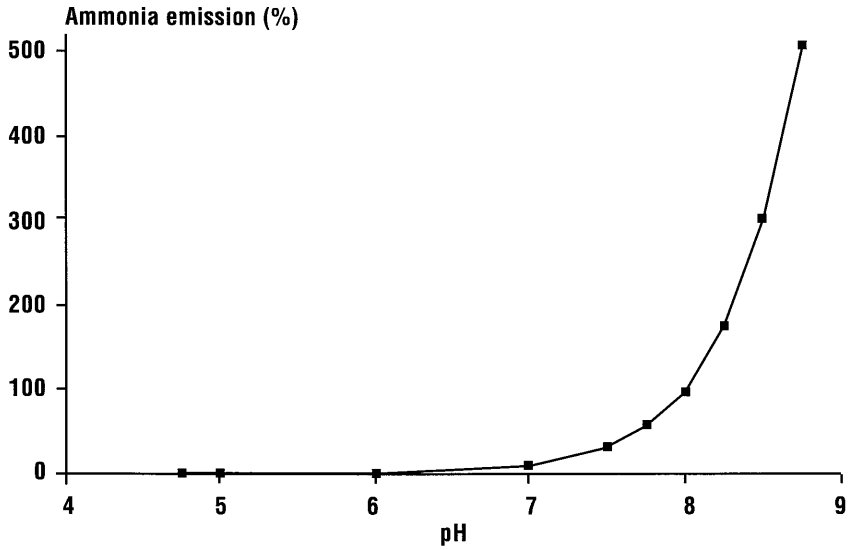

Figure 1: Theoretical relation between pH and ammonia emission

2 MATERIAL AND METHOD

This research was conducted at the Experimental Farm "North- and East Netherlands" in Raalte. During the investigation two experiments were performed at the same time. In experiment I, conducted in compartments 1 and 2, pigs were fed either control or acidified (experimental) feed. Both groups were changed over after each fattening period. By this, measurements could be done as to ammonia emission and pH in slurry, which can only be done at compartment level. Also water intake was measured in these two compartments. In experiment II, performed in compartment 3, during each fattening period, pigs from three pens were fed acidified feed and three pens control feed, so that in this compartment it could be studied whether there was an influence of acidified feed on performance and meat quality of growing/finishing pigs compared with control feed. Table 2 shows the experimental design. The experiment was conducted in three compartments with in total 594 animals over three fattening periods. It started in December 1995 and finished in January 1997.

2.1 Experiment I: ammonia emission and pH

2.1.1 Experimental animals and size of experiment

Research was conducted with barrows and sows of crossbred GY_s-boar x (GY, x NL)-sow, GY_s-boar x NL-sow or GY_z-boar x NL-sow. These animals were started with at approximately 25 kg and the animals were slaughtered at approximately 85 kg slaughter weight. The experiment lasted for three fattening periods with in total 396 animals.

2.1.2 Experimental treatments

Two treatments were compared:

1 feeding control feed with improved pen design;
2 feeding acidified feed with improved pen design.

The acidified starter and growing/finishing feeds contained 1 and 2% of a mixture of organic acids and salts respectively. This mixture was composed of 70% benzoic acid (feed contained 0.7 and 1.4% benzoic acid respectively), 16.5% calcium salts (acidic salts), 6.5% formic acid and 7% propionic acid. Because this mixture already contained various calcium salts, $CaCO_3$ was not necessary, so this was not added to acidified feed. The pigs were fed ad libitum during the entire fattening period. Water was freely available via the drinking nipple in the dry-wet feeder. The first four weeks all pigs were fed starter feed. In the fifth week the feed was gradually changed to growing/finishing feed.

2.1.3 Experimental design

Pigs were started with in both compartments

Table 2: Experimental design

	experiment I		experiment II
period	compartment 1	compartment 2	compartment 3
1 (Dec. 1995 - Apr. 1996)	acidified feed	control feed	control and acidified feed
2 (Apr. 1996 - Sep. 1996)	control feed	acidified feed	control and acidified feed
3 (Sep. 1996 - Jan. 1997)	acidified feed	control feed	control and acidified feed
	compartments 1 and 2		compartment 3
measurements	ammonia emission pH slurry and urine water intake		performance meat quality (period 2)

at the same time. For the starting piglets, only a classification was made on the basis of starting weight. Sows and barrows were housed together.

2.1.4 Feeding

The ingredients and the calculated chemical composition of the different kinds of feeds are in appendix 1. Starter feed had an ME of 13.55 MJ and crude protein content of 170 g/kg. Growing/finishing feed had an ME of 13.43 MJ and contained 150 g/kg crude protein. The control and acidified feeds were made from the same batches and at the same time as much as possible. Because this experiment lasted three periods, small variations in composition could not be avoided. During each fattening period collective samples were taken from the starter and growing/finishing feeds. From each of the four kinds of feed, three collective samples were made, which was done by taking a feed sample from the feed in the dry-wet feeder weekly. These samples were analysed as to contents of dry matter, crude protein, crude fat, crude fibre, starch and ash.

The ingredients in the acidified feeds was slightly changed compared to the control feeds, so that feeds with comparable ME and crude protein content were obtained.

2.1.5 Housing and climate

Housing

Two identical compartments with each six pens for eleven growing/finishing pigs were used. The pens were 2 m wide and 3.95 m long and were designed as follows (seen from the feeding passage, which was 1.05 m wide): a narrow slurry channel with concrete slats (0.50 m), a convex solid floor (1.85 m) and a wide slurry channel with metal tribar slats (1.60 m including manure split of 10 cm). The narrow slurry channel was provided with a gutter with one single valve. Due to the narrow and deep pen design pigs excreted mostly at the back of the pen. The small amount of slurry that came into the narrow slurry channel was slightly diluted by water that was left behind in the channel after cleaning the compartment. The wide slurry channel was provided with a sewerage system. In both compartments the dry-wet feeder was placed at the front of the pen.

Climate

Fresh air came through the central corridor over the ceiling of the compartment and through an opening of 0.30 m wide and 11.5 m long over the feeding passage in the compartment. If necessary, the air in the central corridor was preheated to 5°C. The air was removed via a fan in the ceiling (diameter 45 cm).
At the start a compartment temperature of 22°C was aimed at, dropping to 21°C 15 days after starting and dropping to 19°C 30 days after starting. From day 30 after starting onwards until the end of the period a compartment temperature of 19°C was aimed at. Minimum and maximum ventilation was 10 and 100 m^3/hour per animal respectively. The proportional range varied from 4 to 6°C depending on the outside temperature.

2.1.6 Data collection and processing

Ammonia emission

Ammonia emission was continuously measured in both compartments by means of a Bruël & Kjaer-analyser type 1302.
The ammonia concentration and temperature of the removed air in the ventilation shaft were measured 26 times per day, on average. Moreover, the ventilation flow was determined by means of flow meter (diameter 45 cm). The ventilation shafts with flow meters had been calibrated in a wind tunnel. The setting of the measuring equipment was calibrated and maintained according to the standard guideline of the Research Institute for Pig Husbandry (Van 't Klooster et al., 1992). The measurements were converted to ammonia emission per day (g/day) by means of formula 1.

Ammonia emission was measured from the starting day to the day on which 50% or more pigs had been delivered to the slaughterhouse. Ammonia emission per pig place per year was calculated per fattening period in formula 2 with results from formula 1. A correction factor of 0.9 was applied for the average occupancy rate of the compartment on a yearly basis.

The ammonia emission calculated was not corrected for background concentration, since this concentration was not measured continuously.
Ammonia emission was analysed by means of a variance analysis (SAS, 1990). The model, in which the compartment is the smallest unit, was as follows:

y = μ + compartment temperature + period + treatment + rest, in which y = natural logarithm of the ammonia emission.

Slurry composition and pH
Each fattening period four slurry samples were taken in both compartments at emptying the slurry pit, of which the ammonium, total nitrogen, dry matter and ash contents were determined. The analyses were done at the Environmental Laboratory of IMAG-DLO.
Besides, pH of the slurry was measured in both compartments at two places in the slurry pit (through a wide manure split in pens 2 and 5) once a week. Also, each period urine was collected from a number of pigs (randomly) in these compartments three to five times (once or twice during the starting period and twice or three times during the final period), after which urinary

Formula 1:

$$NH_{3j} = \frac{\sum_{i=1}^{i=n} C_i * Vent_i}{n_j} * 24 * 0{,}001$$

NH_{3j}	= Ammonia emission on day j	(g/day)
C_i	= Ammonia concentration air in pig house at time i	(mg/m³)
$Vent_i$	= Ventilation flow at time i	(m³/hour)
24	= Conversion factor for hours to day	(hour/day)
0.001	= Conversion factor for mg to g	(g/mg)
n_j	= Number of observations on day j	(-)

Formula 2:

$$NH_3 = \frac{\frac{\sum_{j=1}^{j=m} NH_{3j}}{m} * 365 * 0{,}9 * 0{,}001}{z}$$

NH_3	= Ammonia emission per pig place per year	(kg/ppl/year)
NH_{3j}	= Ammonia emission on day j (formula 1)	(g/day)
m	= Number of days (compartment occupied and ammonia emission measured) in measuring period	(-)
365	= Conversion factor from days to year	(day/year)
0.9	= Correction factor for average occupancy	(-)
z	= Number of starting animals in compartment	(ppl)
0.001	= Conversion factor for g to kg	(kg/g)

pH was determined by means of a pH-meter (WTW, type pH95). The pH of the slurry and urine was analysed by means of a variance analysis (SAS, 1990). The model, in which the compartment is the smallest unit, was as follows:

y = μ + period + week number within period + treatment + rest.

Water in take
Four water meters were placed in compartments 1 and 2. Water meters A and B recorded individual water intake in pens 1 and 2 and water meters C and D recorded collective intake in pens 3 and 4 and pens 5 and 6 respectively. This was done weekly.

Pen dirtiness
Once a week the degree of pen dirtiness was measured in both compartments. Dirtiness of both the floor area (concrete slats at the front, convex floor and metal slats at the back) and animals was considered. The wet area was judged visually on a scale of 0 to *4,* corresponding with 0%, 0 - 25%, 25 - 50%, 50 - 75% and 75 - 100% of the area concerned. Whether or not diarrhoea occurred was also taken into account. Pen dirtiness was analysed by means of logistic regression with a threshold model of McCullagh (Oude Voshaar, 1994).

Performance
All animals were weighed at the start. The amount of feed supplied was recorded per pen at disposal and slaughter. On the basis of these data the following production characteristics were calculated: growth per day, feed intake per day and feed conversion. If the pig was disposed of, date, weight and cause of disposal were recorded for each animal. These animals were not taken into account in calculating performance. Performance of the growing/finishing pigs of compartments 1 and 2 that received acidified feed is in appendix 2, only for the purpose of the guideline for ammonia emission measurements (Anonymous, 1996).

2.2 Experiment II: performance and meat quality

2.2.1 Experimental animals and size of experiment
The experiment was carried out with cross-bred growing/finishing pigs as mentioned in section 2.1.1. The animals were started with at a weight of approximately 26 kg and delivered to the slaughterhouse at an average slaughter weight of approximately 85 kg. There were three fattening periods with in total 198 animals.

2.2.2 Experimental treatments
In experiment II the same treatments were done as in experiment I (see section 2.1.2).

2.2.3 Experimental design
In the experiment the pigs were assigned to blocks. One block comprised two pens of pigs. The animals in the pens within a block were almost equal to each other as to cross-breed and starting weight. One pen of a block was assigned to each experimental treatment. In this way three pens were started with in compartment 3, the pigs of which received control feed and three pens received acidified feed. Sows and barrows were housed together.

2.2.4 Feeding
Feeding and provision of water was the same as in experiment I (see section 2.1.4).

2.2.5 Housing and climate
Housing
One compartment with six pens for eleven animals was used. The pens were 2 m wide and 4.45 m deep and had, seen from the feeding passage, a solid concrete convex floor (2.95 m) at the front and a slurry channel with metal tribar slats (1.50 m including manure split of 10 cm) at the back. The slurry channel was provided with a sewerage system. The dry-wet feeder was at the front of the pen.

Climate
The climate setting in experiment II was the same as in experiment I (see section 2.1.5).

2.2.6 Data collection and processing

Performance

In compartment 3 all animals were weighed at the start, at changing from starter to growing/finishing feed and at delivering to the slaughterhouse. Per pen the amount of feed supplied was recorded at in-between weighing, disposal and delivering. On the basis of these data the following production characteristics were calculated: growth per day, feed intake per day and feed conversion. If the pig was disposed of, date, weight and cause of disposal were recorded for each animal. These animals were not taken into account in calculating performance.
The characteristics growth per day, feed intake per day and feed conversion of the animals were statistically analysed by means of variance analysis (SAS, 1990) to determine whether differences were coincidental or not. The model, in which the pen is the smallest unit, was as follows:

y = μ + period + block within period + treatment + rest.

The chi-square test was used to check whether there were differences in the experimental and control groups in compartment 3 as to the number of animals disposed and the number of animals per cause. Slaughter quality and judgments as to type were analysed through logistic regression using the threshold model of McCullagh (Oude Vos haar, 1994).

Meat quality

In period 2 some meat quality characteristics were determined of the pigs delivered of compartment 3. The 66 pigs (33 fed with experimental feed and 33 with control feed) were taken to the slaughterhouse in two batches. Besides the dressing percentage, meat percentage, muscular thickness, fat layer and type judgment, also the following characteristics were measured per pig:
1) pH-warm; 2) pH-cold; 3) drip loss;
4) Japanese colour scale.

ad 1: Immediately after slaughter (after 40 minutes) pH of the meat of each pig was measured in the musculus semimembranosus.

ad 2: Twenty-four hours after slaughter the pH of the meat of each pig was measured in the cold store at the same measuring place as in 1.

ad 3: Twenty-four hours after slaughter the ham was cut from each pig at the height of the 5th and 6th lumbar vertebra. Filter paper was placed on to the fresh cut, which was removed after about 8 seconds. The absorption by the filter paper (the drip loss) was judged visually on a scale of 1 (0 - 20% of filter paper wet) to 5 (80 - 100% of filter paper wet) (Kauffman et al., 1986).

ad 4: Twenty-four hours after slaughter the ham was cut from each pig. The meat colour at the fresh cut was judged visually and compared with the Japanese colour scale (Nakai et al., 1975).

The characteristics of dressing percentage, meat percentage, muscular thickness, fat layer, pH-warm, pH-cold and the difference between pH-warm and cold were statistically tested by a variance analysis (SAS, 1990) according to the model:

y = μ + slaughter weight + sex + day of slaughter + treatment.

The type judgment, drip loss score and the meat colour (Japanese colour scale) were tested by the threshold model of McCullagh (Oude Voshaar, 1994).

3 RESULTS

3.1 Composition of different kinds of feed (experiments I and II)

Table 3 shows the average results of the chemical analyses of the different kinds of control and acidified feeds. In appendix 3 the composition per period is given.

The feed contents analysed did not always correspond to the composition earlier calculated (see appendix 1). The actual crude protein content was in all feeds higher than the value calculated, but is comparable between control and experimental feeds per kind of feed. The actual crude fat content in the acidified feeds was considerably higher in particularly the growing/finishing feed and was lower in the control feeds than the value calculated. The crude fat content in the control growing/finishing feed analysed was, for example, 7 g/kg lower and in the experimental growing/finishing feed 5 g/kg higher. The actual crude fibre content was higher than the value calculated in all cases. The actual calcium content was lower in the acidified feeds and higher in the control feeds than the previously calculated value.

3.2 Experiment I: ammonia emission and pH

3.2.1 Ammonia emission

In figure 2 the course of the ammonia emission in both treatments during the three

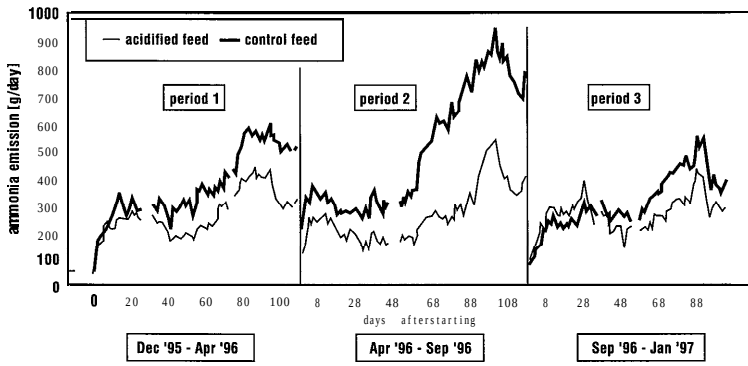

Figure 2: Ammonia emission from a growing/finishing pig compartment, where the pigs have been fed with acidified or control feed

Table 3: Analysed chemical composition of control and acidified (experimental) feeds, in g/kg

	starter feed		growing/finishing feed	
	control	experiment	control	experiment
number	2	2	6	6
dry matter	878	885	882	884
crude protein	177	181	159	159
crude fat	36	40	34	46
crude fibre	51	46	44	46
calcium	7.7	6.4	7.1	4.8
ash	52	51	51	47

periods is presented (not corrected for background concentration and temperature of the removed air). Table 4 shows the average temperature of removed air, ventilation flow, ammonia concentration and ammonia emission per pig place per year. The data per period are in appendix 4. The ammonia emission presented in table 4 per pig place per year has been corrected for temperature of the removed air, while appendix 4 shows the uncorrected values.

Ammonia emission in the control group was normal. In the summer period (in this experiment period 2) ammonia emission was highest because of higher temperatures. In the experimental group this pattern is lacking. There is a clear effect of acid urine on ammonia emission, particularly in the summer period.

Feeding acidified feed led to a reduction of 40% in ammonia emission. Due to the few observations of three per treatment, the test's power of discrimination is limited, however, no significant difference could be demonstrated (p = 0.11). More replicates are necessary to make differences of 40% or more statistically significant.

3.2.2 Slurry composition and pH

In table 5 the average slurry composition of both treatments is presented.

The contents analysed in the slurry of the experimental group proved to be lower than of the control group in all cases.

Figure 3 presents the course of the slurry pH per period. In table 6 the average pH values

Table 4: Temperature, ventilation flow, ammonia concentration and ammonia emission per pig place per year in growing/finishing pigs, fed with acidified and control feed

	control	treatment	SEM[1]	significance[2]
temperature (°C)[3]	21.3	21.7		
ventilation flow (m^3/hour)	2,942	2,956		
ammonia concentration (mg/m^3)[3]	5.79	4.07		
ammonia emission (kg/pig place/yr)[4]	2.04	1.22	0.097	n.s.
reduction in ammonia emission (%)	-	40		

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
3 of the removed air
4 not corrected for background concentration

Table 5: Slurry composition of growing/finishing pigs fed with control or acidified (experimental) feed

	period 1 (n = 4)[1]		period 2 (n = 4)		period 3 (n = 3)		average	
	control	experiment	control	experiment	control	experiment	control	experiment
NH_4-N (g/kg)	5.29	4.72	5.93	5.26	6.48	5.20	5.90	5.06
$N_{kjeldahl}$ (g/kg)	10.6	8.5	10.4	9.7	10.4	8.9	10.5	9.0
DM (g/kg)	174	125	157	150	133	128	155	134
ash (% of dm)	19.3	20.2	22.1	19.4	22.8	19.9	21.4	19.8

1 n = number of observations

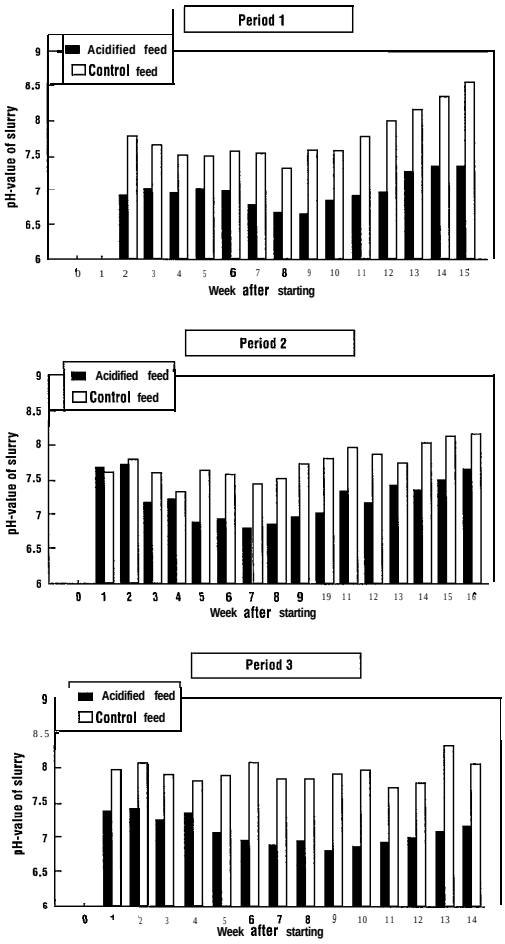

Figure 3: Course of pH-value of slurry of growing/finishing pigs fed with control or acidified (experimental) feed

of the slurry and fresh urine of both treatments over 3 periods are presented. A distinction has been made between starting and fattening period. Appendix 5 presents an overview per period.

The results in figure 3, table 6 and appendix 5 show that the average pH of the slurry of the control group was almost equal in both the starting and fattening period. Slurry pH of the experimental group was 0.5 and 0.8 lower than of the control group in the starting and fattening period respectively. Also urinary pH of the control group was almost the same in both periods. The pH-values of the experimental group were 1.8 and 2.5 lower than of the control group in the starting and fattening period respectively.

3.2.3 Water intake

The average water intake by the animals of the experimental group was 4.32, 4.13, 4.10 litres per pig per day in periods 1, 2 and 3 respectively. In the control group this was 4.24, 4.10 and 4.62 litres per pig per day. Water intake by the control group was on average 3% higher than by the experimental group, particularly due to the results in the third period.

3.2.4 Pen dirtiness

Table 7 presents the results of the pen and animal dirtiness scores that were done during the three periods in compartments 1 and 2. No differences were shown between both groups.

Table 6: Average pH of slurty and fresh urine of growing/finishing pigs fed with control or acidified (experimental) feed

	control	experiment	SEM[1]	significance[2]
slurry pH:				
starting period	7.76	7.28	0.070	***
fattening period	7.82	7.04	0.030	***
urinary pH:				
starting period	7.50	5.69	0.272	*
fattening period	7.48	5.02	0.085	***

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

[2] significance: * = ($p < 0.05$); *** = ($p < 0.001$)

3.3 Experiment II: performance and meat quality

3.3.1 Performance

Table 8 presents the performance from start to finish of both groups in compartment 3. End weight is the end weight weighed.

Table 8 shows that there were no significant differences in growth and feed intake per day between the two groups in compartment 3.

Pigs fed with acidified feed have a better feed conversion ($p = 0.0357$).

In table 9 performance in the period from the start to a weight of approximately 42 kg is presented. During this period only starter feed was given.

Table 7: Frequency distribution (%) of pen and animal dirtiness scores in growing/finishing pigs

	scores	control feed	acidified feed	significance[1]
slats at the front				n.s.
	0	66.6	64.8	
	1	29.6	34.7	
	2 - 3 - 4	3.8	0.5	
solid floor				n.s.
	0	68.5	74.1	
	1	27.3	25.4	
	2 - 3 - 4	4.2	0.5	
slats at the back				n.s.
	0	13.9	15.7	
	1	83.8	83.8	
	2 - 3 - 4	2.3	0.5	
animals				n.s.
	0	76.9	80.1	
	1	20.4	19.4	
	2 - 3 - 4	2.7	0.5	

[1] significance: n.s. = not significant

Table 8: Performance of growing/finishing pigs fed with control and acidified (experimental) feed, in the period from start to finish

	control	experiment	SEM[1]	significance[2]
number of animals started with	99	99		
number of pens	9	9		
weight at start (kg)	26.1	26.2		
end weight (kg)	107.4	108.2		
growth (g/day)	723	737	7.5	n.s.
feed intake (kg/day)	1.97	1.95	0.020	n.s.
feed conversion	2.72	2.64	0.022	*

[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; * = ($p < 0.05$)

Table 9 shows that there were no differences in growth, feed intake and feed conversion between the two treatments at a weight of approximately 42 kg.

In table 10 the performance in the period from approximately 42 kg to the end of the fattening period is presented. During this period only growing/finishing feed was given.

Table 10 shows no differences in growth and feed intake per day between the two treatments in the period from approximately 42 kg to delivering. The group with acidified feed showed a better feed conversion ($p = 0.066$) compared with the control group.

3.3.2 Slaughter quality and disposal

The classification results of the animals slaughtered are presented in table 11. These results show no differences as to meat percentage, type judgment and fat layer between the two treatments.

Table 12 shows the number of animals disposed, as well as the reasons for disposal.

From table 12 can be seen that there were no differences in the number of disposed animals, nor are there clear differences in

Table 9: Performance of growing/finishing pigs fed with control and acidified (experimental) feed, in the period from the start to a weight of approximately 42 kg

	control	experiment	SEM[1]	significance[2]
number of animals started with	99	99		
number of pens	9	9		
weight at start (kg)	26.1	26.2		
in-between weight (kg)	41.8	42.2		
growth (g/day)	645	659	15.8	n.s.
feed intake (kg/day)	1.31	1.30	0.032	n.s.
feed conversion	2.03	1.98	0.045	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 10: Performance of growing/finishing pigs fed with control and acidified (experimental) feed in the period from approximately 42 kg to finish

	control	experiment	SEM[1]	significance[2]
number of animals started with	99	99		
number of pens	9	9		
in-between weight (kg)	41.8	42.2		
end weight (kg)	107.4	108.2		
growth (g/day)	746	761	8.9	n.s.
feed intake (kg/day)	2.15	2.14	0.024	n.s.
feed conversion	2.89	2.81	0.027	#

[1] SEM = pooled standard error of the mean (is indication of the accuracy of the estimate of the variable measured)
[2] significance: n.s. = niet significant; # = ($p < 0.10$)

causes between the animals fed with control or acidified feed.

3.3.3 Meat quality

The 'results of the meat quality measurements, done in pigs during period 2 of compartment 3 are in table 13. The growing/finishing pigs were delivered in two batches with a period of 2 weeks in between. Always the same number of pigs from both groups was slaughtered per slaughter day. There was no interaction between slaughter day and treatment.

From table 13 can be seen that there were no differences between the experimental and control groups as to dressing percentage, meat percentage, muscular thickness, fat layer, pH-warm and pH-cold. During the first 24 hours the meat pH (pH difference) of the experimental group showed a smaller decrease in pH (p = 0.094) than that of the control group. The slaughter weight was included in the analysis, because animals in the experimental group had a higher average slaughter weight (+ 2.6 kg). No difference was found as to type judgment, drip loss (p = 0.95) and Japanese colour scale (p = 0.85). Appendix 6 presents the results of these analyses.

Table 11: Slaughter quality of growing/finishing pigs fed with control and acidified (experimental) feed

	control	experiment	SEM'	significance[2]
number of animals	97	94		
slaughter weight (kg)	85.0	85.8		
meat percentage	56.1	56.3	0.26	n.s.
animals with type AA (%)	13.4	12.8		
animals with type A (%)	84.5	84.0		n.s.
animals with type B (%)	2.1	3.2		
fat layer (mm)	15.84	15.95	0.304	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 12: Disposal of growing/finishing pigs fed with control and acidified feed

	control feed	acidified feed	significance[1]
number of animals started with	99	99	
number of animals disposed	5	2	n.s.
reason for disposal:			
- respiratory problem	2	1	
- nervous system	1	0	
- tail biting	1	0	
- unknown	1	1	

[1] significance: n.s. = not significant

Table 13: Meat quality of growing/finishing pigs fed with control and acidified feed from start to finish

	control feed	acidified feed	SEM'	significance[2]
number of animals	33	33		
slaug hter weig ht (kg)	84.1	86.7		
dressing percentage	79.6	79.4	0.24	n.s.
meat percentage	55.6	56.1	0.41	n.s.
muscular thickness (mm)	51.4	51.9	0.74	n.s.
fat layer (mm)	16.3	15.8	0.50	n.s.
pH-warm	6.40	6.30	0.052	n.s.
pH-cold	5.50	5.53	0.023	n.s.
pH difference	0.90	0.77	0.052	#

[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; # = ($p < 0,10$)

4 DISCUSSION

4.1 Acidity

The pH of fresh urine of the experimental group was 1.8 and 2.5 units lower during the starting and fattening period respectively. The pH reduction in the slurry of the experimental group was much smaller and was 0.5 and 0.8 in the starting and fattening period respectively. Acidifying feed affects mainly urinary pH. As soon as urine comes into contact with faeces, a buffering occurs, due to which the effect on the slurry pH is much smaller. The pH of this buffer (slurry) is responsible for the effect on ammonia emission from the slurry pit. The difference in pH-value of the slurry and urine between the two groups was larger in the fattening period than in the starting period. This has possibly been caused by a higher acidifying percentage in growing/finishing feed as compared to starter feed (1%).
Notable is the increasing pH value of urine in the experimental group in the starting period over the periods 1, 2 and 3 (see appendix 5), while the feed was the same. No clear explanation could be found. This increasing tendency can partly be seen in the slurry pH of the experimental group. The experiment was started with completely clean slurry pits. At the end of each fattening period, 5 to 10 cm of slurry was left behind after removing the slurry. This may explain the higher pH value of the slurry of the experimental group during the starting period of the following fattening periods (periods 2 and 3), in which the groups changed compartments. In figure 2 this effect can clearly be seen in period 2. In practice, this situation will not occur, because between periods the same feed will be given.

The Ca-content calculated earlier per kind of feed was equal in both treatments (appendix 1). The analysis of the composition of the feeds (table 3) showed, however, that the Ca-contents were higher in the control feeds and lower in the experimental feeds than in the values calculated. Research by Canh et al. (1996) has shown that urinary and slurry pH is strongly influenced by Ca-level and Ca-salt. With a higher $CaCO_3$ level in feed, the urinary and slurry pH increased, which led to more ammonia emission. Lower contents of $CaSO_4$, calcium benzoate and $CaCl_2$, on the other hand, also led to a higher urinary and slurry pH and more ammonia emission. This means that no conclusions can be drawn as to this experiment, because the separate effects of the salts on ammonia emission are not clear. Also the electrolyte balance can be an influencing factor. Research by Canh et al. (1996) showed that a lower balance of electrolytes (Na + K - Cl), in general, decreases the pH of urine and slurry. In this study, the electrolyte balances in acidified and control feed barely differed (194 meq/kg of feed and 197 meq/kg of feed respectively), so no effect on ammonia emission can be expected.

4.2 Ammonia emission

Ammonia concentration of incoming air, indicated as background concentration, was not continually recorded during the experiment, so a correction for the emission was not possible. That is why the ammonia emission data in table 4 might be an overestimation of the actual values. In comparable experiments in the area of emission, the corrected ammonia emission was, in general, 0 - 5% lower than the uncorrected value.

The course of ammonia emission was more or less comparable between the experimental and control groups per period, although it was almost continually higher in the control group than in the experimental group, except for the starting stage in period 3. This was partly due to a higher content of crude protein in the starter feed of the experimental group. The effect of acidified feed was most profound during the final stage in all three fattening periods. The higher acid concentration in growing/finishing feed in relation to starter feed led to a lower slurry pH and to less ammonia emission. The difference in ammonia emission between the two treatments was most striking in period 2 (summer

period). During summer ammonia emission is usually higher, due to higher temperatures of compartments and slurry, and to increased pen dirtiness. The course of emission from the control group in period 2 was fairly normal. The course of emission from the experimental group in period 2 showed a deviant, flatter course. A decreased pH of the urine and the top layer of the slurry in the pit appeared to have a greater influence on ammonia emission than increased temperature. Srinath and Loehr (1974) have confirmed this effect. Their experiment dealt with the effect of pH and temperature on the amount of free ammonia in the slurry. With a higher slurry pH than 7.5 - 8, the amount of free ammonia increased as pH or temperature rose. With a pH lower than 7.5, the amount of free ammonia proved to decrease considerably, without the temperature having effects.

During this experiment, also odour emission in the experimental compartment was measured according to the Working group on Emission Factors (1995) procedure, the first results of which are in Verdoes and Ogink (1997). The odour emission was, on average, 14.21 odour units per pig place per second, meaning a reduction of 37% compared to traditional housing. After correcting for the amount of ventilation, reduction was even 64%. Reduction in ammonia emission, therefore, was accompanied by a reduction in odour emission in this experiment. The final results will be published in 1999.

4.3 Feed composition and performance

The amount of crude protein in the starter and growing/finishing feeds analysed was 177 - 181 g/kg and 159 g/kg respectively (table 3) and met therefore the minimum standard for the protocol of Green Label.

The analysis of the composition of feed used in this experiment revealed that, in a number of cases, the values measured did not correspond to the composition that was calculated beforehand. The crude fat content analysed was higher in the acidified starter and growing/finishing feeds and lower in the control feeds than calculated beforehand. By applying our method of analysis for determining crude fat content (extraction by means of petroleum ether 40 - 60 and a soxhlet apparatus), the benzoic acid present might be entirely or partly analysed as crude fat. An extra control-analysis of the different components in standard compound feed with different percentages of benzoic acid has confirmed this assumption. The results of these analyses are presented in appendix 7. With an increased benzoic acid content in feed, crude fat content analysed was increased. In the starting stage this correspondence was not straightforward, in the fattening stage a little. The contents of the other components were not influenced by adding benzoic acid.
The Ca-content in the experimental feeds was lower than in the control feeds. The calcium content analysed (4.8 g/kg) in the experimental growing/finishing feed (table 3) did not even meet the minimum CVB standard of 5.4 g/kg (Anonymous, 1996). Too low a calcium content may have an adverse effect on bone growth of the animal, but possibly not on performance.
The differences in crude protein and crude fibre among the several experimental feeds, particularly among the growing/finishing feeds, were slight. As can be expected, such differences will not affect performance much.
So, there is no reason to assume effects of the differences between the composition analysed and calculated on performance.

Water intake/feed utilization
Research by Mroz et al. (1997) has shown that acidifying pig feed with calcium benzoate and/or an organic acid will result in a reduction in water intake and therefore urine production. There was hardly any difference in the average water intake between the two treatments in this experiment in periods 1 and 2. In period 3 there was less water intake by the group with acidified feed (0.52 l/pig/day). No explanation could be found for this fact. The dry matter content of the slurry of the experimental group was, on average, 21 g/kg lower than in the control group (table 9). This was mainly due to the large difference in dry matter content of the slurry in period 1, while in periods 2 and 3

no differences could be seen.
The research by Mroz et al. (1997) has also shown that by adding organic acids to feed the digestibility is improved of, among other things, crude protein and some essential amino acids (both to 5%) and non-essential amino acids (to 9.8%). Acidified feed in combination with adding calcium benzoate (24 g/kg of feed) also led to an increased digestibility of the above-mentioned components, although to a lesser extent due to a lower buffer capacity (to 1.7, 2.4 and 4.3% respectively).
Our experiment has not shown improvement in growth by acidified feed, but yet a better feed conversion. This may be due to an improved digestibility of the amino acids.
The improved feed conversion of the experimental group compared to the group with control feed may partly explain the difference in composition of the slurry of both treatments (table 5). The NH_4-N and $N_{kjeldahl}$ contents in the slurry of the experimental group were, in all cases, lower than in the control group, possibly due to excreting fewer undigested nutrients.

4.4 Meat quality

In the summer period there is a higher chance of negative influences on meat quality, particularly as to the pH value (Klein Breteler et al., 1995). For this reason, the meat quality measurements were carried out in pigs in period 2. Possible differences are most likely in this period. However, the experiment did not show significant differences in meat quality characteristics between growing/finishing pigs receiving acidified feed (experimental group) and pigs fed control feed. It was striking, however, that the pH-cold of the meat (24 hours after slaughtering) in both treatments was below the optimal level of 5.6 to 5.8 (Van der Fels et al., 1997). Important possible causes are: circumstances on the day of slaughter, such as care entailed in transport, resting period between transport and moment of slaughter, outside temperature et cetera.
The pH-cold < 5.6 entails a higher risk of PSE-meat (Pale Soft Exudative) and a pH-cold of > 5.8 results in a higher risk of DFD-meat (Dry Firm Dark). In both treatments, the chance of PSE-meat is present, but is also dependent on other factors (Van der Fels et al., 1997). In the experiment there was a smaller decrease in pH of the meat (pH difference) in the experimental group compared to the control group during the first 24 hours after slaughtering. Although the pH of the meat was (too) low 24 hours after slaughtering and in both treatments, it seems that acidified feed affected the pH favourably. The difference, however, was small.

4.5 Benzoic acid

The acidified starter and growing/finishing feeds used in this experiment contained 0.7 and 1.4% of benzoic acid respectively. Using this acid in animal feed has not been permitted up to now (exemption was granted for this experiment).
Benzoic acid is, however, allowed and used in human food as a preservative, at a maximum of 0.1%. Besides the difference in concentration, the unvarying feed -pigs are given feed with only this acid- plays a role in total intake of this acid. Further research will be done for the purpose of preparing a file, necessary for getting benzoic acid in pig feed approved.

4.6 Economic evaluation

The difference in ammonia emission between the experimental group and traditional pig housing was not only caused by adjusted feed, but also by the housing system. In the economic calculation the extra housing costs in relation to traditional housing and the differences in feed costs have been distinguished.
In calculating the extra housing costs of the experimental compartment, the standard pig house (as described by Adams et al., 1998) has been used as a starting point. This is a barn for 1,840 growing/finishing pigs with compartments for 80 animals. The pens are partly provided with concrete slats and complete deep slurry pit. The extra investment and annual costs of the growing/finishing pig barn as used in this experiment compared to the standard barn were estimated at Dfl 42.- and Dfl 9.90 per growing/

finishing pig place (Adams et al., 1998). To determine possi ble differences between both experimental groups, a gross margin calculation was done. Feed price (excluding VAT at a minimum of 4 tons) of the control starter feed and the acidified feed was Dfl 46.80 and Dfl 48.77 per 100 kg respectively. The price of the control growing/finishing feed and the acidified growing/finishing feed was Dfl 41.40 and Dfl 45.23 respectively. The differences in feed prices did not only concern the extra costs of the acid mixture added of Dfl 1.50 per kg of product, but also the extra costs of the changed composition. Adding 1% of acid entails a 1% higher concentrated feed composition (metabolisable energy value of benzoic acid is not known; as yet the metabolisable energy is assumed to be zero). The feed company increased the base price of feed by 1% per percentage of acid addition, resulting in a price increase of Dfl 0.47 and Dfl 0.64 per 100 kg of acidified starter and growing/finishing feed respectively. In calculating gross margin the performance realized and the prices mentioned in KWIN-V (1996) were assumed. Other costs for, for example, disposal (3%) and health care were assumed to be equal, because no clear differences could be found in disposal and veterinary treatments.

The gross margins were calculated per average animal in a pen and tested as to differences by variance analysis, according to the same model as with performance. Table 14 shows the results of the economic evaluation. The number of fattening periods was assumed to be 3.17.

From table 14 can be seen that there were no significant differences in total returns per animal, gross margin per animal and gross margin per pig place per year. There were differences in total feed costs per animal ($p = 0.0006$). The feed costs in the experimental group were Dfl 5.55/animal, ie., 3.17 x 5.55 = Dfl 17.60/pig place per year higher than in the control group. Although under experimental conditions there could not be found any significant differences in gross margin between the two treatments (accounting for a lower energy conversion in the treatment), the gross margin per pig place per year in the experimental group was Dfl 5.66 lower than in the control group in the absolute sense. The total extra annual costs per pig place, including improved pen design, were in this study Dfl 5.66 + Dfl 9.90 = Dfl 15.56. Table 15 presents a schematic overview.

Table 14: Economic evaluation of growing/finishing pigs fed with control and acidified feed (experimental group) from start to finish

	control	treatment	SEM[1]	significance[2]
number of animals started	99	99		
number of pens	9	9		
total returns (Dfl/animal)	253.78	257.55	2.204	n.s.
average cost price piglet (Dfl/animal)	100.65	100.65		
total feed costs (Dfl/animal)	93.37	98.92	0.706	***
other costs (Dfl/animal)	14.62	14.62		
gross margin per period (Dfl/animal)	45.14	43.36	2.070	n.s.
gross margin per year (Dfl/pig place)	143.29	137.63	6.572	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; *** = ($P < 0.001$)

Table 15: Overview of extra costs of improved pen design compared to a traditional housing system, with or without using acidified feed

	ammonia emission (kg/ppl/yr)	extra investment costs (Dfl/ppl)[1]	extra annual costs (Dfl/ppl/yr)
traditional housing (concrete slats)	2.52		
improved pen design (metal slats)	2.0	42.00	9.90
improved pen design and acidified feed	1.2	42.00	15.56

[1] Dfl/ppl = Dfl per pig place

[2] 2.5 kg/pl/yr is fixed standard for a traditional housing system for growing/finishing pigs with a partly slatted floor with concrete slats

5 CONCLUSIONS

- The average pH of the urine of growing/finishing pigs fed with control and acidified starter feed was 7.50 and 5.69 respectively (difference is 1.81). For growing/finishing pigs fed with growing/finishing feed the pH of the urine was 7.48 and 5.02 respectively (difference is 2.46).
- The average pH of the top layer of the slurry of growing/finishing pigs fed with control and acidified feed was 7.76 and 7.28 respectively (difference is 0.48). For growing/finishing pigs fed with growing/finishing feed the pH of the top layer was 7.82 and 7.04 respectively (difference is 0.78).
- The improved pen in this study resulted in an ammonia emission of 2.04 kg per pig place per year (standard is 2.5 kg per pig place per year for traditional pen design). The combination of improved pen design and acidified feed resulted in an ammonia emission of 1.22 kg per pig place per year, a reduction of 40%. The ammonia emission rate calculated was not corrected for the ammonia concentration of incoming air.
- Feeding acidified feed to growing/finishing pigs in this research did not influence meat quality.
- Feeding acidified feed to growing/finishing pigs in this research improved the feed conversion by 0.08 (2.64 instead of 2.72). There was no influence on mortality rate.
- The additional feeding costs of using acidified feed in this research were calculated to be Dfl 17.60 per pig place per year. Because of a better feed conversion the gross margin in this research decreased by only Dfl 5.66 per pig place per year. Together with the extra annual costs of Dfl 9.90 per pig place for the improved pen design compared to a traditional housing system, the total extra annual costs were Dfl 5.66 + Dfl 9.90 = Dfl 15.56 per pig place.

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APPENDICES

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

	starter feed		growing/finishing feed	
	experiment	control	experiment	control
rye	5.0	5.0	15.0	15.0
barley	30.0	30.0	15.0	15.0
wheat	27.8	27.2	25.0	24.2
peas	3.5	3.5	14.5	13.0
maize gluten feed			7.1	6.5
rape seed extracted	3.0	3.0	2.3	2.5
soya beans extracted	15.2	14.0	6.5	7.3
wheat middlings	2.8	4.4	5.0	5.0
cane molasses	5.0	5.0	3.2	6.0
meat and bone meal	1.3	2.0		
animal fat	1.90	1.83	2.20	2.21
mervit methionine/cystine 393	0.55	0.56	0.35	0.36
mervit threonine 397	0.26	0.29	0.29	0.30
liquid lysine	0.76	0.78	0.56	0.57
calprona p	0.70	0.70		
mono calcium phosphate	0.33	0.22		0.02
salt	0.22	0.21	0.25	0.24
mervit starter 293	0.50	0.50		
mervit growing/finishing 736			0.50	0.50
mervit phytase 345	0.20	0.24	0.21	0.20
calcium carbonate		0.55		1.13
organic acids and salts	**1.0**		2.0	
Chemical composition calcula ted				
ME	13.55	13.55	13.43	13.43
water	131	132	130	134
ileal digestible lysine	8.4	8.4	7.0	7.0
ileal digestible meth. + cyst.	5.2	5.2	4.5	4.5
starch	380	380	400	388
calcium	7.3	7.3	6.3	6.3
phosphorus	4.8	4.8	4.1	4.1
digestible phosphorus	2.9	2.9	2.1	2.1
sodium	1.2	1.2	1.3	1.4
potassium	9.0	9.0	8.3	9.1
chloride	3.2	3.2	3.0	3.4
Contents per kg				
crude protein	169	170	150	150
crude fat	39	40	41	41
crude fi bre	39	40	40	39
ash	50	53	44	53

Appendix 2: Performance of growing/finishing pigs of compartments 1 and 2, fed with acidified feed

	period 1	period 2	period 3
starting date (number of animals)	29-12-1995 (66)	25-04- 1996 (66)	17-09-1996 (66)
1st delivery date (number of animals)	03-04-1996 (30)	07-08-1996 (19)	11-12-1996 (9)
2nd delivery date (number of animals)	17-04-1996 (36)	21-08-1996 (17)	20-12-1996 (18)
3rd delivery date (number of animals)	-	04-09- 1996 (30)	03-01-1997 (38)
starting weight (kg)	26.2	24.6	24.6
slaug hter weig ht (kg)	84.7	85.6	84.5
growth (kg/pig/day)	806	715	842
feed conversion	2.45	2.64	2.42
feed intake (kg/pig/day)	1.97	1.89	2.04
disposal percentage (%)	0	0	1.5

Appendix 3: Chemical composition analysed of standard feed (control) and acidified feed (experiment) in g/kg

	period 1		period 2		period 3	
	control	experiment	control	experiment	control	experiment
Starter feed[1]						
number			1	1	1	1
dry matter			88.1	89.1	87.4	87.9
crude protein			178	176	176	185
crude fat			36	38	36	41
crude fibre			49	46	52	45
calcium			8.0	6.2	7.4	6.6
ash			55	53	49	48
Growing/finishing feed						
number	2	2	2	2	2	2
dry matter	88.2	89.2	88.7	88.8	87.7	87.7
crude protein	156	159	163	160	159	159
crude fat	33	45	35	48	36	47
crude fibre	42	42	45	49	45	47
calcium	6.1	4.4	7.0	5.0	8.3	4.9
ash	49	46	52	47	53	47

[1] no data on period 1 available

Appendix 4: Temperature, ventilation flow, ammonia concentration and ammonia emission per pig place per year for growing/finishing pigs fed with control and acidified feed

	control feed	acidified feed
Period 1	*(29-12-1995 till 17-4-1996)*	*(29-12-1995 till 17-4-1996)*
% of measuring days	94	*94*
temperature1 (°C)	19.9	*20.9*
ventilation flow (m^3/hr)	2,406	*2,388*
ammonia concentration1 (mg/m^3)	6.40	*4.80*
ammonia emission2 (kg/ppl/yr)	1.82	1.32
reduction in ammonia emission (%)	-	28
Period 2	*(25-4-1996 till 4-9-1996)*	*(25-4-1996 till 21-8-1996)*
% of measuring days	98	*97*
temperature1 (°C)	23.5	*22.9*
ventilation flow (m^3/hr)	3,838	*3,711*
ammonia concentration1 (mg/m^3)	5.78	3.28
ammonia emission2 (kg/ppl/yr)	2.61	1.31
reduction in ammonia emission (%)	-	50
Period 3	*(17-9-1996 till 3-1-1997)*	*(17-9-1996 till 3-1-1997)*
% of measuring days	94	*94*
temperature1 (°C)	20.5	*21.4*
ventilation flow (m^3/hr)	2,584	*2,770*
ammonia concentration1 (mg/m^3)	5.26	4.19
ammonia emission2 (kg/ppl/yr)	1.52	1.31
reduction in ammonia emission (%)		13

1 of removed air

2 not corrected for background concentration

Appendix 5: Average pH of slurry and fresh urine from growing/finishing pigs fed with control or acidified (experimental) feed per period

	period 1		period 2		period 3	
	control	experiment	control	experiment	control	experiment
slurry pH:						
fattening period	7.84 (13)[1]	6.97 (13)	7.76 (13)	7.16 (13)	7.97 (3) 7.90 (11)	6.94 (3) (11)
urinary pH:						
fattening period	7.56 (2)	5.18 (2)	7.41 (2)	5.85 (1) (2)	7.67 (2) (3)	5.09 (2) (3)

[1](..) = number of observations

Appendix 6: Frequency distribution (number of animals) of the meat characteristics type judgment, drip loss and Japanese colour scale

	experimental group	control group	significance[1]
type judgment:			
number of AA type animals	2	2	
number of A type animals	30	29	n.s.
number of B type animals	1	2	
drip loss:			
score 0	3	6	
score 1	16	12	
score 2	7	7	n.s.
score 3	4	1	
score 4	2	5	
score 5	1	2	
Japanese colour scale:			
score 1	1	0	
score 2	0	2	
score 3	16	15	n.s.
score 4	15	16	
score 5	1	0	

[1] significantie: n.s. = not significant

Appendix 7: Chemical composition analysed (g/kg) of control feeds with different percentages of benzoic acid

Starter feed (ME = 13.55 MJ)	amount of benzoic acid added:			
	0%	0.7%	1.4%	2.1%
dry matter	892	891	891	889
crude protein	179	178	177	176
crude fat	43	45	50	51
crude fi bre	55	55	51	52
calcium	6.6	6.7	6.7	6.7
ash	53	52	52	52

Growing/finishing feed (ME = 13.43 MJ)	amount of benzoic acic added:			
	0%	1.4%	2.8%	4.2%
dry matter	888	888	885	879
crude protein	164	162	160	159
crude fat	56	65	72	81
crude fibre	68	71	67	66
calcium	6.5	6.4	6.3	6.4
ash	58	57	57	55

Remark: Objective of this analysis was to examine whether with the determination of the crude fat content in feed (extraction by means of petroleum ether 40 - 60 in a soxhlet apparatus) also the benzoic acid would be analysed as crude fat. The results above confirm this assumption. In the experiment 1 and 2% of the acid mixture was added to starter and growing/finishing feed respectively, of which 0.7 and 1.4% respectively was benzoic acid. That is why in this test experiment each time a multiple concentration of benzoic acid has been added to the samples of feed.

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