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Report 133

Ammonia emission factor for using benzoic acid (1% VevoVitall®) in the diet of growing-finishing pigs

July 2008

ANIMAL SCIENCES GROUP
WAGENINGEN UR

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Colophon

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Abstract
The ammonia emission reduction of adding benzoic acid (1% VevoVitall®) to the diet of growing-finishing pigs was determined and amounted on average 15.8% compared to a diet without VevoVitall.

Keywords
ammonia, emission, benzoic acid, nutrition, pigs

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Samenvatting
Het effect van toevoeging van benzoëzuur (1% VevoVitall®) aan vleesvarkensvoer op de ammoniakemissiereductie is bepaald en bedroeg gemiddeld 15,8% ten opzichte van voer zonder VevoVitall®.

Trefwoorden
ammoniak, emissie, benzoëzuur, voeding, varkens

ANIMAL SCIENCES GROUP
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Report 133

Ammonia emission factor for using benzoic acid (1% VevoVitall®) in the diet of growing-finishing pigs

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July 2008

Samenvatting

De hoofddoelstelling van dit project was het effect te bepalen van toevoeging van 1% benzoëzuur (VevoVitall®) aan vleesvarkensvoer op de ammoniakemissie uit de stal en te bepalen of dit effect onafhankelijk is van het huisvestingssysteem dat toegepast wordt. Aanvullend is het effect van VevoVitall® op de emissies van geur en broeikasgassen (methaan en lachgas) bepaald. De studie is op vier vleesvarkensbedrijven uitgevoerd. Deze bedrijven hadden huisvestingssystemen die veel voorkomen in de vleesvarkenshouderij:

Bedrijf 1. Gedeeltelijk roostervloerstal: (ammoniakemissie: 2,5 kg per varkensplaats per jaar; Rav-nummer D.3.4.1[1]).

Bedrijf 2. Optimaal hok met betonnen roosters, met schuine putwanden en een maximaal emitterend oppervlak van 0,18 m^2 per varken (ammoniakemissie: 1,2 kg per varkensplaats per jaar; Rav-nummer D.3.2.7.2.1).

Bedrijf 3. Optimaal hok met metalen roosters (ammoniakemissie: 1,4 kg per varkensplaats per jaar; Rav-nummer D.3.2.10.1).

Bedrijf 4. Gedeeltelijk roostervloerstal met koeling van de mest; geen metalen roostervloer (ammoniakemissie: 2,0 kg per varkensplaats per jaar; Rav-nummer D.3.2.6.2.2).

Dit project is uitgevoerd in twee fasen. In de eerste fase is het effect van VevoVitall® bepaald op Bedrijf 1. In de tweede fase van het project is het effect van VevoVitall® bepaald op Bedrijf 2, 3 en 4. Fase 1 is uitgevoerd van april tot december 2005 in acht afdelingen, gedurende twee volledige mestronden en een deel van de derde mestronde. VevoVitall® (1%) werd in vier van de acht afdelingen aan het voer toegevoegd. In de andere vier afdelingen, de controleafdelingen, werd een vergelijkbaar voer verstrekt zonder VevoVitall® toevoeging. Fase 2 is uitgevoerd van augustus 2006 tot augustus 2007, gedurende drie vleesvarkensronden. Op Bedrijf 2 en Bedrijf 4 werd het onderzoek gedaan in vier afdelingen, twee afdelingen zonder en twee afdelingen met 1% VevoVitall® in het voer. Op Bedrijf 3 werd het onderzoek in drie afdelingen gedaan, één afdeling zonder en twee afdelingen met 1% VevoVitall® in het voer. Voordat de bedrijven startten met het voeren van VevoVitall® werden de mestkelders leeggemaakt. De ammoniakemissiemetingen startten tenminste één maand na het starten met het voeren van VevoVitall®. Het groeitraject van de varkens was ongeveer van 25 tot 110 kg. De varkens werden onbeperkt of vrijwel onbeperkt gevoerd met brijbakken.

De ammoniakemissie is op elk bedrijf en in elke afdeling zesmaal gedurende 24 uur bepaald. De metingen werden verspreid over het jaar en verspreid over de groeiperiode verricht. De ammoniakemissie is berekend uit de hoeveelheid lucht die de stal verliet en de concentratie ammoniak in die lucht. De achtergrondconcentraties van ammoniak waren laag en werden daarom niet meegenomen in de berekeningen. Gedurende drie van de zes meetdagen voor ammoniak, werden tevens monsters genomen voor het bepalen van de concentraties en emissies van geur en broeikasgassen (methaan en lachgas), in één controle- en één VevoVitall® afdeling op Bedrijf 2, 3 en 4. Tijdens elke meetdag voor ammoniak werden tevens urinemonsters genomen van drie of vier varkens per afdeling. Van deze monsters werd direct op locatie de pH bepaald.

De resultaten lieten een significant effect zien van toevoeging van 1% VevoVitall® aan vleesvarkensvoer op de ammoniakemissie ($P = 0,011$). In dit onderzoek verlaagde VevoVitall® de ammoniakemissie gemiddeld van 2,58 tot 2,17 kg/jaar per varkensplaats (s.e.d. 0,14), ofwel een reductie van 15,8%. Er werd geen interactie gevonden tussen het effect van VevoVitall® en het effect van het Bedrijf (huisvestingssysteem) ($P = 0,503$). Het bedrijf (huisvestingssysteem) had een significant effect op de ammoniakemissie ($P < 0,001$). VevoVitall® verlaagde de pH van de urine ($P < 0,001$). De pH was gemiddeld 6,50 voor de controlegroep en 5,29 voor de VevoVitall® groep (s.e.d. 0,089). VevoVitall® had geen effect op de geuremissie ($P = 0,781$). De medianen van de geuremissie waren respectievelijk 16,2 en 14,6 ou_E/s voor de controle en de VevoVitall® behandelingen (s.e.d. at log-scale = 0,39). VevoVitall® had ook geen effect op de emissies van broeikasgassen. De methaanemissies waren gemiddeld respectievelijk 27,5 en 28,1 g/d per varken voor de controle en de VevoVitall® behandelingen (s.e.d. = 6,4; $P = 0,926$). De gemiddelde lachgasemissies waren respectievelijk 0,85 en 0,91 g/d per varken voor de controle en de VevoVitall® behandelingen (s.e.d. = 0,19; $P = 0,759$).

Uit dit onderzoek kunnen we concluderen dat toevoeging van 1% VevoVitall® aan het voer van vleesvarkens de ammoniakemissie significant verlaagt. Dit effect werd niet beïnvloed door het huisvestingssysteem. Toevoeging van 1% VevoVitall® had geen effect op de emissies van geur of broeikasgassen.

[1] Rav-nummers zijn vermeld in de 'Regeling Ammoniak en Veehouderij'

Summary

The main aim of this project was to determine the effect of using 1% benzoic acid (VevoVitall®) in the diet of growing-finishing pigs on the ammonia emission from the pig house and to determine whether this effect interacts with the housing system being used. Additionally the effects of VevoVitall® on emissions of odour and greenhouse gases (methane and nitrous oxide) were determined. The study was done on four farms with growing-finishing pigs with housing systems that are mostly used at the moment in The Netherlands. The study was done with the following housing systems:

Farm 1. Partly slatted floor (ammonia emission: 2.5 kg per pig place per year; Rav-number[2] D.3.4.1).
Farm 2. Optimal pen design with concrete slatted floor, with sloped pit walls and a maximum emitting area of 0.18 m^2 per pig (ammonia emission: 1.2 kg per pig place per year; Rav-number D.3.2.7.2.1).
Farm 3. Optimal pen design with metal slatted floor (ammonia emission: 1.4 kg per pig place per year; Rav-number D.3.2.10.1).
Farm 4. Partly slatted floor with cooling of manure; no metal slatted floor (ammonia emission: 2.0 kg per pig place per year; Rav-number D.3.2.6.2.2).

The study was done in two phases. In the first phase the effect of VevoVitall® was determined at Farm 1. In the second phase of the study the effect of VevoVitall® was determined at Farms 2, 3 and 4. Phase I of the study was conducted from April to December 2005, during two full fattening periods and a part of a third fattening period in 8 rooms. VevoVitall® (1%) was added to the diet in four of the eight rooms. In the other four rooms, the control rooms, a similar diet without VevoVitall® was fed. Phase II of the study was conducted from August 2006 to August 2007, during three fattening periods. At Farm 2 and Farm 4 four rooms were included in the study, two rooms without and two rooms with 1% VevoVitall® in the diet. At Farm 3 three rooms were included in the study, one room without and two rooms with VevoVitall® in the diet. Before starting to feed VevoVitall® the farmers emptied there manure pits. Ammonia emission measurements were started at least one month after the start of feeding VevoVitall®. The growing period of the pigs was approximately from 25 to 110 kg. They were fed *ad libitum* or almost *ad libitum* with feed hoppers.

Ammonia emission was determined six times 24 hours, spread over the year and spread over the growing period. Ammonia emission was calculated from the volume of air leaving the room by the fan shaft and the concentration of ammonia in that air. Background concentrations were low and therefore neglected. During three out of the six measuring days for ammonia, samples were taken for determining concentrations and emissions of odour and greenhouse gases (methane and nitrous oxide), in one control room and one VevoVitall® room at Farms 2, 3, and 4. During every measuring day for ammonia, urine samples were taken from three or four pigs within each room. The pH of each sample was measured directly at the location.

The results showed a significant effect of 1% VevoVitall® addition to the diet of growing finishing pigs on ammonia emission ($P = 0.011$). In this study VevoVitall® in the diet reduced ammonia emission on average from 2.58 to 2.17 kg/y per pig place (s.e.d. 0.14), equalling a reduction of 15,8%. No interaction was found between the effect of VevoVitall® and Farm (housing system) ($P = 0.503$). Farm had a significant effect on ammonia emission ($P < 0.001$). VevoVitall® lowered the pH of the urine ($P < 0.001$). The pH was on average 6.50 for the control treatment and 5.29 for the VevoVitall® treatment (s.e.d. 0.089). VevoVitall® had no effect on odour emission ($P = 0.781$). Median odour emissions were 16.2 and 14.6 ou_E/s for the control and VevoVitall® treatments, respectively (s.e.d. at log-scale = 0.39). VevoVitall® had no effect on emissions of greenhouse gases, as well. Mean methane emissions were 27.5 and 28.1 g/d per pig for the control and VevoVitall® treatments, respectively (s.e.d. = 6.4; $P = 0.926$). Mean nitrous oxide emissions were 0.85 and 0.91 g/d per pig for the control and VevoVitall® treatments, respectively (s.e.d. = 0.19; $P = 0.759$).

It is concluded that addition of 1% VevoVitall® to the diet of growing-finishing pigs significantly lowers ammonia emission from houses for growing-finishing pigs. This effect was not influenced by housing system. Addition of 1% VevoVitall® had no effect on the emissions of odour and greenhouse gases.

[2] Rav-numbers are listed in the 'Regeling Ammoniak en Veehouderij'

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1 Introduction

Addition of VevoVitall® to the diet of pigs can reduce ammonia emission considerably Canh et al. (1998). VevoVitall mainly consists of benzoic acid (99.9%) and is produced and distributed by DSM. Benzoic acid is an aromatic compound with the chemical formula C_6H_5COOH. It is converted in the liver to hippuric acid, which is excreted in the urine. Hippuric acid is a weak acid which lowers the pH of urine and increases the buffer capacity of urine. In this way the pH of manure is lowered, as well. In a study of Canh et al. (1998) finishing pigs in metabolism cages were given 18.4 and 36.8 g/kg of benzoic acid, in the form of Ca-benzoate. Ammonia emission, measured in a laboratory set up, was reduced by 50 and 60%, respectively. In a study at the Pig Research Station in Raalte addition of 7 and 14 g/kg of benzoic acid to diets of growing pigs and finishing pigs, respectively, reduced ammonia emission by 40%, on average (Brok et al., 1999). In this study, however, the effect on ammonia emission was not statistically significant and the effect was confounded with the Ca-level in the diet.

DSM wants VevoVitall® being implemented in the Rav (Regulation to ammonia control in animal production) (Infomil, 2004). In this way VevoVitall® is officially recognized as a low ammonia emitting system in pig production and it will get an emission factor for ammonia (in kg ammonia per pig place per year).

Because VevoVitall® alone will not reach the threshold value of 1.4 kg per pig place per year, necessary to be recognized as a low emitting system, this product will be tested in combination with different (low) emitting housing systems. Our hypothesis was that the relative effect of Vevovitall® is independent of the housing system being used. The working mechanism of Vevovitall® is based on shifting the equilibrium in urine and manure from the volatile ammonia to the ionized and non-volatile ammonium. The principle of low emission systems are mainly based on reducing the emitting manure surface or cooling the manure. Scientifically no interaction is expected between emitting surface area and pH of manure or between manure temperature and pH of manure. The effect of Vevovitall® might be different for low emission systems that affect the pH of manure, e.g. acidification of manure. Acidification of manure, however, is not done at the moment in Dutch pig houses. The hypothesis of independency of housing systems was tested for some main housing systems for fattening pigs in The Netherlands at this moment:

1. Partly slatted floor (ammonia emission: 2.5 kg per pig place per year; Rav-number D.3.4.1).
2. Optimal pen design with concrete slatted floor, with sloped pit walls and a maximum emitting area of 0.18 m^2 per pig (ammonia emission: 1.2 kg per pig place per year; Rav-number D.3.2.7.2.1).
3. Optimal pen design with metal slatted floor (ammonia emission: 1.4 kg per pig place per year; Rav-number D.3.2.10.1).
4. Partly slatted floor with cooling of manure; no metal slatted floor (ammonia emission: 2.0 kg per pig place per year; Rav-number D.3.2.6.2.2).

The aim of this project was to determine the effect of using 1% VevoVitall® in the diet of growing-finishing pigs on the ammonia emission and to determine whether this effect interacts with the housing system being used. According to the EU registration 1% Vevovitall® is the maximum amount that can be added to the diet of growing-finishing pigs. Most of the houses for growing-finishing pigs in The Netherlands have one of the four systems as used within this study, or very similar systems. In the Starting Note (Levrouw et al., 2006), sent to the Technical Advising Committee, it is proposed to add VevoVitall® to the RAV list as a measure to reduce ammonia emission from houses for growing-finishing pigs with a certain percentage, the so-called emission factor; this percentage is determined within this study.

The study was done in two phases. In the first phase the effect of 1% VevoVitall® in the diet was determined in the above mentioned housing system 1 (partly slatted floor, Rav-number D.3.4.1). In the second phase of the study the effect of VevoVitall® was determined in housing systems 2 to 4. The first phase of the study was already reported in Aarnink et al. (2006) and was initially performed for an European registration of VevoVitall®. Within this report both phases of the study are reported. In the second phase of the study additional measurements were done on emissions of odour and green house gases (methane and nitrous oxide). We did not expect any effect of VevoVitall® in the diet on emission of fine dust, therefore this parameter was not measured within this study.

2 Material and methods

2.1 General plan

Phase I of the study on the housing system with Rav-number D.3.4.1 was conducted from April to December 2005, during two full fattening periods and a part of a third fattening period. At the 20th of April, one week after all the manure pits were emptied, the farmer started feeding the experimental diet with 1% VevoVitall® to the pigs in 4 of the 8 rooms. In the other 4 rooms a similar diet without VevoVitall® was fed. Ammonia emissions from the 8 rooms were measured 6 times during 24 hours, from May to December. The first measurement took place approximately one month after the start of feeding the experimental diets.

Phase II of the study on housing systems with Rav-numbers D.3.2.7.2.1, D.3.2.10.1 and D.3.2.6.2.2 was conducted from August 2006 to August 2007, during three fattening periods. At two of the three farms four rooms were included in the study, two rooms without VevoVitall® in the diet and two rooms with VevoVitall® in the diet. For practical reasons, on the third farm three rooms were included in the study, one room without VevoVitall® in the diet and two rooms with VevoVitall® in the diet. Before starting to feed VevoVitall® the farmers emptied there manure pits. Ammonia emission measurements were started at least one month after the start of feeding VevoVitall®. Ammonia emission was measured 6 times 24 hours, spread over the year and spread over the growing period.

2.2 Housing

In phase I the measurements were done at a practical farm for fattening pigs (Farm 1). This farm had one building for fattening pigs with nine rooms. There were approximately 80 animals per room housed in eight pens (ten animals per pen). The space per animal was 0.7 m^2; total pen space was 7.2 m^2. 60% of the pen area had a concrete slatted floor; the other 40% was a solid concrete floor. Each room was ventilated with a fan of 50 cm diameter. The inlet air came from the main alley through automatically controlled valves. Ventilation rate was fully automatically controlled and depended on the age of the pigs and the temperature in the room.

Underneath the slatted and solid floors there were manure pits of 1.25 m depth. The manure pits under the solid floor and the slatted floor were physically separated by a wall with only small openings at the bottom. So manure could go underneath the solid floor, but there was no air exchange between these two manure pits. At the 13th of April, one week before the start of the experiment, all manure pits were emptied. **This farm is called Farm 1** in the rest of the report.

In phase II the measurements were done at the following locations:

1. **Farm 2.** This farm had a house for growing-finishing pigs with 17 rooms for 132 animals, each. Two control rooms with standard diets were compared with two rooms with 1% VevoVitall® in the diet. The first round started at 28th of August 2006. Rooms were pair wise filled with a maximum of 1 week in between a control and a VevoVitall® room. The housing system had an emission factor of 1.2 kg of ammonia per pig per year. The pen had a convex solid floor with concrete slatted floors in the front and in the back of the pen. The manure channel in front of the pen was a water channel and the manure channel in the back of the pen had a slanting plate to reduce the emitting surface area of the manure. The manure channels had a depth of approximately 0.80 m. Manure was removed every 1.5 to 2.5 months at the same date from all the rooms. The pen area per pig was approximately 0.80 m^2. The full requirements of this system with Rav-code D 3.2.7.2.1 can be found at the Infomil-website (Infomil, 2007). **This farm is called Farm 2** in the rest of the report.
2. **Farm 3.** At this farm three rooms for 110 growing-finishing pigs were used. One control room with standard diets were compared with two rooms with 1% VevoVitall® in the diet. The first round started at 22nd of August 2006. The three rooms were filled with an interval in between of approximately 2 weeks. The housing system had an emission factor of 1.4 kg of ammonia per pig per year. The pen is a so called 'ideal pen' (Verhoeven system) and had a convex solid floor with concrete slats in the front of the pen and metal slats in the back of the pen. The manure channel in front of the pen was a water channel and the manure channel in the back of the pen mainly collected the urine and faeces. The manure channels had a depth of approximately 0.75 m. Manure was removed after each fattening period. The pen area per pig was approximately 0.84 m^2. The full requirements of this system with Rav-code D 3.2.10.1 can be found at the Infomil-website (Infomil, 2007). **This farm is called Farm 3** in the rest of the report.

3. **Farm 4.** This farm had a house for growing-finishing pigs with eight rooms for 80 animals, each. Two control rooms with standard diets were compared with two rooms with 1% VevoVitall® in the diet. The first round started at 14th of August 2006. Rooms were pair wise filled with a 1 week interval between a control and a VevoVitall® room. The housing system had an emission factor of 2.0 kg of ammonia per pig per year. The pen had a convex solid floor with metal slatted floors in the front and in the back of the pen. The manure channel had a depth of approximately 2.25 m. A big part of the manure was removed once during the whole measuring period, in April 2007. The pen area per pig was approximately 0.80 m^2. The full requirements of this system with Rav-code D 3.2.6.2.2 can be found at the Infomil-website (Infomil, 2007). **This farm is called Farm 4** in the rest of the report.

2.3 Experimental design

Phase I, Farm 1
At the start, rooms were randomly assigned to treatment (figure 1) and they kept the same treatment during the whole measuring period. Rooms were filled with pigs in pairs of two rooms; one treatment room (diet with VevoVitall®) and one control room (diet without VevoVitall®).
In figure 1 the assignment of the rooms to experimental and control diets is given. During the whole measuring period room 6 was empty.

Figure 1 Assignment of the experimental and control diets to the rooms at Farm 1

Room 1	Room 2	Room 3	Room 4	Room 5	Room 6	Room 7	Room 8	Room 9
Vevo Vitall®	control	Vevo Vitall®	Vevo Vitall®	Control	empty	Vevo Vitall®	control	control
Central alley								

In table 1 the starting dates and the finishing dates of the fattening periods in the different pairs of rooms are given. The age difference between the two rooms in each pair was aimed to be not more than 2 weeks. The diets were assigned to the rooms in such a way that two of the rooms with VevoVitall® in the diet had the oldest pigs within a pair and two the youngest pigs. Two times the difference in age was more than two weeks within a pair. In those occasions pigs in one room were just filled with young pigs, while the pigs in the other room still needed to be delivered to the slaughterhouse. Because the heavy pigs were delivered a few weeks before the rest of the pigs, during every measuring period there was always one room with less pigs than 80.

Table 1 Starting and finishing dates of the fattening periods in the different pairs of rooms at Farm 1

Room	Pair	Diet	First fattening period		Second fattening period		Third fattening period	
			Start	Finish	Start	Finish	Start	Finish
1	A	VevoVitall®	05-04-05	18-07-05	26-07-05	09-11-05	15-11-05	01-03-06
2	B	Control	22-03-05	06-07-05	12-07-05	26-10-05	01-11-05	15-02-06
3	B	VevoVitall®	07-03-05	23-06-05	28-06-05	12-10-05	18-10-05	01-02-06
4	C	VevoVitall®	21-02-05	08-06-05	14-06-05	28-09-05	04-10-05	18-01-06
5	C	Control	08-02-05	25-05-05	31-05-05	14-09-05	20-09-05	06-01-06
7	D	VevoVitall®	19-05-05	31-08-05	06-09-05	22-12-05	-	-
8	D	Control	03-05-05	18-08-05	23-08-05	07-12-05	13-12-05	29-03-06
9	A	Control	19-04-05	05-08-05	09-08-05	23-11-05	03-12-05	15-03-06

Phase II, Farm 2
At the start treatments were assigned to the rooms as shown in figure 2. The rooms kept the same treatment during the whole measuring period. Rooms were filled with pigs in pairs of two rooms; one treatment room (diet with VevoVitall®) and one control room (diet without VevoVitall®).

Figure 2 Assignment of the experimental and control diets to the rooms at Farm 2

	Room 5 control	Room 7 VevoVitall®	
	Room 6 VevoVitall®	Room 8 Control	

In table 2 the starting dates and the finishing dates of the fattening periods in the different rooms are given. The age difference between the two rooms within each pair was not more than 1 week.

Table 2 Starting and finishing dates of the fattening periods in the different rooms of Farm 2

Room	Pair	Diet	First fattening period		Second fattening period		Third fattening period	
			Start	Finish	Start	Finish	Start	Finish
5	A	Control	22-8-2006	22-12-2006	29-12-2006	21-4-2007	28-4-2007	26-8-2007
6	A	VevoVitall®	15-8-2006	20-12-2006	27-12-2006	19-4-2007	26-4-2007	24-8-2007
7	B	VevoVitall®	16-8-2006	5-12-2006	12-12-2006	4-4-2007	11-4-2007	9-8-2007
8	B	Control	8-8-2006	6-12-2006	13-12-2006	5-4-2007	12-4-2007	10-8-2007

Phase II, Farm 3
At the start treatments were assigned to the rooms as shown in figure 3. Treatments were assigned to these rooms during the first two fattening periods. In the last fattening period the treatments of room 6 and 7 were exchanged between each other.

Figure 3 Assignment of the experimental and control diets to the rooms at Farm 3 during the first two fattening periods. In the last fattening period the treatments of room 6 and 7 were exchanged between each other

	Room 5 VevoVitall®	Room 6 VevoVitall®	Room 7 Control	

In table 3 the starting dates and the finishing dates of the fattening periods in the different rooms are given. The age difference between one control and one VevoVitall room was not more than 17 days.

Table 3 Starting and finishing dates of the fattening periods in the different rooms of Farm 3

Room	Pair	Diet	First fattening period		Second fattening period		Third fattening period	
			Start	Finish	Start	Finish	Start	Finish
5	A	VevoVitall®	22-8-2006	20-12-2006	27-12-2006	1-5-2007	8-5-2007	5-9-2007
6	A	VevoVitall®	4-9-2006	2-1-2007	9-1-2007	15-5-2007	22-5-2007	19-9-2007
7	A	Control	21-9-2006	19-1-2007	26-1-2007	29-5-2007	5-6-2007	3-10-2007

[1] In the third fattening period treatments in room 6 and 7 were exchanged after emptying the manure pits

Phase II, Farm 4

At the start treatments were assigned to the rooms as shown in figure 4. The rooms kept the same treatment during the whole measuring period. Rooms were filled with pigs in pairs of two rooms; one treatment room (diet with VevoVitall®) and one control room (diet without VevoVitall®).

Figure 4 Assignment of the experimental and control diets to the rooms at Farm 4

	Room 5 control	Room 6 VevoVitall®	Room 7 Control	Room 8 VevoVitall®	

In table 4 the starting dates and the finishing dates of the fattening periods in the different rooms are given. The age difference between the two rooms within each pair was not more than 2 weeks.

Table 4 Starting and finishing dates of the fattening periods in the different rooms of Farm 4.

Room	Pair	Diet	First fattening period		Second fattening period		Third fattening period	
			Start	Finish	Start	Finish	Start	Finish
5	A	Control	14-8-2006	27-11-2006	4-12-2006	27-3-2007	3-4-2007	1-8-2007
6	A	VevoVitall®	21-8-2006	11-12-2006	18-12-2006	3-4-2007	10-4-2007	8-8-2007
7	B	Control	28-8-2006	11-12-2006	18-12-2006	10-4-2007	17-4-2007	15-8-2007
8	B	VevoVitall®	4-9-2006	12-12-2006	19-12-2006	11-4-2007	18-4-2007	16-8-2007

2.4 Diets and animals

Phase I, Farm 1

Pigs were fed *ad libitum* with dry feeders with a maximum daily feed gift of 2.5 kg per pig. In the morning the feed hoppers were filled. A drinking nipple was located in the trough of the dry feeders. The diets were formulated using the Bestmix optimizing program. Compositions of the control and treatment diets were very similar. Net energy, protein, and amino acids compositions of the diets were very similar. Only minor differences regarding basal feed ingredients can be seen, because VevoVitall® has no nutritional value, so this needed to be compensated by other compounds. The calculated compositions of the control and the VevoVitall® diets are shown in Appendix 1. In Appendix 1 compositions are given for the starter diets (fed during 3 weeks from the start) and for the finishing diets (fed during the rest of the fattening period). No extra acids or other (anti microbial) additives were added to the diets or to the drinking water. The diets were fed as pellets.

Pigs were commercial breeds (♀ rotation cross x ♂ Duroc) and had initial live weights of on average 26 kg and final slaughter weights of on average 90 kg. There were equal numbers of gilts and barrows in each room. Gilts and barrows were housed in different pens. The general health state of the pigs was very good. This resulted in a low percentage of culled animals, on average 1%, and a high growth rate, on average 860 g/d.

Samples of the control and VevoVitall® diets were taken to check the VevoVitall® content of the diet. All samples of control diets did not contain any benzoic acid .The results of in-feed analyses of the VevoVitall® diet are summarized in table 5.

Table 5 Analysed amount of benzoic acid in the VevoVitall® diet

Product number	Sampling date	Benzoic acid (w/w %)
6855 (starter)	18-05-'05	1.00
6855 (starter)	08-06-'05	0.97
6895 (finishing)	21-04-'05	1.01
6895 (finishing)	02-05-'05	0.98
6895 (finishing)	12-05-'05	0.97
6895 (finishing)	18-05-'05	0.98
6895 (finishing)	30-05-'05	1.02
6895 (finishing)	08-06-'05	1.00
6895 (finishing)	20-06-'05	1.00

Phase II, Farm 2

Pigs were fed by feed hoppers with dry feed. During the first 1.5 months they were fed *ad libitum*. During the rest of the fattening period they were fed restrictedly. A drinking nipple was located in the trough of the dry feeders. The diets were formulated using the Libra optimizing program. The following diets were fed: 'Super Startkorrel', codes 23124 and 23161 (starting diet), fed during the first 3.5 weeks, 'Standaard Groei', codes 24744 and 24081 (standard growth diet), fed during approximately 2 weeks, 'Standaard Vleesvarkens', codes 24464 and 24091 (standard fattening diet), fed during the rest of the fattening period. Compositions of the control and treatment diets were similar. Net energy, protein, and amino acids compositions of the diets were very similar. Only some differences regarding basal feed ingredients can be seen, because VevoVitall® has no nutritional value, so this needed to be compensated by other compounds. The calculated compositions of the control and the VevoVitall® diets are shown in Appendix 2. To the control starting diet 5 g/kg and to the control growth and fattening diets 1 g/kg of organic acids were added.

Pigs were commercial breeds (♀ rotation cross x ♂ 'Tempobeer') and had initial live weights of approximately 23 kg and final live weights of approximately 110 kg. Approximately equal number of gilts and barrows were housed in each room and they were mixed within the different pens.

Phase II, Farm 3

Pigs were fed by feed hoppers with dry feed. Gilts were fed *ad libitum* during the whole growing-finishing period. Castrates boars were fed restrictedly at the end of the fattening period at a level of approximately 2.6 kg/d per animal. During the rest of the fattening period they were a bit restricted in their feed. A drinking nipple was located in the trough of the dry feeders. The diets were formulated using the Libra optimizing program. The following diets were fed: 'Super Startkorrel', codes 23124 and 23161 (starting diet), fed during the first 4 weeks, 'Standaard Vleesvarkens', codes 24464 and 24091 (standard fattening diet), fed during the rest of the fattening period until February and 'Sel. Vleesvarkens', codes 240009 and 24101 (special fattening diet), from March onwards. Compositions of the control and treatment diets were similar. Net energy, protein, and amino acids compositions of the diets were very similar. Only some differences regarding basal feed ingredients can be seen, because VevoVitall® has no nutritional value, so this needed to be compensated by other compounds. The calculated compositions of the control and the VevoVitall® diets are shown in Appendix 2. To the control starting diet 5 g/kg and to the control fattening diets 1 g/kg of organic acids were added. By mistake also 1 g/kg organic acid was added to the special fattening diet with VevoVitall® (fed from March onwards).

Pigs were commercial breeds (♀ Toppig 20 x ♂ Duroc) and had initial live weights of approximately 25 kg and final live weights of approximately 110 kg. There were equal numbers of gilts and barrows in each room. Gilts and barrows were housed in different pens.

Phase II, Farm 4
Pigs were fed *ad libitum* with dry feeders. A drinking nipple was located in the trough of the dry feeders. The diets were formulated using the Libra optimizing program. The following diets were fed: 'Super Startkorrel', codes 23124 and 23161 (starting diet), fed during the first 3 weeks, 'Super Groeikorrel', codes 24324 and 24071 (super growth feed), fed during the rest of the fattening period. Compositions of the control and treatment diets were similar. Net energy, protein, and amino acids compositions of the diets were very similar. Only some differences regarding basal feed ingredients can be seen, because VevoVitall® has no nutritional value, so this needed to be compensated by other compounds. The calculated compositions of the control and the VevoVitall® diets are shown in Appendix 2. To the control starting diet 5 g/kg and to the control super growth diet 2 g/kg of organic acids were added.

Pigs were commercial breeds (♀ Toppig 20 x ♂ Pietrain) and had initial live weights of approximately 25 kg and final live weights of approximately 110 kg. There were equal numbers of gilts and barrows in each room. Gilts and barrows were housed in different pens.

Phase II, VevoVitall
Samples of the control and VevoVitall® diets were taken to check the VevoVitall® content of the diet. None of the samples of the control diets did contain any benzoic acid .The results of in-feed analyses of the VevoVitall® diets are summarized in table 6.

Table 6 Analysed amount of benzoic acid in the VevoVitall® diets at Farm 2, 3 and 4

Sampling date	Farm	Room	Benzoic acid (w/w %)
13-03-'07	2	7	1.02
13-03-'07	2	6	1.03
16-02-'07	2	6	0.95
09-01-'07	4	8	1.00
15-11-'06	4	6	0.00
13-02-'07	4	6	0.95
13-02-'07	4	8	1.02
09-01-'07	2	7	1.00
07-02-'07	3	5	0.96
27-02-'07	3	6	1.02
28-03-'07	3	6	1.06
28-03-'07	3	5	0.99
19-10-'06	4	8	0.99
15-11-'06	4	8	0.00
07-02-'07	3	6	0.82

From table 6 it can be seen that all the samples from the VevoVitall® diets had benzoic acid contents of approximately 1%, only the samples taken at the 15th of November '06 at Farm 4 showed no VevoVitall® in the diet. The urine pH of the pigs during the sampling at that day showed normal values (difference in pH between control and VevoVitall® of approx. 1.5 units), so it seems something went wrong with labelling of the samples, so the sample was labeled as a VevoVitall® diet, while in fact it was a control diet.

2.5 Measurements

Ammonia emission was calculated from the volume of air leaving the room by the fan shaft and the concentration of ammonia in that air. At every measuring day ammonia concentration in the incoming air was checked with a ammonia absorption tube (Kitagawa, Japan). These concentrations were not detectible (< 0.5 ppm) and therefore were neglected in the analyses.

An anemometer with the same diameter as the ventilator measured the volume of air leaving the room. The amount of air was recorded by counting the rotations of the anemometer every second. Data were stored in a data logger by a wire connection. Ammonia concentration was measured by sampling the air in the fan shaft with a constant airflow through heated and insulated Teflon tubes. The sampled air was led through impingers filled with a solution of sulphuric acid. In this way ammonia was washed from the air and bound in the acid solution.

The sampling airflow was 2 litres per minute. The concentration of ammonia in the solution was determined by spectrophotometry. During a measuring day the air from each room was separately sampled. At 6 days spread over the experimental period samples were taken during 24 h from each room.

Data of the room temperatures were collected from the automatic controller system of the farmer at Farm 1. This was checked with a handheld temperature / humidity sensor (Rotronic AG, Schwitzerland) during every visit to the farm. At Farm 2, 3 and 4 room temperature and relative humidity of the exhaust air were measured with a Rotronic T/RH sensor. Carbon dioxide levels were measured a few times using Kitagawa gas detector tubes (Tube no. 126SG).

During every visit, urine samples were taken from three or four pigs within each room. The samples were taken by catching the urine in a pan with long steel when a pig was urinating. The pH of each sample was measured directly at the location. The pH was measured with a Sentron 2001 pH analyzer.

During three out of the six measuring days for ammonia, samples were taken for determining odour concentration and emission, as well, in one control room and one VevoVitall® room at Farms 2, 3, and 4. During three or four out of the six measuring days in one control and one VevoVitall® room also 24 h air samples were taken for determining concentrations of carbon dioxide and the green house gasses methane and nitrous oxide. Odour samples were taken according to the standard protocol from 10:00 – 12:00 h. Odour concentrations were determined by olfactometry at the certified odour lab of the Animal Sciences Group. Samples for green house gases were collected in so called canisters. These canisters were gradually filled during the 24 h sampling period. Concentrations of methane and nitrous oxide were determined by gas chromatography. From the average 24-h concentrations of odour, methane, and nitrous oxide and the corresponding 24-h average ventilation rate emissions of these gases were calculated. Background concentrations of odour and the green house gases were assumed to be negligible. This assumption could be made, because ammonia concentrations were negligible (not detectable), as well. At farm 1 no odour and green house gas concentrations were determined. Carbon dioxide concentrations at farm 1 were measured every measuring period with absorption tubes (Kitagawa, Japan), so these were spot measurements.

2.6 Statistical analyses

Means of ammonia emissions and pH of urine were calculated for the control and VevoVitall® treatments for each measuring period. Furthermore, means of number of animals, day number of measurements after start of fattening period, ventilation rate, temperature and relative humidity were calculated. Standard errors of overall means were calculated, as well.

The effect of VevoVitall® on ammonia emission was determined by using the Restricted Maximum Likelihood (REML) procedure of Genstat (Genstat Committee, 2003). Within the model the interaction between farms, with different housing systems, and treatment (control, VevoVitall®) was included to determine whether the effect of VevoVitall® was influenced by housing system. Within the model a correction was made for effects of differences in measuring day (number of days the measurements were done after the start of the fattening period) within farms. Because the six measurements per farm were done spread over the growing period and spread over the year, it was assumed that they were not correlated. The following model was used:

$$Y_{ijk} = F_i * V_j + F_i \,.\, N_{ijk} + e_{ijk} \qquad (1)$$

Where: Y_{ijk} = ammonia emission (g/h) in period i with treatment j and in room k (i = 1…6; j = 0, 1; k = 1…4;
F_i = Farm i (i = 1…4);
V_j = treatment (j = control, VevoVitall®);
N = measuring day, in number of days after start of fattening period;
k = room within treatment (1…4);
e_{ijk} = rest error

The effects of VevoVitall® on the pH of urine and on the emissions of odour, methane, and nitrous oxide were determined with model 2. The interaction effects between farms and VevoVitall® treatment on the emissions of odour, methane, and nitrous oxide were not significant and were left out of this model for simplification. Odour emission was analysed after log-transformation.

$$Y_{ijk} = F_i + V_j + e_{ijk} \quad (2)$$

Where: Y_{ijk} = pH of urine in period i with treatment j and in room k (i = 1…6; j = 0, 1; k = 1, 2, 3, 4).

In these models 'room' was the random factor.

3 Results

Phase I, Farm 1

The main results of Farm 1 are summarized in table 7. The Table shows that the VevoVitall® treatment gave lower ammonia emissions than the control treatment during every measuring period. Average uncorrected emissions were 2.74 and 2.16 kg/y per pig place for the control and VevoVitall® treatments, respectively. The pH of urine was consistently lower for the VevoVitall® treatment, on average 1.0 unit. The mean numbers of pigs per room are comparable between the treatments. The measuring day numbers are somewhat lower for the control than for the VevoVitall® treatment. Within the statistical analyses, in which the overall effect of VevoVitall® on ammonia emission was calculated, a correction was made for this difference (see statistical model 1).

Table 7 Mean ammonia emissions and pH of urine in the six measuring periods for the control and VevoVitall® treatments at Farm 1. Each value is the mean of four compartments; s.e. is the standard error of the overall mean

Period	Number of pigs		Days after start		NH_3-emission per pig place[1] (kg/y)		pH urine	
	Control	VevoVitall	Control	VevoVitall	Control	VevoVitall	Control	VevoVitall
1	76	80	55	55	3.42	2.82	n.m.[2]	n.m.[2]
2	80	76	54	54	2.34	1.80	5.99	5.09
3	76	80	55	55	2.85	2.06	6.25	5.27
4	80	75	41	69	2.95	2.61	6.10	5.26
5	79	76	55	55	2.55	1.85	6.48	5.15
6	80	76	40	69	2.34	1.80	5.76	4.98
Overall means	78	77	50	59	2.74	2.16	6.11	5.15
s.e.	0.9	0.9	3.0	3.0	0.17	0.18	0.11	0.05

[1] Calculation based on 80 pigs per room and an inoccupation of 10%
[2] Not measured

The means of the climate variables ventilation rate, temperature and relative humidity are reported in table 8. From this table it can be seen that the climate variables were, on average, very comparable between the control and the VevoVitall® treatments. Carbon dioxide concentrations (spot measurements) were on average 0.18 vol% (s.d. 0.05) and were always lower then 0.30 vol%, except for the last measuring period, with a max of 0.35 vol%.

Table 8 Mean numbers and live weights of pigs, ventilation rate and temperature in the six measuring periods for the control and VevoVitall® treatments at Farm 1; s.e. is the standard error of the overall mean

Period	Ventilation rate (m^3/h)		Temperature (°C)		RH(%)	
	Control	VevoVitall	Control	VevoVitall	Control	VevoVitall
1	2493	2690	21.9	22.2	51	48
2	4958	4474			44	43
3	2943	3325	24.3	24.3		
4	2975	3584	24.6	24.2	68	69
5	2356	1869	23.1	24.2	82	84
6	1520	1632	22.1	21.6		
Overall means	2874	2929	23.2	23.3	61	61
s.e.	469	441	0.5	0.5	7	8

Phase II, Farm 2

The main results of Farm 1 of pH of urine and ammonia emission are summarized in table 9. The table shows that the VevoVitall® treatment gave on average lower ammonia emissions than the control treatment. Average uncorrected emissions were 1.91 and 1.67 kg/y per pig place for the control and VevoVitall® treatments, respectively. The pH of urine was consistently lower for the VevoVitall® treatment, on average 1.3 units. The number of pigs and the moments of the measurements given as number of days after the start of the fattening period were very similar for the control and VevoVitall® treatments.

Table 9 Mean ammonia emissions and pH of urine in the six measuring periods for the control and VevoVitall® treatments at Farm 2. Each value is the mean of two compartments; s.e. is the standard error of the overall mean

Period	Number of pigs		Days after start fattening period		NH_3-emission per pig place[1)] (kg/y)		pH urine	
	Control	VevoVitall	Control	VevoVitall	Control	VevoVitall	Control	VevoVitall
1	131	131	75	75	2.15	2.00	5.60	4.92
2	131	133	20	21	1.27	0.97	7.23	5.42
3	130	129	57	58	1.34	1.37	6.48	4.89
4	130	130	83	84	2.72	1.79	5.72	4.95
5	132	132	30	27	1.64	1.40	6.95	5.14
6	132	132	54	51	2.36	2.48	6.46	5.34
Overall means	131	131	53	52	1.91	1.67	6.41	5.11
s.e.	0.4	0.6	10	10	0.24	0.22	0.26	0.09

[1)] Calculation based on 132 pigs per room and an inoccupation of 10%

In table 10 the mean emissions of odour, methane, and nitrous oxide are given for Farm 2. Odour emissions were measured at three out of the six measuring days, while the green house gases were measured at four out of the six measuring days. The table shows that odour emission seems to be lower for the VevoVitall® treatment. Methane and nitrous oxide emissions were very comparable between the VevoVitall® and control treatments. The average 24-h carbon dioxide concentration was 0.23 vol% (s.d. 0.11) and it had a max of 0.37 vol%.

Table 10 Mean emissions of odour, methane (CH_4), and nitrous oxide (N_2O) in the different measuring periods for the control and VevoVitall® treatments at Farm 2. Each value is measured in one compartment; s.e. is the standard error of the overall mean

Period	Odour emission per pig (ou_E/s)		CH_4 emission per pig (g/d)		N_2O emission per pig (g/d)	
	Control	VevoVitall	Control	VevoVitall	Control	VevoVitall
2	21.2	13.9	5.2	4.8	0.6	0.5
3	26.9	15.5	7.4	6.8	0.8	0.9
5			5.3	5.5	0.6	0.7
6	20.2	7.4	3.5	3.4	0.6	0.8
Overall means	22.8	12.3	5.4	5.1	0.7	0.7
s.e.	2.1	2.5	0.8	0.7	0.0	0.1

The climate variables ventilation rate, temperature and relative humidity are reported in table 11. The table shows that ventilation rate, temperature and relative humidity during the measuring days were very comparable between the control and VevoVitall® treatments.

Table 11 Mean ventilation rate, temperature and relative humidity in the six measuring periods for the control and VevoVitall® treatments at Farm 2. Each value is the mean of two compartments; s.e. is the standard error of the overall mean

Period	Ventilation rate per pig (m^3/h)		Temperature (°C)		RH(%)	
	Control	VevoVitall	Control	VevoVitall	Control	VevoVitall
1	27.9	27.3	24.2	24.8	55.7	56.2
2	16.5	14.8	25.5	24.8	55.4	55.0
3	14.8	18.6	24.4	24.1	53.8	48.9
4	24.4	24.8	24.1	23.7	50.9	49.2
5	21.2	20.8	25.6	25.4	53.5	54.3
6	40.8	40.0	29.4	29.4	61.6	61.6
Overall means	24.3	24.4	25.5	25.4	55.1	54.2
s.e.	3.8	3.6	0.8	0.8	1.5	1.9

Phase II, Farm 3

The main results of Farm 3 of pH of urine and ammonia emission are summarized in table 12. The table shows that the VevoVitall® treatment on average gave a little lower ammonia emissions than the control treatment. Average uncorrected emissions were 2.36 and 2.21 kg/y per pig place for the control and VevoVitall® treatments, respectively. The pH of urine was consistently lower for the VevoVitall® treatment. The pH of urine was on average 1.7 units lower for the VevoVitall® treatment. The number of pigs was very similar between control and VevoVitall® treatments. The moments of the measurements given as number of days after the start of the fattening period, however, were rather different between treatments. To determine the real effect of VevoVitall® on ammonia emission on this farm a correction for day number has to be made.

Table 12 Mean ammonia emissions and pH of urine in the six measuring periods for the control and VevoVitall® treatments at Farm 3. Each value of the control treatment is based on one compartment, while each value of the VevoVitall® treatment is the mean of two compartments; s.e. is the standard error of the overall mean.

Period	Number of pigs		Days after start fattening period		NH_3-emission per pig place[1)] (kg/y)		pH urine	
	Control	VevoVitall	Control	VevoVitall	Control	VevoVitall	Control	VevoVitall
1	109	108	59	76	3.59	2.25	6.60	4.74
2	110	110	11	35	2.47	2.04	7.83	4.95
3	110	110	32	56	1.27	1.75	6.90	5.09
4	109	109	61	85	1.93	2.61	6.63	5.63
5	109	110	52	49	1.98	1.90		
6	109	109	82	79	2.90	2.70	6.11	5.03
Overall means	109	109	49	63	2.36	2.21	6.81	5.09
s.e.	0.22	0.37	10	8	0.33	0.16	0.26	0.14

[1)] Calculation based on 110 pigs per room and an inoccupation of 10%

In table 13 the mean emissions of odour, methane, and nitrous oxide for Farm 3 are given. Odour and green house gas emissions were measured at three out of the six measuring days. The table shows that odour, methane and nitrous oxide emissions were comparable between the control and the VevoVitall® diets. The average 24-h carbon dioxide concentration was 0.25 vol% (s.d. 0.11) and it had a max of 0.40 vol%.

Table 13 Mean emissions of odour, methane (CH_4), and nitrous oxide (N_2O) in the different measuring periods for the control and VevoVitall® treatments at Farm 3. Each value is measured in one compartment; s.e. is the standard error of the overall mean

Period	Odour emission per pig (ou_E/s)		CH_4 emission per pig (g/d)		N_2O emission per pig (g/d)	
	Control	VevoVitall	Control	VevoVitall	Control	VevoVitall
1	36.2	33.9	25.8	27.7	0.6	0.7
2	6.9	12.0				
3	11.7	15.5	19.4	31.8	0.8	1.0
5			5.7	4.2	0.7	0.8
Overall means	18.3	20.5	16.9	21.2	0.7	0.8
s.e.	9.1	6.8	5.9	8.6	0.0	0.1

The climate variables ventilation rate, temperature and relative humidity are reported in table 14. The table shows that ventilation rate during the measuring days was a bit lower for the control room compared to the VevoVitall® rooms. Temperatures and relative humidity were comparable between the treatments. The difference in ventilation rate seems to be mainly caused by the observed difference in measuring days after the start of the fattening period (see table 12).

Table 14 Mean ventilation rate, temperature and relative humidity in the six measuring periods for the control and VevoVitall® treatments at Farm 3. Each value of the control treatment is based on one compartment, while each value of the VevoVitall® treatment is the mean of two compartments; s.e. is the standard error of the overall mean

Period	Ventilation rate per pig (m^3/h)		Temperature (°C)		RH(%)	
	Control	VevoVitall	Control	VevoVitall	Control	VevoVitall
1	21.7	22.3	24.7	25.0	67.6	71.9
2	6.9	11.8	24.8	24.3	72.6	66.3
3	12.9	18.2	24.9	24.7	60.5	68.1
4	28.1	32.9	23.2	23.2	46.6	47.1
5	27.9	27.9	23.7	24.0	56.6	59.9
6	46.0	41.1	23.9	24.1	59.8	62.5
Overall means	23.9	25.7	24.2	24.2	60.6	62.6
s.e.	5.6	4.3	0.3	0.2	3.7	3.6

Phase II, Farm 4

The main results of Farm 4 of pH of urine and ammonia emission are summarized in table 15. The table shows that the VevoVitall® treatment gave on average a bit lower ammonia emissions than the control treatment. Average uncorrected emissions were 2.99 and 2.80 kg/y per pig place for the control and VevoVitall® treatments, respectively. The pH of urine was consistently lower for the VevoVitall® treatment. The pH of urine was on average 1.4 units lower for the VevoVitall® treatment. The number of pigs and the moments of the measurements given as number of days after the start of the fattening period were similar for the control and VevoVitall® treatments.

Table 15 Mean ammonia emissions and pH of urine in the six measuring periods for the control and VevoVitall® treatments at Farm 4. Each value is the mean of two compartments; s.e. is the standard error of the overall mean

Period	Number of pigs		Days after start		NH_3-emission per pig place (kg/y)		pH urine	
	Control	VevoVitall	Control	VevoVitall	Control	VevoVitall	Control	VevoVitall
1	80	79	58	51	2.91	2.77	7.50	5.33
2	78	79	86	79	3.41	2.80	7.12	5.49
3	80	80	29	26	2.73	2.09	6.85	5.70
4	79	80	64	61	2.42	2.51	6.96	5.65
5	80	80	58	55	3.20	3.57	6.57	5.44
6	76	80	80	77	3.26	3.05	6.60	5.63
Overall means	79	80	63	58	2.99	2.80	6.93	5.54
s.e.	0.59	0.20	8	8	0.15	0.20	0.14	0.06

[1)] Calculation based on 80 pigs per room and an inoccupation of 10%

In table 16 the mean emissions of odour, methane, and nitrous oxide are given for Farm 4. Odour emissions were measured at three out of the six measuring days, while the green house gases were measured at four out of the six measuring days. The table shows that all these emissions were very comparable between the VevoVitall® and control treatments. The average 24-h carbon dioxide concentration was 0.21 vol% (s.d. 0.06) and it had a max of 0.32 vol%.

Table 16 Mean emissions of odour, methane (CH_4), and nitrous oxide (N_2O) in the different measuring periods for the control and VevoVitall® treatments at Farm 4. Each value is measured in one compartment; s.e. is the standard error of the overall mean

Period	Odour emission per pig (ou_E/s)		CH_4 emission per pig (g/d)		N_2O emission per pig (g/d)	
	Control	VevoVitall	Control	VevoVitall	Control	VevoVitall
2	9.4	9.4				
3			91.8	108.1	0.9	1.0
4			76.9	95.0	1.0	1.0
5	9.1	18.9	46.1	40.8	0.8	0.7
6	15.3	14.1	100.2	101.2	2.8	2.6
Overall means	11.3	14.1	78.8	86.3	1.3	1.3
s.e.	2.0	2.7	11.9	15.4	0.5	0.5

The climate variables ventilation rate, temperature and relative humidity are reported in table 17. The table shows that ventilation rate, temperature and relative humidity during the measuring days were very comparable between the control and VevoVitall® treatments.

Table 17 Mean ventilation rate, temperature and relative humidity in the six measuring periods for the control and VevoVitall® treatments at Farm 4. Each value is the mean of two compartments; s.e. is the standard error of the overall mean.

Period	Ventilation rate per pig (m^3/h)		Temperature (°C)		RH(%)	
	Control	VevoVitall	Control	VevoVitall	Control	VevoVitall
1	34.4	35.3	23.3	22.9	62.6	63.8
2	31.9	33.4	23.2	22.5	63.7	61.1
3	29.0	29.7	22.6	21.9	54.2	56.6
4	23.5	22.2	21.2	20.8	56.6	56.8
5	36.5	37.4	24.2	24.1	54.0	53.7
6	40.4	40.8	26.1	26.5	68.9	67.9
Overall means	32.6	33.1	23.4	23.1	60.0	60.0
s.e.	2.4	2.7	0.7	0.8	2.5	2.2

Overall statistical analysis

The overall statistical analyses with model 1, with a correction for differences in measuring day number after the start of the fattening period, showed a significant effect of VevoVitall® on ammonia emission (P = 0.011). In this study VevoVitall® in the diet of growing finishing pigs reduced ammonia emission on average from 2.58 to 2.17 kg/y per pig place (s.e.d. 0.14), equalling a reduction of 15,8%. No interaction was found between the effect of VevoVitall® and Farm (housing system) (P = 0.503). Farm had a significant effect on ammonia emission (P < 0.001). In table 18 the corrected ammonia emissions are given for each farm. From Table 18 it can be seen that the measured emissions from the control rooms are all higher then the ammonia emission factor in the Rav-list.

Table 18 Mean corrected ammonia emissions (with model 1) for the control and VevoVitall® treatments at the different farms

Farm	Rav-code	Ammonia emission factor	NH_3-emission per pig place (kg/y)		Reduction (%)
			Control	VevoVitall	
1	D.3.4.1	2.5	2.81	2.16	23.0
2	D.3.2.7.2.1	1.2	1.87	1.76	5.9
3	D.3.2.10.1	1.4	2.71	2.19	19.1
4	D.3.2.6.2.2	2.0	2.93	2.57	12.2
Overall means			2.58	2.17	15.8
s.e.d.			0.14		

VevoVitall® lowered the pH of the urine. The pH was on average 6.50 for the control treatment and 5.29 for the VevoVitall® treatment (s.e.d. 0.089; P < 0.001). There was a significant difference of urinary pH between farms (P < 0.001).

VevoVitall® had no effect on odour emission. Median odour emissions were 16.2 and 14.6 ou_E/s for the control and VevoVitall® treatments, respectively (s.e.d. at log-scale = 0.39; P = 0.781). No significant differences between farms were found, as well.

VevoVitall® had no effect on methane emission. Mean methane emissions were 27.5 and 28.1 g/d per pig for the control and VevoVitall® treatments, respectively (s.e.d. = 6.4; P = 0.926). A significant effect of farm was found. Farms 2, 3, and 4 had mean methane emissions of 5.8, 19.1, and 58.4 g/d per pig, respectively.

VevoVitall® had no effect on nitrous oxide emission. Mean nitrous oxide emissions were 0.85 and 0.91 g/d per pig for the control and VevoVitall® treatments, respectively (s.e.d. = 0.19; P = 0.759). No significant differences between farms were found, as well.

4 Discussion

4.1 Diets

In this study it was tried to keep the composition of the VevoVitall® diets as close as possible to their control diets. Because addition of VevoVitall® reduces the nutritional value of the diet, it had to be compensated by shifting some ingredients. This caused some small differences in the nutrient composition of the diets (see Appendix 2). From research of Canh (1998) and from the review paper of Aarnink and Verstegen (2007) the following effects can be calculated:

- Protein effect: decrease of protein content of the diet with 10 g/kg: 10% reduction in ammonia emission.
- NSP-effect: Increase of NSP content with 10 g/kg at an NSP level of approx 100 g/kg: 2.2% reduction in ammonia emission.
- Electrolyte balance: decrease of the electrolyte balance with 10 meq/kg: 0.5% reduction in ammonia emission.

From these effects an estimation can be made of the effect of differences in the dietary composition between the VevoVitall® diets and the control diets on ammonia emission, excluding the VevoVitall® effect itself. These calculations show maximum effects on ammonia emissions ranging between -2.2% to 1.8%. So these calculated confounding effects are low and are partly compensating each other.

Contrary to the diets fed at Farm 1, diets at Farm 2, 3, and 4 differed not only in the addition of VevoVitall®, but also in the addition of organic acids, varying in level of addition between 1 and 5 g/kg. We discussed a lot about possible confounding effects of the organic acids on the ammonia emission. For practical reasons we decided to include the organic acids to the control diets at Farms 2, 3, and 4. In fact VevoVitall® is an alternative feed additive for the organic acids. Pig farmers want some acid in their diets to prevent intestine problems of the pigs. A control diet without organic acids added would therefore be a less practical control diet. The other reason why we decided to add the organic acids was that we didn't expect any effect of the organic acids on ammonia emission. The organic acids are fully broken down in the intestines and are absorbed in the blood. No acidifying conversion products of these organic acids are excreted in urine, like hippuric acid when adding benzoic acid to the diet. So it is expected that these organic acids have little effect on the pH of faeces and manure and therefore will have little effect on the ammonia emission.

The dietary electrolyte balance (dEB) varied between the different diets from 158 to 190 meq. Addition of $CaCO_3$ varied between diets from 4.6 to 7.0 g of Ca. Within these ranges Canh et al. (1998) found urine pH varying from approximately 6.0 to 7.0. The measured pH of the urine from pigs fed the control diets within this study were in the same range; the means of the different farms varied from 6.11 to 6.93.

4.2 Ammonia emission

When adding VevoVitall® to the diet ammonia emission was reduced on average by 15.8%. It is remarkable that the emissions measured in the control rooms were all (clear) higher then the corresponding emission factors in the Rav-list (Table 18). The measured emission at Farm 3 was almost two times higher than the emission factor (2.71 versus 1.4 kg/y per pig place). At this farm a lot of pen fouling occurred; this might be the reason of the high ammonia emission. For the other two farms not a clear reason of the high ammonia emission can be given. The measuring days were rather equally spread over the fattening periods. On average the day number of the measurements after the start of the fattening period was 56. This was just in the middle of the average length of a fattening period of 113 days.

The effect of VevoVitall® on ammonia emission was somewhat lower than expected from previous studies. In a study of Canh et al. (1998) a reduction was found of 50% when 1.84% of benzoic acid in the form of Ca-benzoate was added to the diet; by linear interpolation to 1% this equals a reduction of 27%. The higher reduction in that study might be caused by the form in which benzoic acid was added to the diet. In that study Ca-carbonate was replaced by Ca-benzoate. Ca-carbonate is a base, so in that study in fact a double effect was reached, the pH was lowered by a lower Ca-carbonate content of the diet and was additionally lowered by the addition of benzoate to the diet.

The effect of VevoVitall® on ammonia emission on the different farms is rather variable. From previous research we know that a lot of variation exists in ammonia emission between farms with similar housing systems (Mosquera et al., 2004). Also the effect of VevoVitall® can be affected by different factors, e.g. composition of the whole diet, storage period of the manure, pen fouling. From the standard error of difference a 95% confidence interval for the mean reduction percentage of ammonia emission can be calculated from 5 to 27%.

No interaction effect was found between housing system and VevoVitall® on ammonia emission. This is according to our theoretical expectations. From this study, however, we can not conclude that there is no interaction effect between housing system and VevoVitall® on ammonia emission, because within this study the effect of housing system was confounded with the farm effect. More farms with the same housing systems should have been included within this study to statistically prove the absence of an interaction effect.

4.3 Emissions of odour and greenhouse gases

Odour emission varied greatly between and within farms, but differences between farms and between treatments (control and VevoVitall®) were not significant. At farm 2 odour emissions from the VevoVitall® room was consequently lower for the three measuring periods than the odour emissions from the control room. However, at farms 3 and 4 odour emissions were very similar. Differences between farms could have been caused by differences in housing systems and differences in diets. Differences between treatments could have been caused by differences in ingredient composition of the diet . On average odour emissions from the control (16.2 ou_E/s) and VevoVitall® (14.6 ou_E/s) treatments were lower than the existing odour emission factor (23 ou_E/s).

Addition of VevoVitall® had no effect on methane emission. Very similar emissions were found for the control and VevoVitall® treatments, 27.5 and 28.1 g/d per pig, respectively. This equals an emission of approximately 10 kg per pig per year. At present, no emission factors are available for methane. Monteny *et al.* (2006) reported a mean methane emission from houses for growing-finishing pigs of 4.8 kg per pig per year. A clear difference in methane emission was found between farms, 5.8, 19.1, and 58.4 g/d per pig for farms 2, 3, and 4, respectively. This equals emissions of 2.1, 7.0, and 21.3 kg per pig per year. The high methane emission at Farm 4 seems to be mainly caused by the long storage time of the manure and the inability to completely empty the deep manure pits. The difference in methane emission between farms 2 and 3 could also have been caused by differences in storage period. At farm 2 manure pits were emptied every 1.5 to 2.5 months, while this was done after every fattening period (approx 3 months) at farm 3. Another reason might be that the manure pits at farm 2 had a slanting plate in the manure channel; this might have approved the complete removal of manure from the pit.

The emissions of nitrous oxide was low and not differing between treatments or between farms. An average nitrous oxide emission of 0.88 g/d per pig was found; this equals an emission of 0.32 kg per pig per year.

5 Conclusions

Within this study the effect of addition of 1% VevoVitall® to the diet of growing-finishing pigs on ammonia, odour and greenhouse gas emissions was determined. The following can be concluded from the results:

- VevoVitall® has a significant effect on ammonia emission (P=0.011). On average, ammonia emission was reduced by 15.8%.
- No interaction was found between the effect of housing system and the effect of VevoVitall®. This means that within this study it could not be proven that the effect of VevoVitall® was influenced by housing system. The set-up of this study, however, was not suitable to statistically prove that there is no interaction between the effects of VevoVitall® and housing system on ammonia emission.
- VevoVitall® has no effect on odour emission and emissions of the greenhouse gases methane and nitrous oxide.

6 Appendices

Appendix 1 Calculated feed composition of the diets used in Phase I of the study at Farm 1

Compound	Starter diet, without VevoVitall	Starter diet, with VevoVitall	Finishing diet without VevoVitall	Finishing diet with VevoVitall
	6850	**6855**	**6890**	**6895**
Crude protein, g	171.24	170.92	160.00	160.00
Crude fat, g	58.05	62.70	44.46	49.15
Starch-ew g	395.46	384.46	406.39	394.97
Crude fibre, g	45	45	55	55
Ca, g	7	7	5	5
P, g	5.14	5.12	4.63	4.61
Digestible P, g	2.7	2.7	1.6	1.6
FTU	500.00	500.00	241.06	243.86
Na, g	1.50	1.50	1.25	1.25
K, g	7.91	7.92	7.39	7.41
Cl, g	2.84	2.84	2.66	2.65
Ileal digestible lysine, g	8.8	8.8	7.0	7.0
Net energy, MJ/kg	10.02	10.02	9.67	9.67
C18:2, g	9.43	9.83	7.56	7.96
VIT A, IE	8000	8000	6400	6400
VIT D3, IE	2000	2000	1600	1600
VIT E , mg	100	100	75	75
CHOLINCL, mg	250	250	150	150
Zn added, mg	100	100	80	80
Cu added, mg	130	130	12	12
Weight, kg	100	100	100	100
Salt (S)	0.32%	0.32%	0.28%	0.28%
Chalk (S)	0.77%	0.77%	0.52%	0.52%
Wheat	28.06%	26.15%	23.28%	21.29%
Barley	25%	25%	15%	15%
Sunflower meal	4.85%	5.03%	6.94%	7.10%
Palm nut flakes			5%	5%
Sugar beet pulp	7.50%	7.50%	10%	10%
Lysine ELL50	0.57%	0.56%	0.43%	0.42%
Soya 50-(Bras)	10.68%	10.94%	4.04%	4.40%
Triticale	15%	15%	30%	30%
Molasses	1.50%	1.50%	1.50%	1.50%
Modical 21.8	0.39%	0.39%		
Vit 166 Copper-mix	0.20%	0.20%		
CholineCl 75%	0.03%	0.03%	0.02%	0.02%
Natuphos 5000L	0.01%	0.01%	0.01%	0.01%
Liquimeth (40%)	0.13%	0.13%		
Vit 348 VLV S/F	0.50%	0.50%	0.40%	0.40%
Threonine mix 40% (S)	0.17%	0.17%	0.05%	0.05%
VM 532 E/Se	0.10%	0.10%	0.07%	0.07%
VevoVitall (DSM)		1%		1%
Palm-Oil VW-002	3%	3%	1.50%	2%
Palm-Oil V-003	1.21%	1.69%	0.96%	0.95%
Belfeed B1100MP	0.01%	0.01%	0.01%	0.01%

Appendix 2 Calculated feed composition of the diets used in Phase II of the study (in Dutch). Ingredient composition is given in % and the nutrient composition in g/kg. The vitamins are given in IU

	23124	23161	24464	24091	24009	24101	24324	24071	24744	24081
	Super Startkorrel	Sel. Start 161	Stand. Viv. korrel	Sel. Viv. 091	Sel.Viv. 009	Sel.Viv.101	Super Groeikorrel	Sel. Viv.071	Stand.Groeikorrel	Sel.Viv.081
Gerst	30	26	25	34	30	35	20	25	25	33
Tarwe	10	24	15	30	17,5	20	15	25	21	40
Maïs	17	11	17,5	5	10		20	10	17,5	5
Chocomix	10	10	1,5				10	7,5	3,5	
Palmpitschilfers					9	9				
Erwten						2				
Raapzaadschroot	3	3	15	14,2	17,5	16,1	5	5	15	10
Sojaschroot	18	18	1,6				10	10	1,9	5
Zonnebloemz.schroot			1,5				2		2	1
Tarwegries	5		15	10	5,9	6	10	10	8,4	
Pulp					5	5				
Melasse	3	3	4	3	3	3	4	3	3	3
Olie	0,9	0,9	0,4	0,5	0,6	1,2	0,8	1,1	0,4	0,4
Org. Zuur	0,5		0,1		0,1	0,1	0,2		0,1	
Benzoëzuur		1		1		1		1		1
Vitamine/Mineralen	2,6	3,1	3,4	2,3	1,4	1,6	3	2,4	2,2	1,6
EW	1,12	1,12	1,05	1,05	1,04	1,04	1,12	1,12	1,08	1,08
dv Lysine	9,4	9,4	6,6	6,6	6,5	6,5	7,7	7,8	7,2	7,3
Zetmeel	390	400	390	415	350	330	385	395	410	440
Ca	7	7	4,6	4,7	4,9	4,9	5	5	5	5
P	4,7	4,7	5	4,7	4,8	4,6	4,3	4,3	4,7	4
Na	1,6	1,8	1,3	1,2	1,2	1,2	1,5	1,5	1,3	1,2
K	9	8,7	9	7,5	7,7	8,1	8,9	8,4	7,8	7
Cl	3,9	3,9	3,7	3,5	3,2	3,1	4	3,8	3,5	3,4
dEVs	77	79	50	40	40	55	64	67	35	29
Ruw Eiwit	181	182	151	147	154	156	162	162	155	154
Ruw Vet	40	37	33	27	32	39	45	44	32	25
Ruwe Celstof	35	32	53	51	72	70	42	39	51	43
Ruw As	51	51	44	41	46	46	45	43	44	40
NSP	95	92	104	98	151	149	96	97	98	88
Vit. A	7500	7500	5000	5000	5000	5000	7500	7500	5000	5000
Vit. D3	1500	1500	1000	1000	1000	1000	1500	1500	1000	1000
Vit E.	75	75	50	50	50	50	75	75	50	50

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