TEST OF FEEDING CONCEPTS AS AN ALTERNATIVE TO ZINC OXIDE FOR WEANED PIGS

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One concept improved productivity and lowered diarrhoea outbreaks compared with feed including zinc oxide. One concept was level with feed including zinc oxide, and two were level with feed without zinc. Production economy dropped with all four concepts as feed costs per pig increased.

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Abstract

Four feeding concepts for weaned pigs in the 7-30 kg period were compared with feed including zinc oxide the first 14 days post-weaning and with feed without zinc. The trial was conducted at SEGES Danish Pig Research Centre's trial station Grønhøj.

Elimination of zinc oxide from the feed lowered the production value by roughly DKK 1.90 per pig. Corrected for savings in feed costs when not using zinc oxide the loss per pig amounted to roughly DKK 1. Diarrhoea frequency increased and consequently the number of antibiotic treatments nearly doubled, which further increased production costs by about DKK 0.80 per pig.

The concept from Trouw Nutrition significantly improved productivity and lowered treatment frequency compared with group 1 (with zinc oxide) but added net DKK 8 per pig to the total cost of production.

The concept from Vitfoss was identical to group 1 in terms of both productivity and treatments for diarrhoea, but cost DKK 6.60 per pig. The remaining two concepts (FRAmelco and Evonik) did not stand out from the group given 0 ppm zinc oxide in terms of productivity and diarrhoea treatments.

None of the four concepts improved productivity to such an extent that they were able to cover the increased feed costs compared with the control groups. The effect on diarrhoea and the savings on antibiotics were not enough to neutralize the increased feed costs.

Background

The EU Commission has banned the use of zinc oxide in feed for weaned pigs as of June 2022 due to its negative environmental impact.

The majority of conventional and organic farms today use prescription-only zinc oxide in feed for weaned pigs the first 14 days post-weaning to control E.coli diarrhoea. This helps lower the frequency of diarrhoea outbreaks immediately post-weaning, and experience shows that it also keeps antibiotic use for treatment of diarrhoea low later in the period.

For years, numerous additives have been tested in the search for alternatives to zinc oxide, but so far no products (except antibiotics) have been found to be able to replace zinc oxide. It is therefore necessary to test new products or products in different combinations and compare them to zinc oxide, both in terms of their effect on diarrhoea and the overall antibiotic use per pig, but also in terms of productivity in the 7-9 kg period and the entire 7-30 kg period.

The purpose of this trial was to compare 2,500 ppm zinc oxide (positive control) with 0 ppm zinc oxide (negative control) and with four select concepts to find competitive alternatives to zinc oxide. The trial period lasted from weaning until 30 kg.

Material and method

Design of the concept test

The purpose of this concept test was to investigate alternatives – nationally or internationally – to zinc oxide in feed for weaned pigs. Interested parties were invited to submit an application to SEGES describing concepts for feeding of weaned pigs in the 7-30 kg period. Three diets were required, one for each of the periods 7-9 kg, 9-15 kg and 15-30 kg. All products and additives included in the concepts must be approved by the EU and available for purchase at the time of application. The trial comprised weaned pigs in the period 7-30 kg as it was not technically possible to include housing conditions and feeding in the farrowing pen or technical changes to accommodation in the weaner unit.

Twenty-three applicants submitted an application describing the composition of their concepts, the expected effect of the components and documentation of the effect on productivity and health. A selection committee consisting of four SEGES employees and two representatives from Copenhagen University and Aarhus University subsequently evaluated the applications. Selection criteria were based on the applicants' scientific argumentation; proposed interaction with subcomponents and the enclosed documentation of the effect of the concept. The selection process did not specifically consider the cost of the concepts compared with the use of zinc oxide. Of the 23 submitted proposals, four were selected for the trial: FRAmelco (The Netherlands), Trouw Nutrition (The Netherlands), Evonik (Germany), and Vitfoss (Denmark). Participation in the trial was free, but the companies supplied the components (premixes/additives) required for the concepts free of charge. None of the participants influenced the practical implementation of the trial, but were invited to visit the trial herd.

Transfer of pigs and implementation of the trial

The trial was performed at SEGES Danish Pig Research Centre's trial station Grønhøj. Halfway through the trial, Grønhøj switched suppliers of weaned pigs, and the pigs in this trial thus originated from two different herds. The first supplier delivered 20 batches and the other 43 batches. The trial comprised a total of 63 batches (replicates), six groups of approx. 700 pigs in each group and a total of roughly 4,500 weaned pigs in the entire trial. Pigs were delivered at an average weight of 6-9 kg and were transferred to the trial at approx. 7 kg and left at approx. 30 kg. The trial ran for 34 weeks. Six pens holding either 10 or 15 pigs constituted a batch (one replicate).

Upon transfer to the weaner unit, the pigs were sorted according to gender and weight to ensure that all six groups were identical in terms of female pigs and castrates. There was a max. difference in average start weight of 0.25 kg per pig between pens within each batch.

Four days after transfer to Grønhøj, the pigs were vaccinated against Lawsonia with 2 ml Enterisol and against PCV2 with 0.5 ml circovac per pig.

Trial design and feed

The first 14 days post-weaning, the pigs were fed diet 1 containing either 2,500 (positive control) or 0 ppm zinc oxide per kg feed (negative control) or one of the four concepts containing no zinc oxide (trial design shown in table 1). 100 ppm zinc was added per kg feed to the control diets (groups 1 and 2) as micromineral. Furthermore, xylanase (5,000 U Danisco beta xylanase from DuPont) and 200% phytase (1,000 FYT Ronozyme HiPhos from DSM) were added to the control diets. Organic acids were not included in the feed. After 14 days, the feed in groups 1 and 2 was identical in composition.

The pigs gradually switched to diet 2 at approx. 9 kg (roughly 11 days intro the trial) and by d 14 they were fed diet 2 exclusively, and from that point on no pigs were given zinc oxide. The pigs were weighed again at roughly 15 kg and then started a gradual transition to diet 3 that was used in the period 15-30 kg (table 1).

Apart from the inclusion of zinc oxide in diet 1 the first 14 days post-weaning, there were no differences in the feed used in groups 1 and 2. In terms of ingredients and nutrients, the composition of the feed in group 3 (FRAmelco) was identical with the feed in group 2 with the exception of the concept components FRA® LAC34 Dry and FRA® C12 Dry. In group 4 (Trouw Nutrition), two different additive mixes were used. The rest of the feed contained the same ingredients as in groups 1 and 2, but the content of amino acids and additives differed. Furthermore, Selko (acid blend) was added to the drinking water. In group 5 (Evonik), the ingredients were largely the same as in the control groups, but in particular the amino acid profile differed, and Fecinor (probiotic) was added to the drinking water. In group 6 (Vitfoss), three different additive mixes were used, one for each of the three periods, but apart from this, the ingredients were identical to those of the control groups. All diets were formulated according to the wishes and requirements of the participating companies. In groups 4 and 6, where Trouw Nutrition and Vitfoss, respectively, supplied additive mixes, their information regarding nutrient content and digestibility of the additive mixes was used for the final formulation of the diets. The composition of the diets is shown in appendix 1.

Table 1. Trial design

Group	1	2	3	4	5	6
	Positive control	Negative control	FRAmelco	Trouw Nutrition	Evonik	Vitfoss
7-9 kg, diet 1 Zinc oxide, ppm	2500	0	0 0.4% LAC 34 0.4% C12 Dry	0 5% Nucleo 20% Vario	0 0.12% CreAmino	0 30% diet 1
9-15 kg, diet 2			0.3% LAC 34 0.3% C12 Dry	5% Nucleo 8% Vario	0.12% CreAmino	17% diet 2
15-30 kg, diet 3			0.2% LAC 34 0.2% C12 Dry	5% Nucleo	0.12% CreAmino	7.1% diet 3
Drinking water				Selko 1,5 L/1000L	Fecinor 50 g/1000L	

Description of the four concepts

Group 3 - FRAmelco

The only difference between group 2 (negative control) and group 3 is the addition of varying doses of FRA® LAC34 Dry and FRA® C12 Dry in the three periods. FRA® LAC34 is a specific blend consisting mainly of α-monopropionin, α-monobutyrin and lactic acid, whereas the main ingredient of FRA® C12 Dry is α-monolaurin. With this combination, FRAmelco aims to lower diarrhoea outbreaks caused by Gram-negative bacteria, e.g. E. coli, and reduce the chance of secondary challenges by Gram-positive bacteria like Streptococcus when zinc oxide levels are removed from the diet. The upside of using these α-monoglycerides instead of their free fatty acids is that the alpha-monoglycerides allegedly have a greater antibacterial effect than the free fatty acids as they are pH independent and reach the small intestine intact, whereas free fatty acids will dissociate due to their low pKa value and lose their antibacterial activity. The natural decomposition of triglycerides in dietary fat that takes place in the gut primarily produces β-monoglycerides, but the synthetically produced α variant is allegedly more efficient against bacteria.

Group 4 - Trouw Nutrition

This concept is based on two components: Vario (specific quality feed components), which is added in different doses in the three periods, and 5% Nucleo (feed additive mix) added to the feed for the entire period. Nucleo primarily consists of minerals, vitamins, probiotics, enzymes and feed additives, such as Presan FX (which contains slow release C12, target release butyrates, MCFAs (C8, C10 and C12), phenols, and organic acids) and Selko AOmix (polyphenols with high antioxidant effect). Vario includes a mix of various carbohydrates, milk products such as Nucleospray E50 (milk products and homogenized vegetable oil of a high digestibility) and specific fibre components (special processing technique).

In addition, Selko-pH (a synergistic blend of free and buffered organic acids) is added to the pigs' drinking water.

All three diets have a low protein content and the amino acid profile differs from the Danish profile (less lysine and more threonine and methionine). Calcium content is also lower than in the control diets.

According to Trouw Nutrition, the concept supports healthy gut development, positively affects the microflora and ensures a high nutrient digestibility.

Group 5 - Evonik

This concept is based on low protein content in diet 1 and altered amino acid profile in all three diets. In particular threonine and tryptophan levels differ from the Danish standards (2018). Lysine content follows the Danish standard, but relative to lysine, the tryptophan content constitutes 22% of lysine (Danish standard: 21%), threonine constitutes 70% of lysine (Danish standard: 61%), and methionine constitutes 33% of lysine (Danish standard: 32%). CreAMINO, which is a new product, is added to the feed and features in the creatine synthesis in the organism. Creatine plays an important role in energy turnover, and increased creatine content allegedly increases energy available for muscle growth. The concept also contains fibre in the form of wheat bran and beet pellets, and Fecinor (probiotic) is added to the drinking water.

Low protein content and an increased threonine content are supposed to lower the frequency of diarrhoea and enhance the production of mucin in the gut mucosa thereby promoting gut health.

Group 6 - Vitfoss

This concept is based on low protein content, altered amino acid profile and an improved protein digestibility. The diets also include specific fibre and a range of different additives. Vitfoss supplied three different additive mixes for the three diets.

In diet 1, the protein content is very low, while diets 2 and 3 follow the Danish protein standard. The lysine content is slightly above the Danish standard, but primarily threonine is designed to be significantly above the Danish standard in diets 1 and 3, but not in diet 2. Methionine follows the Danish standard.

The concept includes inert fibre and additives such as benzoic acid; mono-butyric acid;
Hy-D vitamin; Availa zinc; selenomethionine; TBCC copper compound; super dosing of phytase; xylanase and glucanase; Miya-Gold (probiotic); acid blend; and vitamins (OVN = Optimum Vitamin Nutrition). The concept allegedly stimulates the gut microflora, enhances and protects the gut mucosa, improves the immune system and improves nutrient digestibility.

Table 2 outlines the main subcomponents in each of the four concepts.

Table 2. Outline of concepts.

	FRAmelco	Trouw Nutrition	Evonik	Vitfoss
Reduced protein		X	X	X
Increased threonine/lysine		X	X	X
Monoglycerides	X			X
Organic acids	X	X	X	X
Probiotics		X	X	X
Fibre		X	X	X
Additional enzymes		X		X
Organic minerals				X
Addition to drinking water		X	X	

Feed analyses

All feed samples were collected representatively at the feed mill according to the TOS principles.

Feed was produced on three occasions. On each occasion, three samples per diet were forwarded to Eurofins Steins Laboratory for analysis of energy, protein, calcium, phosphorus, phytase activity, zinc, copper and the amino acids lysine, methionine, cystine and threonine.

Evonik received one sample of all three diets from all batches produced for analysis of all amino acids and the amino acids added to the feed.

Recordings

Productivity

Weight and feed consumption were recorded at pen level for the periods: 7-9 kg, 9-15 kg, 15-30 kg and the entire 7-30 kg period. Daily gain, feed intake and feed consumption were recorded as primary parameters.

Treatments for disease

Treatments for disease, mortality and percentage pigs moved to a hospital pen were recorded as secondary parameters. Treatment for diarrhoea was initiated when two clinically ill pigs were observed in a pen (single animal treatment). If more than two pigs in a pen were observed with diarrhoea, flock treatment was initiated by adding medication to the feeder. Section-wise treatments were not practised. Single animal treatments were administered for three days, flock treatments for five days. Treatment for diarrhoea was administered by the staff according to guidelines issued by the herd vet based on the following symptoms of diarrhoea: dirty hind part around rectum, hollow eyes and/or flanks, and depressive behaviour.

Treatments for disease were analysed partly as single animal treatments in per cent of feeding days and partly as per cent pens with flock treatment. Prophylactic antibiotic treatments against digestive disorders were not practised.

Statistical analyses

The variables ”Feed intake, FUgp per day”, ”FCR, FUgp per kg gain”, ”Daily gain” and ”Production value per place unit per day” were statistically analysed for the periods 7-9 kg, 7-15 kg and 7-30 kg. The variables ”Weight at trial start”, ”Weight at 1st intermediate weighing”, ”Weight at 2nd intermediate weighing” and ”Weight at trial end” were also subject to statistical analysis.

The above variables were subject to analysis in proc mixed in SAS using the factor “Group” as systematic effect. “Batch” was included as random effect. Analyses made for the periods 7-9 kg, 7-15 and 7-30 kg were corrected for start weight at 7 kg. Additional analyses were made for the periods 9-15 kg and 15-30 kg in groups 1 and 2, also corrected for start weight.

The variables ”Dead”, ”Dead and culled” and the variables “Flock treatment for diarrhoea” and “Diarrhoea treatment days in % of feeding days” were subject to logistic regression in proc glimmix in SAS using the factor “Group” as systematic effect and “Batch” as random effect. Corrections were made for start weight.

In all analyses, group 1 (2,500 ppm zinc oxide) is compared with the other five groups. Furthermore, group 2 (0 ppm zinc oxide) is compared with the other five groups, ie. no paired comparisons were made.

Calculation of production value

The production value (PV) per place unit per day for the entire weaner period was calculated as follows:

- Production value in DKK per place unit per day = (value of gain – feed costs) / feeding days.

When calculating the production value, identical feed pricing in all groups (average prices of five years, September 2012 – September 2017) and the value of 1 kg gain were used:

- Average price of 7 kg pigs of DKK 222 per pig, DKK ± 11.20 per kg (7-9 kg), DKK ± 8.08 per kg (9-12 kg) and DKK ± 6.28 per kg (12-25 kg).
- Average price of 30 kg pigs of DKK 380 per pig, kg regulations of DKK -5.95 per kg (25-30 kg) and DKK + 5.93 per kg (30-40 kg).
- Feed (7-10 kg): DKK 3.40 per FUgp and (10-30 kg) DKK 2.05 per FUgp, which is used for all groups.

Definition of individual variables

- Value of gain = pigs' gain in kg in the trial period × value of 1 kg gain (in this case: DKK 6.85)

Feed costs were calculated using the below equation based on analysed feed units in the basic diets (EDOMi analyses) and the actual amount of feed supplied per pen:

- Feed costs = (end weight – start weight) × FUgp per kg gain × DKK per Fugp

Feeding days = the number of days a pig was averagely in the trial.

Results and discussion

Analysis of feed

The outcome of the feed analyses is shown in appendix 2. The digestible nutrient content per feed unit is based on the analysed levels and on the digestibility used in the formulation of the diets, including the digestibility data provided by the companies.

Analyses generally showed an excess content of phytase, which is, however, not unusual: 300-500 phytase units originate from the natural content in the ingredients and phytase activity in phytase products is commonly higher than what is listed on the label. The feed for groups 4 (Trouw Nutrition) and 6 (Vitfoss) was designed to have a higher phytase content than the control diets, and this was confirmed by the analyses. The zinc content in diet 1 in group 1 (zinc oxide) was roughly 10% below the planned content, but this probably did not affect the pigs, as previous research showed that 1,500 ppm zinc generated the same results in terms of productivity and diarrhoea as 2,500 ppm zinc [1].

The content of digestible protein per FUgp, which is known to affect diarrhoea in weaned pigs, in diet 1 corresponded to the expected content in groups 1, 2 and 3 (FRAmelco). In group 4 (Trouw Nutrition), the content in diet 1 was designed to be roughly 12% lower than in the control group, but analyses revealed a higher content than expected and as a result the content was only 7% lower than that of the control group. Diet 1 in group 6 (Vitfoss) was designed to have a low protein content, and this was also retrieved in the analyses. Analyses of diets 2 and 3 for all groups demonstrated fine agreement between the analysed and designed content of digestible protein per feed unit (see appendix 2).

The amino acid analyses made by Eurofins and Evonik were largely identical: variations were lower than 2% between the two laboratories. However, due to SEGES standard trial procedures the amino acid values in the tables originate exclusively from Eurofins.

Analyses generally revealed 4-7% less methionine than planned, but the deficiency was nearly identical in all groups.

In groups 1, 2 and 3 analyses revealed fine correspondence between the planned and the analysed amino acid content. Digestible threonine content per FUgp, which in groups 5 (Evonik) and 6 (Vitfoss) should be approx. 15 and 17%, respectively, above group 1, turned out to be 6% below expected level for diet 1 in both groups, ie. threonine content was only 10 and 12% higher than in group 1. In diets 2 and 3, threonine content was 7-9% below expected level in group 5 (Evonik), and yet the analysed content per FUgp was 22-25% higher than in group 1. Correspondingly, in group 6 (Vitfoss) threonine content was approx. 6% below planned level, but still 25% above the level of the group 1.

For group 5 (Evonik) the 9-15 kg feed from the first batch did not contain the expected amount of creamino, which was supposed to be >1000 mg/kg. Only 23 mg/kg was found when the feed was analysed.

Inclusion in drinking water

In group 4, 1.5 l Selko was added per 1000 l drinking water using a medicator leading to a pH in drinking water of 3.2-3.4.

In group 5, 50 g Fecinor was added per 1000 l drinking water. Initially, Fecinor precipitated in the bottle containing the stock solution and it is therefore unclear whether the desired concentration was in fact achieved in the beginning. The problem was, however, quickly resolved.

It was generally challenging at the beginning of the trial to correctly dose Selko and Fecinor in the drinking water and water analyses may therefore be slightly inaccurate. Consequently, it remains uncertain whether the first eight of 63 batches received the correct concentration. However, records show that the actual consumption of Selko and Fecinor corresponded with the expected consumption even though it is uncertain whether the exact concentration was consistently present in the water for the entire period.

Production results

Table 3 shows the production results for all six groups.

Tabel 3. Production results.

Group	1	2	3	4	5	6
Treatment	2500 ppm zinc oxide	0 ppm zinc oxide	FRAmelco	Trouw Nutrition	Evonik	Vitfoss
Pens	63	63	61	63	61	62
Pigs at transfer	705	705	686	705	682	690
Weight at transfer	6.7	6.8	6.8	6.7	6.8	6.7
Period 1, 7-9 kg						
Daily gain, g/day	221a	162b (z)	158b (z)	206b (y)	172b (z)	174b (z)
Feed intake, FUgp/day	0.29a	0.24b (z)	0.24b (z)	0.27b (y)	0.25b (z)	0.26b (y)
FCR, FUgp/ kg gain	1.32a	1.58b (z)	1.56b (z)	1.35a (y)	1.54b (z)	1.55b (z)
Periods 1+2, 7-15 kg						
Daily gain, g/day	351a	314b (z)	323b (z)	354a (y)	319b (z)	321b (z)
Feed intake, FUgp/day	0.52a	0.47b (z)	0.48b (z)	0.52a (y)	0.48b (z)	0.50b (y)
FCR, FUgp/ kg gain	1.48a	1.51b (z)	1.49a (z)	1.49a (z)	1.51a (z)	1.56b (y)
Entire period, 7-30 kg						
Daily gain, g/day	537a	516b (z)	523b (z)	548b (y)	515b (z)	530a (y)
Feed intake, FUgp/day	0.88a	0.85b (z)	0.86b (z)	0.88a (y)	0.85b (z)	0.87a (z)
FCR, FUgp/ kg gain	1.64a	1.65a (z)	1.65a (z)	1.60b (y)	1.65a (z)	1.64a (z)
PV, DKK/pig/day, same feed price	1.82a	1.75b (z)	1.76b (z)	1.88b (y)	1.74b (z)	1.80a (y)
PV, index[1], Comp. w/gr 1, same feed price	100	96	97	104	96	99
PV, DKK/pig, same feed price	83.4a	81.5b (z)	82.5a (z)	85.8b (y)	81.5b (z)	83.6a (y)
Difference in PV per pig from gr 1,	-	-1.90	-0.90	+2.40	-1.90	+0.20

DKK, same feed price						
Price dif feed comp w/gr 1, DKK/pig***	-	-0.94	+4.27	+10.52	+16.91	+6.85

1) Smallest significant difference in index observed at 3.0 index points

* Different superscripts (a,b) within a row indicate significant (p-value < 0,05) difference compared with group 1 (2500 ppm zinc oxide).

** Different superscripts (y,z) within a row written in parenthesis indicate significant (p-value < 0.05) difference compared with group 2 (0 ppm zinc oxide).

*** Prices are based on ingredient prices from Danish Agro and the prices of the concept specific ingredients provided by the companies. The price per pig also includes the cost of adding Selko/Fecinor to 120 l drinking water per pig (Trouw Nutrition/Selko = DKK 2.65; Evonik/Fecinor =DKK 1.13).

Group 1 (zinc oxide) vs group 2 (no zinc oxide)

Results revealed significant differences in productivity between group 1 (positive control, incl. zinc oxide) and group 2 (negative control, no zinc oxide) as found in previous trials [1], [2]. The difference in gain in the 7-9 kg period was 59 g a day, which corresponds to the outcome in [1] that demonstrated a difference of 69 g a day. The difference in FCR was also identical to that found in [1]. The difference in the entire 7-30 kg period was 21 g a day, which was also found in [1]. Statistical analyses of daily gain in the periods 9-15 kg and 15-30 kg in groups 1 and 2 demonstrated that the effect of zinc oxide is solely observed in the period in which it is used as analyses revealed no differences in daily gain in the subsequent periods when the pigs were fed identical diets (as in groups 1 and 2) (data not included here). The difference in gain shown in table 3 in the periods 7-15 kg and 7-30 is thus exclusively attributed to the difference in the period 7-9 kg.

Compared with group 1 (2500 ppm zinc oxide)

In the 7-9 kg period, the pigs in group 1 had a significantly higher feed intake and gain than the other pigs. Feed conversion in group 4 (Trouw Nutrition) did not differ from that in group 1, but the remaining concepts resulted in a poorer FCR than in group 1.

In the 7-15 kg period, only the pigs in group 4 (Trouw Nutrition) had the same daily gain as the pigs in group 1 (with zinc oxide).

In the entire trial period (7-30 kg), the production value (PV) in group 1 (with zinc oxide) was significantly higher than in groups 2 (no zinc oxide), 3 (FRAmelco) and 5 (Evonik), but not different from group 6 (Vitfoss). PV in group 4 (Trouw Nutrition) was significantly better than in group 1 (with zinc oxide), which is attributed to a significantly higher daily gain and a better feed conversion. It is interesting that FCR is improved in group 4 in the last part of the 15-30 kg period, as analyses show no improvement in FCR in the period up to 15 kg.

Compared with group 2 (no zinc oxide)

There were no differences in production traits between the pigs in group 2 (no zinc oxide) and groups 3 (FRAmelco) and 5 (Evonik), respectively. The pigs in group 6 (Vitfoss) had the same daily gain and FCR as the pigs in group 2 in the 7-9 kg period, but a higher daily gain in the entire trial period. Only the pigs in group 4 (Trouw Nutrition) had a better productivity than the pigs in group 2 (no zinc oxide).

Compared with group 2, the pigs in groups 4 (Trouw Nutrition) and 6 (Vitfoss) performed significantly better in the period 7-30 kg, while the pigs in groups 3 (FRAmelco) and 5 (Evonik) were level with the pigs in group 2.

Overall, the pigs fed the concept from Trouw Nutrition performed almost as well as the pigs given zinc oxide post-weaning and better than these pigs in the entire trial period. The pigs fed the Vitfoss concept performed as well as the pigs given zinc oxide and better than the pigs given no zinc oxide. The pigs fed the concepts from FRAmelco and Evonik performed poorer than the pigs given zinc oxide and not better than the pigs in group 2.

When the production value is calculated per pig, the difference in daily gain is assigned no value in the model. However, when the production value per feeding day is calculated, daily gain is assigned a value in the model. Therefore, the PV differences between the groups are not necessarily the same, when looking at PV per feeding day or PV per pig, respectively (see table 3).

Table 3 shows differences in production value per pig in the entire period compared with the pigs given no zinc oxide. To be able to determine whether these differences in productivity can cover the increased feed costs the table also shows the increased feed costs of the concepts compared with the pigs given no zinc. Even in group 4 (Trouw Nutrition), which generated the best production results, net costs increased by approx. DKK 8.10 per pig. This calculation does not include potential costs for diarrhoea treatments (this will be addressed below).

Health

There was a distinct difference between the groups in the percentage of flock treatments for diarrhoea. Table 4 shows the total percentage of pens where flock treatment is administered, ie. a pen in which flock treatment is administered is included in the data analysis only once, even if flock treatment is repeated at a later point in time. In groups 2 (no zinc oxide), 3 (FRAmelco) and 5 (Evonik) significantly more flock treatments were administered than in group 1 (with zinc oxide). Group 6 (Vitfoss) did not differ from group 1, whereas significantly fewer flock treatments were administered in group 4 (Trouw Nutrition) than in group 1 (table 4 and figure 1).

Table 4. Treatment frequency and dead/culled pigs, entire period 7-30 kg.

Group	1	2	3	4	5	6
Treatment	2500 ppm zinc oxide	No zinc oxide	FRAmelco	Trouw Nutrition	Evonik	Vitfoss
Pens	63	63	61	63	61	62
Treatment against diarrhoea						
Flock treatments, 7-9 kg, % pens	0.0	1.5	7.8	1.5	1.6	1.5
Flock treatments, 7-30 kg, % pens	30.2a	58.8b (z)	63.9b (z)	6.4b (y)	57.4b (z)	19.3a (y)
Total treatments per feeding day, 7-9 kg	0.002a	0.01a (z)	0.04b (y)	0.01a (z)	0.02a (z)	0.02a (z)
Total treatments per feeding day, 7-30 kg	0.06a	0.12b (z)	0.14b (z)	0.01b (y)	0.11b (z)	0.03a (y)
-converted to treatment days/pig	2.4	5.2	6.3	0.6	4.9	1.5
-of this, single treatments, % of treatment days	18.2	13.5	9.9	38.3	14.2	21.4
Dead and culled						
Mortality	0.3	0.7	0.6	0.3	0.7	0.6
Dead & culled, %	4.4	4.7 (z)	3.4 (z)	2.5 (y)	4.6 (z)	4.1 (z)

* (a,b) p-value < 0.05 compared with group 1 (2,500 ppm zinc oxide)

** (y,z) p-value < 0.05 difference from group 2 (0 ppm zinc oxide)

Total number of treatments per feeding day is the sum of treatment days per group divided by feeding days and is the sum of the number of days when single pigs were treated for three days and the number of days when flock treatments were administered (five days).

In the 7-9 kg period, the number of treatments for diarrhoea was low, and did not differ between the groups. In the entire 7-30 kg period, the pigs in group 4 (Trouw Nutrition) received significantly fewer treatments than the pigs in group 1 (zinc oxide). The pigs in groups 2 (no zinc oxide), 3 (FRAmelco) and 5 (Evonik) were treated significantly more often than the pigs in group 1. Group 6 (Vitfoss) did not differ from group 1.

Roughly DKK 0.30 per treatment day for antibiotic treatment is normally a fair estimate, but it depends of the drug. Costs for antibiotic treatments when zinc oxide is removed from the feed will amount to (5.2 -2.4)*DKK 0.30 = DKK 0.84 per pig (difference between groups 1 and 2). As pigs are treated individually (first two pigs) before flock treatment is initiated, a high percentage of single animal treatments indicates a low diarrhoea frequency. In group 4 (Trouw Nutrition), the percentage of single animal treatments is high, but flock treatments are rare, which results in a low total number of treatment days (table 4). Compared with group 1, pigs were treated for 1.7 days fewer, which corresponds to a saving of DKK 0.54 per pig.

Figure 2 shows the distribution of treatment days during the growth period. Treatments peak around d 12-21 and again around d 32-40, which confirms that efforts to prevent diarrhoea should not exclusively take place in the immediate post-weaning period, but also later in the growth period.

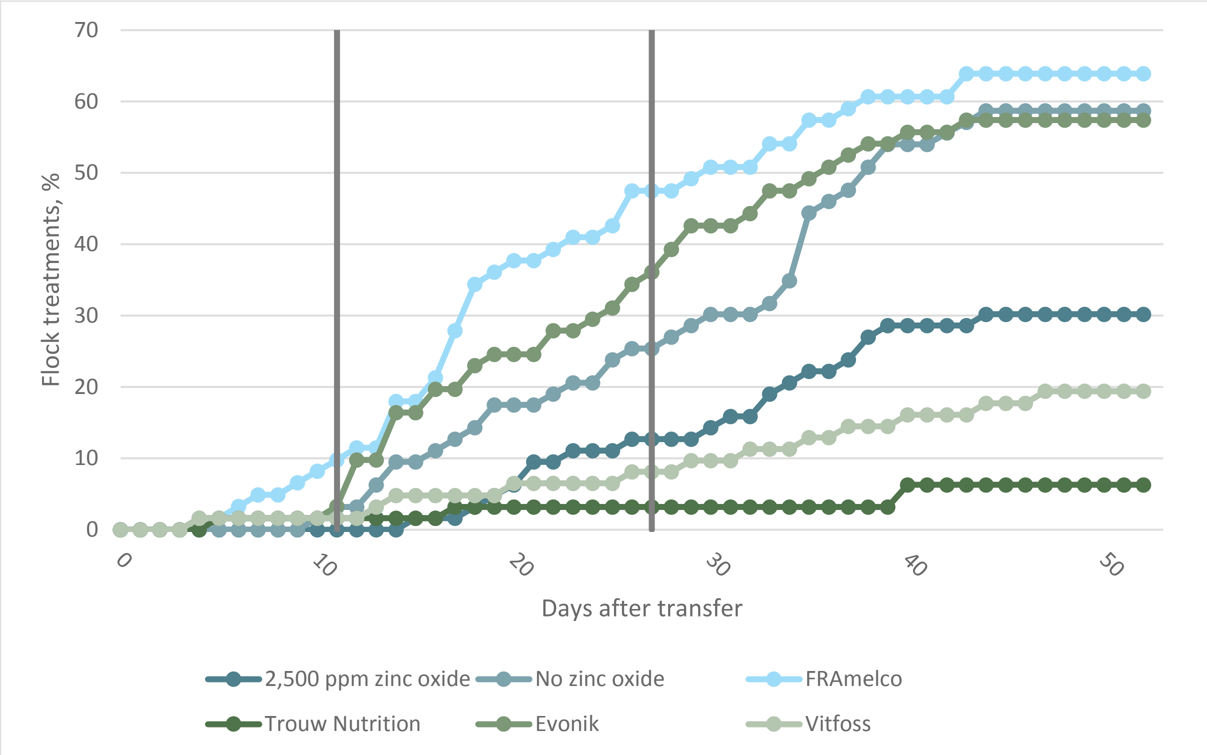

Figure 1. % flock treatments (pens) during the entire trial period in each of the six groups, accumulated. Vertical lines indicate changes in diets.

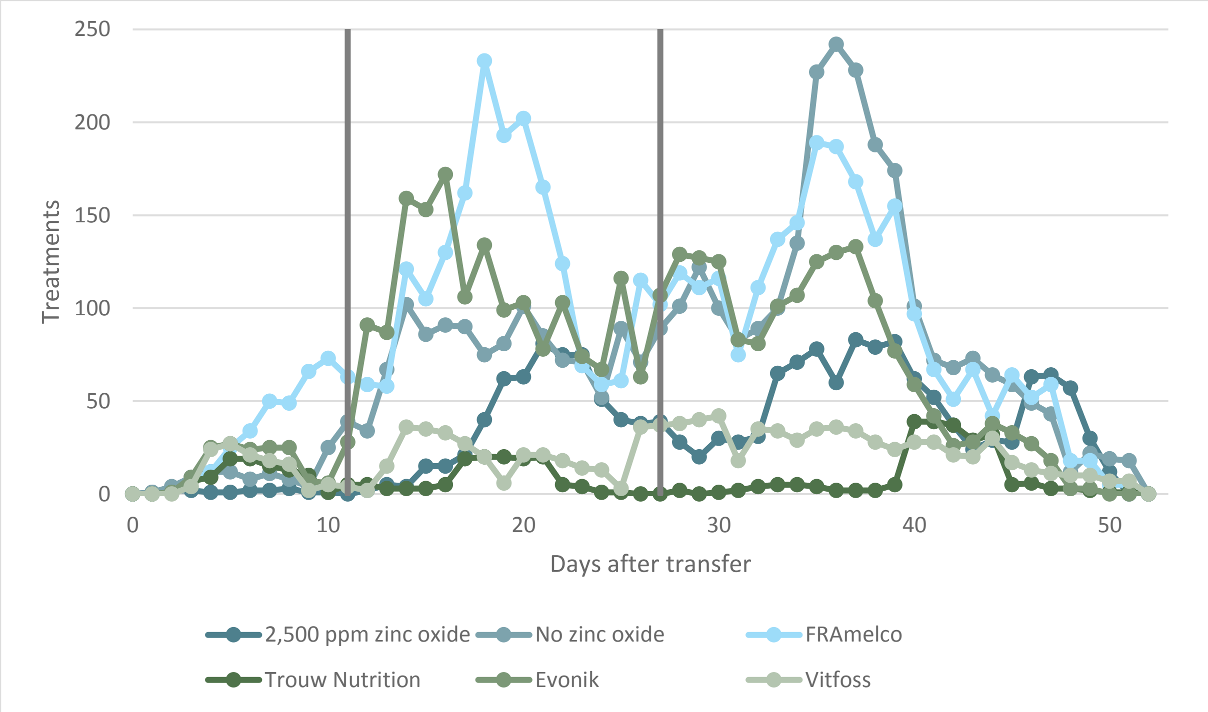

Figure 2. Total number of treatments against diarrhoea during the entire trial period in each of the six groups. Vertical lines indicate changes in diets.

As shown in table 4, there were no differences in mortality between the groups. Significantly fewer pigs were culled from group 4 (Trouw Nutrition) compared with group 2 (no zinc oxide), which is in line with the fact that markedly fewer pigs were treated for diarrhoea in this group than in group 1 (zinc oxide) and group 2.

The outcome of this trial indicates that it is difficult to find a single compound to replace zinc oxide, in this trial monoglycerides in group 3 (FRAmelco), without also taking other steps, which confirms findings in previous trials [1]. Besides the addition of various additives, the concepts in groups 4 (Trouw Nutrition), 5 (Evonik) and 6 (Vitfoss) also included a reduction in protein content, and in group 4 also a reduction in calcium levels. Research has previously confirmed that these factors reduce diarrhoea outbreaks [2], [3]. However, based on this trial it is not possible (nor was it the intention) to conclude which elements did or did not have an impact on productivity and diarrhoea.

Effect of changing pig suppliers and pigs' start weight

The pigs in this trial were delivered from two different herds, but analyses showed no interaction between herds and flock treatments (data not included).

Upon arrival at Grønhøj, the pigs were sorted according to weight and assigned to batches of large and small pigs, respectively. Start weight for the small pigs averaged 6.1 kg and 7.4 for the large pigs. Analyses showed no interaction between start weight and effect of flock treatments, which shows that the small pigs were no more vulnerable than the large pigs. In fact, the large pigs were treated significantly more often than the small pigs (0.07 and 0.05 treatments per feeding day). Due to differences in start weight, the large pigs grew significantly faster than the small pigs in the entire trial period (542 g/day vs 515 g/day), but results show no differences in feed conversion, which is another indicator that small pigs are just as good as large pigs. It should be noted that the trial did not include pigs weighing less than 5.5 kg.

The pigs in group 1 were given 2,500 ppm zinc oxide in their feed for max. 14 days and the pigs in group 2 exclusively got standard feed based on common ingredients and nutrient content complying with the Danish standards. The concepts include a range of expensive additives and ingredients, and it is therefore remarkable that daily gain and feed conversion in the period after the first 14 days were no better than in the control groups. This is also observed in other SEGES trials.

This trial indicates that pigs that, through feed or other factors, have a healthy gut and are thereby not treated with antibiotics for diarrhoea perform better than pigs treated with antibiotics. The potential growth-promoting effect of antibiotics is thereby not enough to neutralize the negative effect of contracting diarrhoea.

Conclusion

Removal of zinc oxide from feed for weaned pigs lowered the production value by roughly DKK 1.90 per pig. Corrected for savings in feed costs when not using zinc the loss per pig amounted to roughly DKK 1. In addition, the diarrhoea frequency and thereby antibiotic treatments increased significantly to approximately twice the number of treatment days, which amounted to approximately DKK 0.80 per pig.

The concept from Trouw Nutrition significantly improved productivity and lowered treatment frequency compared with group 1 (with zinc oxide) but added net DKK 8 per pig to the total cost of production. The concept from Vitfoss was identical to group 1 in terms of both productivity as well as treatments for diarrhoea, but cost DKK 6.60 per pig. The remaining two concepts (FRAmelco and Evonik) did not stand out from the group given no zinc oxide in terms of productivity and diarrhoea treatments.

None of the four concepts improved productivity to such an extent that they were able to cover the increased feed costs compared with the two control groups. The effect on diarrhoea and the savings on antibiotics were not enough to neutralize the increased feed costs.

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Trial no. 1507

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Appendix 1. Feed composition

7-9 kg, Diet 1

Group	1	2	3	4	5	6
	Positive control	Negative control	FRAmelco	Trouw Nutrition	Evonik	Vitfoss
Wheat, %	51.00	51.00	51.00	29.50	51.00	33.00
Barley, %	22.70	23.42	22.01	30.00	14.84	30.00
ViloSoy, soy prot., %	13.43	13.34	13.57	5.60	16.13	
Potato protein, Protastar, %	3.00	3.00	3.00	3.50	2.00	
Fish meal, %)	2.80	2.80	2.80	3.50		4.00
Palm, fatty acid dest., %	2.42	2.26	2.58	2.40	2.55	3.00
Sugar beet molasses, %	0.50	0.50	0.50	0.50	0.50	
Calcium carbonate, %	0.66	0.76	0.76		0.47	
Mono calcium phosphate, %	1.23	1.01	1.01		1.26	
Salt, sodium chloride, %	0.31	0.31	0.31		0.39	
Concept specific, %			0.4 % LAC 34+ 0.4 % C12 Dry	5% Nucleo 20% Vario	0.12% CreAmino, 1.50% wheat bran, 1.50% beet pellets, 5% Dextrose, 0.5% Ca-formate	30% diet 1
Lysine sulphate 70, %	0.75	0.75	0.75		0.99	
Methionine DL 98, %	0.12	0.12	0.12		0.18	
Threonine 98 %, %	0.15	0.15	0.15		0.35	
Tryptophan 99, %	0.05	0.05	0.05		0.08	
Valine L 96.5, %	0.06	0..06	0.06		0.17	
Vitamin premix, %	0.40	0.40	0.40		0.40	
Ronozyme HiPhos, %	0.025	0.025	0.025		0.025	
Zinc oxide, premix, %	0.30	-	-	-	-	-

9-15 kg, Diet 2

Group	1	2	3	4	5	6
	Positive control	Negative control	FRAmelco	Trouw Nutrition	Evonik	Vitfoss
Wheat, %	53.11	53.11	51.57	35,85	44.50	40.40
Barley, %	21.00	21.00	21.00	30,00	21.00	30.10
Soy bean meal	8.00	8.00	8.00	10,00	6.80	8.00
ViloSoy, soy prot., %	6.75	6.75	6.98	3,80	10.00	-
Potato protein Protastar, %	3.50	3.50	3.50	1,50	2.00	-
Fish meal, %)	1.00	1.00	1.00	2,00	0.50	2.00
Palm, fatty acid dest., %	1.98	1.98	2.30	3,10	2.38	2.50
Sugar beet molasses, %	0.50	0.50	0.88	0,50	0.50	
Calcium carbonate, %	1.25	1.25	1.25	0,25	0.83	
Mono calcium phosphate, %	1.06	1.06	1.07		1.10	
Salt,sodium chloride, %	0.36	0.36	0.35		0.37	
Concept specific, %			0.3% LAC 34+ 0.3% C12 Dry	5% Nucleo 8% Vario	0.12% CreAmino, 1.50% wheat bran, 1.50% beet pellets, 4.% Dextrose, 0.5% Ca-formate	17% diet 2
Lysine sulphate 70, %	0.67	0.67	0.67		1.05	
Methionine DL 98, %	0.11	0.11	0.11		0.19	
Threonine 98%, %	0.12	0.12	0.12		0.38	
Tryptophan 99, %	0.04	0.04	0.04		0.10	
Valine L 96.5, %	0.02	0.02	0.02		0.20	
Vitamin premix, %	0.40	0.40	0.40		0.40	
Ronozyme HiPhos, %	0.025	0.025	0.025		0.025	

15-30 kg, Diet 3

Group	1	2	3	4	5	6
	Positive control	Negative control	FRAmelco	Trouw Nutrition	Evonik	Vitfoss
Wheat, %	47.03	47.03	46.33	38.75	39.11	33.50
Barley, %	21.00	21.00	21.00	30.00	21.00	32.00
Soy bean meal	22.00	22.00	22.00	22.00	20.00	24.40
ViloSoy, soy prot., %	2.74	2.74	2.87	-	4.00	-
Palm, fatty acid dest., %	2.47	2.47	2.65	3.30	3.07	3.00
Sugar beet molasses, %	0.50	0.50	0.50	0.50	0.50	
Calcium carbonate, %	1.52	1.52	1.52	0.45	1.09	
Mono calcium phosphate, %	0.85	0.85	0.85		0.91	
Salt, sodium chloride, %	0.39	0.39	0.39		0.39	
Concept specific, %			0.2% LAC 34+ 0.2% C12 Dry	5% Nucleo	0.12% CreAmino, 1.50% wheat bran, 1.50% beet pellets, 4% Dextrose, 0.5% Ca-formate	7.1% diet 3
Lysine sulphate 70, %	0.66	0.66	0.65		0.99	
Methionine DL 98, %	0.15	0.15	0.15		0.21	
Threonine 98 %, %	0.15	0.15	0.15		0.39	
Tryptophan 99, %	0.03	0.03	0.03		0.08	
Valine L 96.5, %	0.06	0.06	0.06		0.21	
Vitamin premix, %	0.40	0.40	0.40		0.40	
Ronozyme HiPhos, %	0.025	0.025	0.025		0.025	

Appendix 2

7-9 kg	1		2		3		4		5		6	
	Positive control		Negative control		FRAmelco		Trouw Nutrition		Evonik		Vitfoss	
	Design	Analysed	Design	Analysed	Design	Analysed	Design	Analysed	Design	Analysed	Design	Analysed
FUgp/kg	1.14	1.15	1.14	1.14	1.14	1.15	1.20	1.20	1.14	1.15	1.19	1.17
Crude protein (g/kg)	194	194	194	196	194	196	170	183	182	189	166	168
Dig. crude prot. (g/FUgp)	148	148	148	150	148	148	122	131	138	142	121	125
Lysine (g/kg)	14.00	14.31	14.01	14.27	14.01	14.46	12.88	13.10	13.91	14.40	14.47	13.73
Dig. lysine (g/FUgp)	11.02	11.20	11.03	11.27	11.03	11.24	9.26	9.44	11.03	11.30	11.24	10.81
Threonine (g/kg)	8.73	8.70	8.75	8.87	8.74	8.81	9.30	9.52	9.81	9.40	10.29	9.62
Dig. threonine (g/FUgp)	6.71	6.65	6.72	6.85	6.72	6.69	6.67	6.84	7.72	7.33	7.89	7.47
Methionine (g/kg)	4.44	4.26	4.43	4.35	4.44	4.33	5.66	5.26	4.43	4.26	4.40	4.21
Dig. methionine (g/FUgp)	3.61	3.44	3.61	3.56	3.62	3.49	4.37	4.07	3.64	3.47	3.45	3.34
Calcium (g/kg)	7.08	6.50	7.09	7.53	7.09	7.27	5.39	5.48	7.09	7.90	7.34	7.24
Phosphorus (g/kg)	6.51	6.18	6.00	6.22	6.00	6.07	5.94	5.85	6.02	6.20	6.58	6.21
Phoshporus (g/FUgp)	5.71	5.40	5.26	5.48	5.26	5.26	4.95	4.88	5.28	5.39	5.53	5.29
Dig. phosphorus (g/FEsv)	3.61	3.41	3.31	3.45	3.31	3.30	3.91	3.86	3.31	3.38	3.46	3.30
Phytase activity (FYT)	1,000	1,670	1,000	1,896	1,000	1,677	1,500	2,065	1,000	1,671	4,000	4,052
Zinc (mg/kg)	2,502	2,258	100	188	100	150	105	134	100	151	110	169
Copper (mg/kg)	160	140	160	152	160	152	160	148	160	158	160	143

9-15 kg	1		2		3		4		5		6	
	Positive control		Negative control		FRAmelco		Trouw Nutrition		Evonik		Vitfoss	
	Design	Analysed	Design	Analysed	Design	Analysed	Design	Analysed	Design	Analysed	Design	Analysed
FUgp/kg	1.12	1.12	1.12	1.12	1.12	1.13	1.16	1.18	1.12	1.13	1.10	1.13
Crude protein (g/kg)	186	187	186	187	186	188	174	182	186	188	187	183
Dig. crude protein (g/FUgp)	144	145	144	145	144	145	132	136	143	144	149	142
Lysine (g/kg)	13.15	12.82	13.15	12.82	13.15	13.31	12.77	13.18	14.58	14.05	12.92	12.38
Dig. lysine (g/FUgp)	10.53	10.25	10.53	10.25	10.53	10.59	9.78	9.96	11.83	10.30	10.83	10.15
Threonine (g/kg)	8.30	8.05	8.30	8.05	8.30	8.30	9.10	9.29	10.33	9.78	8.22	8.05
Dig. threonine (g/FUgp)	6.42	6.22	6.42	6.22	6.42	6.38	6.90	6.95	8.29	7.75	6.56	6.29
Methionine (g/kg)	4.14	3.89	4.14	3.89	4.14	3.96	5.13	4.96	4.67	4.65	4.10	3.86
Dig. methionine (g/FUgp)	3.38	3.17	3.38	3.17	3.40	3.23	4.11	3.92	3.90	3.84	3.46	3.18
Calcium (g/kg)	8.09	7.70	8.09	7.70	8.14	9.30	5.32	5.70	8.09	7.56	7.38	7.04
Phosphorus (g/kg)	5.75	5.79	5.75	5.79	5.75	6.53	5.75	5.80	5.76	5.90	6.16	5.95
Phosphorus (g/FUgp)	5.13	5.16	5.13	5.16	5.13	5.80	4.96	4.93	5.14	5.21	5.60	5.30
Dig. phosphorus (g/FUgp)	3.21	3.22	3.21	3.22	3.21	3.62	3.77	3.75	3.21	3.25	3.54	3.35
Phytase activity (FYT)	1,000	1,642	1,000	1,642	1,000	1,662	1,500	2,148	1,000	1,791	4,000	3,797
Zinc (ppm)	100	193	100	193	100	183	105	146	100	163	110	263
Copper (ppm)	160	134	160	134	160	155	130	127	160	108	160	138

15-30 kg	1		2		3		4		5		6	
	Positive control		Negative control		FRAmelco		Trouw Nutrition		Evonik		Vitfoss	
	Design	Analysed	Design	Analysed	Design	Analysed	Design	Analysed	Design	Analysed	Design	Analysed
FUgp/kg	1.11	1.13	1.11	1.13	1.11	1.13	1.13	1.14	1.12	1.13	1.09	1.10
Crude protein (g/kg)	189	187	189	187	189	186	178	177	190	187	186	186
Dig. crude protein (g/FUgp)	148	144	148	144	148	144	141	138	147	144	148	146
Lysine (g/kg)	12.93	12.67	12.93	12.67	12.93	12.63	12.73	12.52	14.50	14.62	13.79	13.58
Dig. lysine (g/FUgp)	10.53	10.16	10.53	10.16	10.53	10.14	10.24	9.97	11.83	11.83	11.64	11.31
Threonine (g/kg)	8.18	7.86	8.18	7.86	8.18	7.81	8.99	9.07	10.32	9.55	9.88	9.39
Dig. threonine (g/FUgp	6.42	6.08	6.42	6.08	6.42	6.04	7.11	7.11	8.29	7.62	8.15	7.64
Methionine (g/kg)	4.07	3.86	4.07	3.86	4.07	3.96	4.68	4.41	4.64	4.49	4.06	3.87
Dig. methionine (g/FUgp)	3.41	3.19	3.41	3.19	3.41	3.27	3.88	3.62	3.90	3.75	3.45	3.25
Calcium (g/kg)	8.57	8.16	8.57	8.16	8.57	9.27	5.10	5.58	8.65	9.45	9.45	9.05
Phosphorus (g/kg)	5.39	5.54	5.39	5.54	5.39	5.66	5.50	5.62	5.43	5.61	5.45	5.37
Phosphorus (g/FUgp)	4.86	4.91	4.86	4.91	4.86	5.03	4.87	4.92	4.85	4.97	5.00	4.86
Dig. phosphorus (g/FUgp)	3.01	3.04	3.01	3.04	3.01	3.12	3.55	3.59	3.01	3.08	3.11	3.03
Phytase activity (FYT)	1,000	1,636	1,000	1,636	1,000	1,848	1,500	2,326	1,000	1,792	1,000	1,355
Zinc (ppm)	100	226	100	226	100	154	105	129	100	169	100	187
Copper (ppm)	110	95	110	95	110	100	110	107	110	100	90	94

For phytase, zinc and copper, the designed content is the amount added, while the analysed content also includes the feed’s natural content. The analysed content should thus be larger than the designed content.

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