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LOW PROTEIN FOR WEANED PIGS CAN REDUCE DIARRHOEA

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Main conclusion

Weaned pigs fed a low protein diet in the 6-15 kg period experienced a 30% drop in diarrhoea treatments compared with pigs fed no therapeutic ZnO; pigs given feed including ZnO experienced a 50% drop. The low protein strategy also generated the lowest productivity of the four protein strategies in this trial.

Abstract

This trial demonstrated that two of four protein strategies reduced the number of diarrhoea treatments among weaned pigs. Weaned pigs fed low-low-high protein levels in the three growth phases, 6-9 kg, 9-15 kg and 15-30 kg, respectively, had significantly fewer (30%) diarrhoea treatments per feeding day compared with the control group given no therapeutic zinc oxide (ZnO). Pigs fed according to a very low-medium-high protein strategy tended towards fewer diarrhoea treatments. The addition of ZnO to the feed resulted in a 50% reduction in diarrhoea treatments per feeding day.

The trial confirmed that reduced protein content in pig feed is a potential tool for affecting diarrhoea when ZnO is no longer allowed in pig feed. The two protein strategies that lowered diarrhoea occurrence also led to a 15 g drop in daily gain in the entire 6-30 kg period.

Contrary to conclusions in recent SEGES trials, results indicated no productivity differences between the pigs given ZnO and the pigs given no ZnO.

Results showed no interaction between initial weight and feeding strategies, neither in terms of productivity nor diarrhoea. Results revealed a significantly lower diarrhoea occurrence among the small pigs (5.8 kg) compared with medium-sized pigs (6.6 kg) and large pigs (7.6 kg), which shows that in this trial small pigs were not more predisposed to diarrhoea than large pigs.

Background

The EU Commission has banned the use of therapeutic zinc oxide (ZnO) for weaned pigs by June 2022 due to its potential negative impact on the environment [1]. Today, ZnO is used in feed for weaned pigs the first 14 days post-weaning to control post-weaning diarrhoea. Consequently, the ZnO ban will potentially lead to a rise in diarrhoea outbreaks and thereby an increased antibiotic use.

Research has previously shown reduced protein content post-weaning to be one of the most promising means to reduce diarrhoea outbreaks among newly weaned pigs [2], [3], [4]. High-protein feed increases the amount of undigested protein in the large intestine, which produces ammonia and toxic nitrogen compounds that may harm the gut [5], [6].

A comprehensive Danish trial with reduced protein demonstrated that low protein (18%) feed for four weeks post-weaning lowered diarrhoea treatments to 0.5 treatment days/pig in the 7-16 kg period (25 days) versus 1.6 treatment days/pig in the group given high protein (21%) feed [7].

Low protein levels lead to a deficiency in limiting amino acids and a drop in productivity, and consequently, free amino acids must be added to the feed to keep the negative impact on performance to a minimum.

The aim of this trial was to affect diarrhoea occurrence - and thereby antibiotic use - by reducing the protein content of the feed. Four protein strategies were compared with two control groups with and without ZnO, respectively, partly to determine the effect on diarrhoea, partly to determine which strategy to apply to curb the negative effect on productivity.

Materials and methods

Transfer of pigs and implementation

The trial was conducted at SEGES Danish Pig Research Centre's Grønhøj trial station that is health status 'SPF Blue'. Pigs from one sow farm were delivered weekly - from the same weekly batches - at a weight of 5.5-9.0 kg and were included in the trial until roughly 30 kg. The trial period lasted 36 weeks and comprised a total of 6,800 weaned pigs and six groups. Six pens with either 10 or 15 pigs constituted a batch (one replicate). A total of 75 replicates were performed in groups 1, 3, 4, 5 and 6, and 187 replicates were performed in group 2 (negative control), ie. not all groups were represented in each batch, as illustrated below. This procedure was repeated 18 times.

	Batch				
Group	1	2	3	4	5
1	X	X	X	X	
2	XX	XX	XX	XX	XX
3	X	X	X		X
4	X	X		X	X
5	X		X	X	X
6		X	X	X	X

Treatments for diarrhoea constituted the primary parameter in this trial. The trial was designed to identify a reduction in diarrhoea treatments, and this usually requires more replicates than identifying, for instance, impact on in daily gain. Consequently, in this design group 2 was compared with the remaining five groups (five comparisons) rather than an 'all versus all' approach, which would result in 15 comparisons and require more replicates. Comparison of group 2 with the remaining groups requires more replicates than the other groups. The design does, however, allow an 'all versus all' comparison of the production traits.

Upon trial start, the pigs were sorted according to gender and weight, to ensure that all six pens in one batch were identical in terms of female pigs and castrates. There was a maximum difference in average initial weight of 0.25 kg per pig between the pens in each batch. Upon arrival at Grønhøj trial station, the pigs were vaccinated against Lawsonia with 2 ml Enterisol and against PCV2 with 0.5 ml Circovac.

Trial design and feed

All feed was produced by Danish Agro and delivered as pelleted feed.

The first 14 days post-weaning, the pigs were given either control feed with 2,500 mg ZnO per kg feed (positive control) or 0 mg ZnO per kg feed (negative control) *or* one of the four protein strategies containing no therapeutic zinc oxide. Table 1 provides an outline of the four strategies and the trial design. The feed in groups 1 and 2 only differed only in the inclusion or omission of ZnO in phase 1.

Table 1. Trial design.

Group	1	2	3	4	5	6
Description	Positive control	Negative control	Low, Standard, Standard	Low, Low, High	Very low, High, High	Very low, Medium, High
Zinc oxide	+	-	-	-	-	-
Phase 1, 6-9 kg						
Protein*	Standard 145	Standard 145	Low 125	Low 125	Very low 105	Very low 105
Lysine*	Standard 10.6	Standard 10.6	Low 10.0	Low 10.0	Low 10.0	Low 10.0
Phase 2, 9-15 kg						
Protein*	Standard 144	Standard 144	Standard 144	Low 126	High 151	Medium 136
Lysine*	Standard 10.6	Standard 10.6	Standard 10.6	Low 10.0	High 11.1	High 11.1
Phase 3, 15-30 kg						
Protein*	Standard 143	Standard 143	Standard 143	High 150	High 150	High 150
Lysine*	Standard 10.6	Standard 10.6	Standard 10.6	High 11.1	High 11.1	High 11.1

*'Protein" = gram digestible crude protein per feed unit. "Lysine" = gram digestible lysine per feed unit. This table only includes lysine; the remaining free amino acids added to the diets comply with the 2018 standard profile relative to lysine.

Protein strategies

The supply of protein and amino acids was largely identical in all three phases in groups 1 and 2; only the ingredients differed.

In phase 1, the protein content in groups 3 and 4 was determined on the basis of an at the time ongoing trial of amino acid profiles and protein. This trial indicated that it was possible to reduce protein-bound amino acids (such as isoleucine, leucine and histidine) by approx. 10% compared with the standard profile. To be able to lower protein by roughly 15%, the content of lysine and other added amino acids was reduced to the levels currently recommended in the protective standards [8]. The protein level in groups 5 and 6 was lowered by a further 15%, which resulted in a significant deficiency in protein-bound amino acids compared with the recommended amino acid profile.

In group 3, the protein content in phases 2 and 3 was raised to the standard level to be able to illustrate the effect of reduced protein exclusively in the 6-9 kg period when post-weaning diarrhoea is most common. By raising the content to the standard level at roughly 9 kg, productivity in the entire growth period is expected to be largely unaffected by the low protein level in phase 1.

In group 4, the protein level remained low in phase 2, as previous trials at Grønhøj trial station showed a significant increase in diarrhoea outbreaks in the 9-15 kg period [10], [11]. In order to compensate for the expected drop in productivity, the protein content was raised beyond the standard in phase 3 in this group.

In group 5, the protein content in phases 2 and 3 was raised above the standard to compensate for the very low protein level in phase 1.

In group 6, the feed in phase 2 had a medium protein content to avoid very large changes in protein levels when switching from one phase to the next. In phase 3, the feed in group 6 had a high protein content as in groups 4 and 5.

Diet composition is shown in appendix 1.

Benzoic acid and calcium formate were added to all diets. Benzoic acid inhibits the microbial activity and lowers diarrhoea outbreaks [12], [13], and calcium formate inhibits the acid binding capacity of the feed and has been found to improve productivity in several trials [14], [15]. Consequently, this trial analysed the effect of ZnO and reduced protein combined with common additives known to affect post-weaning diarrhoea.

A recent SEGES trial revealed no difference between soybean meal and soy protein concentrate [9], and all groups were therefore given the same amount of soybean meal: 7% in phase 1; 14% in phase 2; and 21% in phase 3. The reduction in protein was achieved by using less of ‘expensive’ feedstuffs such as fishmeal, potato protein and soy protein concentrate. Likewise, the increase in protein beyond the standard in groups 4, 5 and 6 was achieved by using an expensive type of potato protein concentrate and by using soy protein concentrate. The price of the feed was therefore not a factor in this trial, and ‘the actual production value’ should not be assigned too much value as the high-protein diets could be produced cheaper by increasing the content of soybean meal beyond the 21% which was the maximum level used in this trial.

The pigs were fed ad lib and had access to feed 24 hours a day.

The pigs gradually switched to phase 2 feed after 11 days (roughly 9 kg), when they were weighed, and were by day 14 given phase 2 feed exclusively. No pigs were given ZnO after 9 kg. The pigs were weighed again at approx. 15 kg when they switched to phase 3 feed over three days, and they were given this feed until 30 kg.

The amount of feed allocated to each pen was recorded before the pigs were weighed, and leftovers in the feeders were removed and are not included in the feed consumption data before or after the pigs were weighed.

Analyses of feed

Representative samples of all diets were collected at the feedmill according to the principles of the Theory of Sampling.

The feed was produced over four rounds. In each production round, three samples were taken from each diet and subject to analysis of energy, protein, calcium, phosphorus, zinc, copper and amino acids at Eurofins Steins Laboratory.

Recordings

Productivity

All recordings were made at pen level and determined for each of the periods: transfer to 9 kg, 9-15 kg, 15-30 kg and the entire trial period 6-30 kg. Recordings included daily gain, feed intake and feed consumption.

Treatments for disease

Treatments for diarrhoea were recorded as primary parameter, and mortality and pigs moved to a hospital pen were recorded as secondary parameters. The first two clinically ill pigs in a pen were treated for diarrhoea individually; when it was estimated that more than two pigs in a pen suffered from diarrhoea, the entire pen was medicated via the feed. Section-wise treatments were not practised.

Pigs were treated individually for three days, and flock treatments lasted five days. Treatments for diarrhoea were administered by the staff according to guidelines issued by the herd vet when the following symptoms were observed: dirty hindpart around rectum, sunken eyes, hollow flanks and depression.

All pigs were treated with the same type of antibiotics.

Disease treatments were determined as per cent pens treated and as treatments for diarrhoea per feeding day. Prophylactic treatments with antibiotics against diarrhoea were not practised.

Statistical analyses

Treatment frequency (per cent flock-treated pens / diarrhoea treatments per feeding day) was subject to analysis in a logistic regression model with group (protein strategy) as systematic effect, initial weight as covariate, and batch as random effect. In these models, all groups were compared with group 2 with no correction made for pairwise comparisons. Consequently, significantly more replicates were conducted in group 2, as group 2 represented control in the five comparisons.

Productivity parameters (gain, feed intake, feed conversion and production value) were subject to analysis in a linear mixed model with group as systematic effect, initial weight as covariate and batch as random effect. In this model, all groups were compared with each other and correction was therefore made for 15 pairwise comparisons using a Sidak correction.

Prerequisites for calculation of the production value

The production value (PV) per pig place per day for the entire 6-30 kg period was based on the following factors:

Production value, DKK/pig place/day = (value of gain – feed costs) / feeding days

Calculations included identical feed prices in all groups (five years' prices September 2013 – September 2018) and the value of 1 kg gain:

Average pig price, 7 kg pigs: DKK 214 per pig ± DKK 10.1 per kg (7-9 kg), ± DKK 8.0 per kg (9-12 kg), and ± DKK 6.2 per kg (12-25 kg).

Average pig price, 30 kg pigs: DKK 368 per pig, kg corrections DKK -5.67 per kg (25-30 kg) and DKK +5.65 per kg (30-40 kg).

Feed, weaned pigs: 7-10 kg: DKK 3.58 per feed unit, and 10-30 kg DKK 2.05 per feed unit, used in all groups.

Definition of variables:
Value of gain: pigs' gain (kg) in the trial period x value of 1 kg gain (DKK 6.85 which was used in the entire trial period).

Feed costs were determined using the below equation, and are based on the content of analysed feed units (EDOMi[1] analyses) of the basic diets and the actual amount of feed allocated per pen:

Feed costs = (final weight – initial weight) x feed units per kg gain x price per feed unit

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

Results and discussion

Analyses of feed

The results of the feed analyses are shown in appendix 2. Three samples were taken of each diet in each of the four production rounds, ie. the results shown are an average of 12 feed samples.

Results generally revealed good agreement between the expected content and the analysed content. Amino acid deviations overall ranged from 0 to 5%. A slightly larger discrepancy was found for methionine, but the discrepancies found were largely identical in all groups and have therefore not affected the difference between the groups.

Treatments for diarrhoea

Table 2 shows the number of diarrhoea treatments and dead and culled pigs. Results revealed no differences between the groups in mortality or culling. The results are based on statistical analyses of all groups compared with group 2 with no ZnO, ie. the groups were not compared with each other.

In the entire 6-30 kg period, results showed significantly fewer flock treatments in group 1 (with ZnO) than in group 2 (no ZnO). There was also a tendency to fewer flock treatments in group 4 compared with group 2. Flock treatments are determined as cumulated treatments, ie. a flock-treated pen is only included in the analyses once, even if two flock-treatments were administered in the trial period.

Table 2 also shows the total number of diarrhoea treatments per feeding day. There were significantly fewer treatments in group 1 (approx. 50%) given ZnO compared with group 2 without ZnO. The number of diarrhoea treatments per feeding day was also significantly lower in group 4 (approx. 30%) and there was a tendency to fewer treatments in group 6 (approx. 22%) compared with group 2.

[1] Enzyme Digestible Organic Matter ileum

Table 2. Disease treatments and dead/culled pigs, entire 6-30 kg period.

Group	1	2	3	4	5	6
Description	**Positive control Standard**	**Negative control Standard**	**Low, Standard, Standard**	**Low, Low, High**	**Very low, High, High**	**Very low, Medium, High**
Pens included	73	187	73	75	73	77
Flock treatments, %*	28.2b	48.7a	46.7a	36.1y	45.2a	39.1a
Diarrhoea treatments per feeding day**	0.047b	0.093a	0.083a	0.066b	0.079a	0.073y
Drop comp. w. group 2, %	49.5	-	10.8	29.0	15.1	21.5
Treatment days/pig***	2.0b	4.2a	3.8a	3.1b	3.7a	3.2y
Dead and culled						
Dead, %	0.7	0.9	1.1	0.8	1.0	0.6
Dead and culled, %	3.8	4.7	4.2	5.1	3.9	3.0

*Different superscripts (a,b) indicate significant (P-value <0.05) difference from group 2.

** Different superscripts (a,y) indicate tendency (P-value <0.10) to difference from group 2.

***Estimate based on the number of pigs at trial start, first and second weighings.

In the 6-9 kg period, there were virtually no flock treatments in any of the groups (figure 1). In the 9-15 kg period, a significant increase in treatments is seen in all groups; particularly in group 2 where flock treatment was administered in 30-40% of the pens. The lowest treatment frequencies were found in group 1 (ZnO in phase 1) and groups 4 and 6 given low-low and very low-medium protein in phases 1 and 2.

In the 15-30 kg period, the curves flattened and remained fairly stable in all groups. In this period, the highest treatment frequency was observed in group 2 (no ZnO) where flock treatment was administered in around 50% of the pens. In group 1, 30% of the pens received flock treatment and in groups 4 and 6 35% to 40% of the pens received flock treatments.

Figure 2 shows the total number of pigs treated per day in each group. The figures shown are the sum of single animal treatments and flock-treatments, ie. the number of pigs treated daily for diarrhoea.

The figure shows a very low diarrhoea frequency in the 6-9 kg period followed by two large waves around day 15 and day 23. In all groups, the number of daily treatments increased after day 15. It is also clear that after day 25, treatment frequency dropped, and this was the case in all groups.

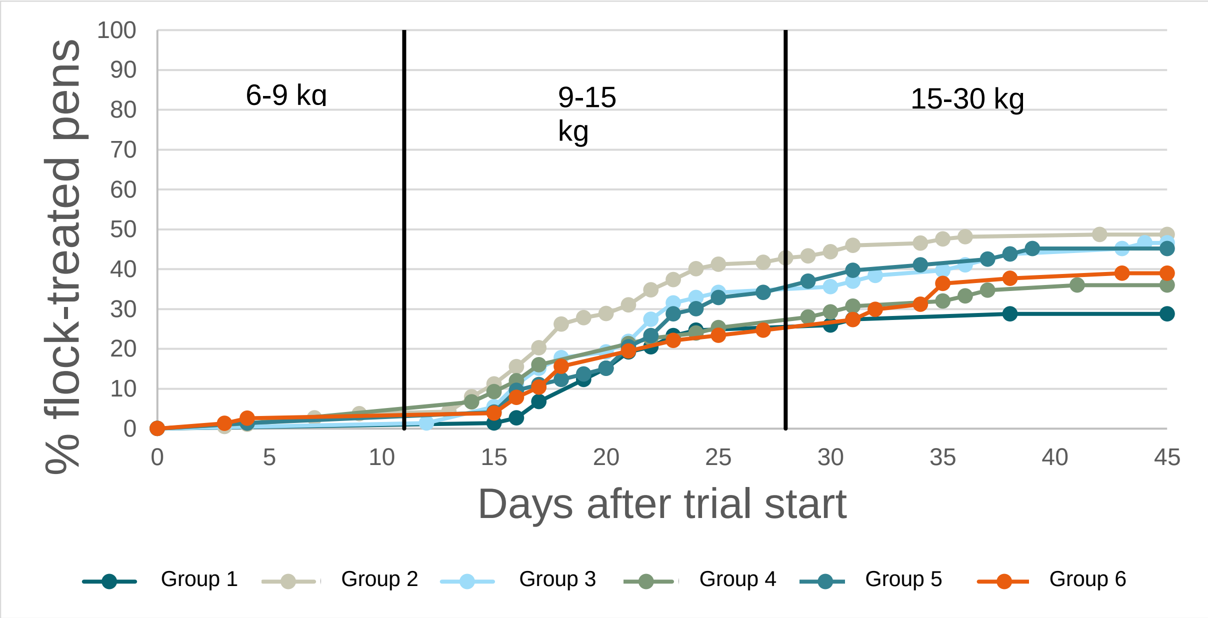

Figure 1: Flock treatments, %, days after trial start, cumulated.

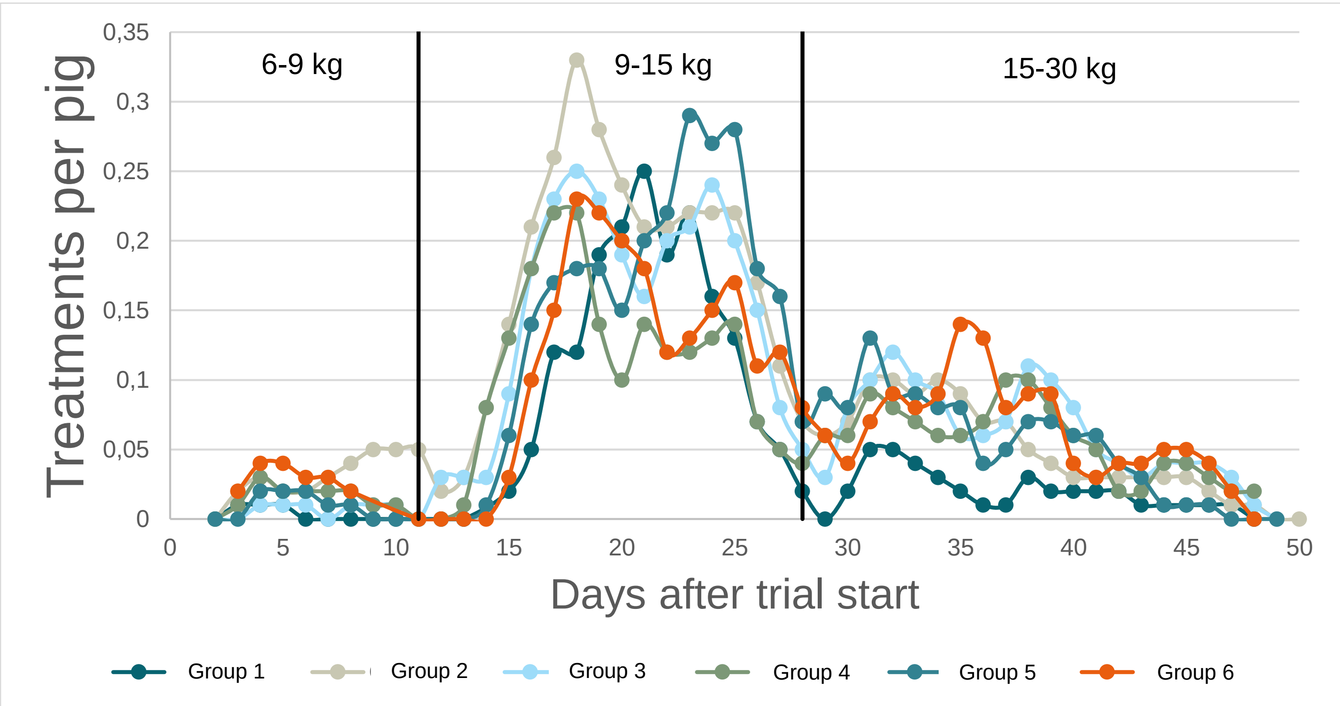

Figure 2: Average number of treatments per pig, days after trial start.

Interestingly, in phase 2 treatment days per pig were significantly lower in group 1 (1.6 days) compared with group 2 (2.4 days) despite the fact that the feed no longer contained ZnO. This points to a possible 'long term effect' of ZnO on gut health. This observation was also made in two previous trials [10], [11]. The body is quick to excrete ZnO and no carry over effect was observed on productivity, but it is possible that ZnO has a positive effect on the microflora or gut health that lasts even after zinc is no longer used.

Production results

Production results for each of the six groups are shown in table 3 where different superscripts within a row indicate significant differences (P value < 0.05). All groups are compared with each other.

In the 6-9 kg period, there were no differences in daily gain, feed intake or feed conversion between the two control groups, ie. the pigs that received no ZnO the first 14 days post-weaning managed just as well as the pigs given 2,500 mg ZnO per kg feed. This outcome was surprising as previous trials found a significantly lower daily gain (approx. 60 g/day) among pigs given no ZnO [10] as well as in phase 1 [11].

The pigs in groups 5 and 6 given a very low protein supply in phase 1 had a significantly lower daily gain in the 6-9 kg period than the pigs in the remaining groups, whereas no significant differences were found between the remaining four groups. However, in phase 1 the pigs in all the trial groups had a significantly poorer feed conversion compared with the pigs in the two control groups – the pigs in groups 3 and 4 managed slightly poorer than the control groups, and the pigs in groups 5 and 6 had a significantly poorer feed conversion.

In the entire 6-30 kg period, results revealed no differences between the two control groups in daily gain, feed intake, feed conversion and production value. Previous studies found a significantly lower daily gain (roughly 20 g/day) among pigs given no ZnO [10], [11]. The three trials differed mainly in feed composition: the feed used in this trial contained benzoic acid and calcium formate, but it is not possible to determine for certain whether this had any effect.

Daily gain was significantly lower in groups 4 and 6 compared with the control groups in the entire 6-30 kg period, whereas groups 3 and 5 did not differ from the control groups. This was expected as the pigs in groups 4 and 6 received low protein up to 15 kg, and the increase in protein in phase 3 was not sufficient to compensate for the low gain in phases 1 and 2. The pigs in groups 3 and 5 given protein according to the standard or beyond in phase 2 were not affected by the low protein supply in phase 1, when seen over the entire 6-30 kg period.

The pigs in groups 4, 5 and 6 had a significantly lower feed intake than the pigs in group 2 which is attributed to a lower feed intake in phase 3 (data not shown) when these groups received protein beyond the standard.

Table 3. Productivity, phase 1 (6-9 kg) and the entire period (6-30 kg).

Group	1	2	3	4	5	6
Description	**Pos. control Standard**	**Neg. control Standard**	**Low, Standard, Standard**	**Low, Low, High**	**Very low, High, High**	**Very low, Medium, High**
Pens included	73	187	73	75	73	77
Pigs at transfer	904	2300	899	919	893	948
Initial weight, kg	6.7	6.7	6.7	6.7	6.7	6.7
Final weight, kg	31.3	31.2	31.2	30.9	31.3	30.8
Phase 1, 6-9 kg						
Daily gain, g/day*	184a	184a	177a	173a	148b	143b
Daily feed intake, feed units/day	0.25	0.26	0.26	0.26	0.25	0.24
FCR, feed units/kg gain*	1.40a	1.42a	1.50b	1.55b	1.68c	1.72c
Entire period (6-30 kg)						
Daily gain, g/day*	520a	519a	516ab	504b	517ab	504b
Daily feed intake, feed units/day*	0.84ab	0.85a	0.84ab	0.82bc	0.83bc	0.81c
FCR, feed units/kg gain*	1.63a	1.64a	1.64a	1.64a	1.60b	1.62ab
Production value (PV), same feed price in all groups						
PV, DKK/pig/day*	1.71ab	1.70ab	1.69ab	1.65b	1.73a	1.66b
PV index,* 1)	101ab	100ab	99ab	97b	102a	98b
Actual production value (gross margin (GM)), current feed price per group						
Gross margin, DKK/pig/day*	1.81a	1.81a	1.81a	1.76ab	1.76ab	1.74b
Gross margin, index,* 2)	100a	100a	100a	97ab	97ab	96b
Dig. protein entire period, g total Dig. protein, % of group 1	5,668 100	5,672 100	5,660 99.8	5,534 97.5	5,632 99.3	5,492 96.8
Current feed price, DKK/feed unit (avg. entire 6-30 kg period)	2.05	2.04	2.03	2.04	2.13	2.07

*Different superscripts (a,b,c) within a row indicate significant difference (P value 0.05).

1) Minimum definite difference in index (identical feed price): 3.4 index points

2) Minimum definite difference in index (identical feed price): 3.2 index points

When all production traits are pooled in a production value (PV) based on identical feed prices in all groups, table 3 shows that there is no difference in PV between the two control groups. None of the four protein strategies differed significantly from the control groups. The pigs in group 5 given high-protein feed in phases 2 and 3 had a significantly better feed conversion and a higher PV than the pigs in groups 4 and 6 that received protein below the standard in phases 1 and 2. This is explained by the high protein content in group 5 in phase 2, which resulted in a better feed conversion specifically in phase 2 compared with groups 4 and 6.

The pigs in group 5 had a higher protein uptake in the entire 6-30 kg period than the pigs in groups 4 and 6. This led to more expensive feed and consequently the production-wise advantage of a high protein uptake was neutralized by a higher feed price. However, this is partly explained by the ingredients as a maximum of 14 and 21% soybean meal was allowed in the feed in phases 2 and 3, respectively.

Overall, of the four protein strategies, the two that positively affected diarrhoea outbreaks (groups 4 and 6) also led to a lower protein uptake in the entire period, which in turn led to a lower production value (though not significantly lower) compared with the two control groups, when identical feed prices were used.

Effect of initial weight

At trial start, the pigs were assigned to batches according to their weight. To be able to determine whether initial weight affected the subsequent productivity and diarrhoea frequency, the data material was divided into large, medium and small pigs. Interaction was not observed between the six groups and initial weight.

Initial weight differed by averagely 1 kg between large and medium pigs and by a further 800 g for small pigs (table 4). Analyses revealed an effect on the subsequent daily gain and feed intake where medium and large pigs managed significantly better than the small pigs in the entire 6-30 kg period. However, there were no significant differences in feed conversion and production value between large, medium and small pigs in the entire 6-30 kg period, but for the small pigs analyses showed a tendency (P=0.058) to a low production value.

Table 4. Productivity, the entire 6-30 kg period, in batches with small, medium or large pigs at trial start.

Pig size	Small pigs	Medium pigs	Large pigs
Pens included	184	182	192
Initial weight, kg	5.8	6.6	7.6
Daily gain, g/day*	495a	523b	521b
Daily feed intake, feed units/day*	0.80a	0.85b	0.85b
FCR, feed units/kg gain	1.62	1.63	1.64
Production value, DKK/pig/day (same feed price)	1.65	1.72	1.70

*Different superscripts (a,b) within a row indicate significant difference (P value 0.05).

Table 5 provides an outline of treatment frequency, partly as flock treatments and partly as treatments per feeding day for large, medium and small pigs, respectively. Compared with medium and large pigs, the small pigs received significantly fewer flock treatments and treatments per day in the entire 6-30 kg period, whereas medium and large pigs were largely identical in this respect. Age was not recorded, but as the pigs originated from the same weekly batches, it is likely that, despite different weight, the pigs were largely of the same age in all three groups.

Table 5. Treatments for diarrhoea, the entire 6-30 kg period, in batches with small, medium or large pigs at trial start.

Pig size	Small pigs	Medium pigs	Large pigs
Pens included	184	182	192
Initial weight	5.8	6.6	7.6
Flock treatments, %*	31.8a	47.0b	42.6b
Treatments/feeding day*	0.06a	0.08b	0.08b

* Different superscripts (a,b) within a row indicate significant difference (P-value 0.05).

Conclusion

This trial confirmed that two of the four protein strategies had a positive effect on diarrhoea occurrence. In group 4, where the pigs were given low-low-high protein in the three phases, results revealed significantly fewer (approx. 30%) treatments per feeding day compared with the control group given no ZnO. In group 6, where pigs were given very low-medium-high protein results showed a tendency to fewer treatments. Therapeutic zinc oxide reduced diarrhoea treatments per day by roughly 50%.

The trial demonstrated that protein reduction is a possible way to reduce diarrhoea outbreaks when Zno is no longer allowed in pig feed. The pigs in groups 4 and 6 had a slightly lower protein uptake in the entire 6-30 kg period, which led to a 15 g drop in daily gain, but the production value was not significantly lower than that of the control groups.

As opposed to conclusions in recent SEGES trials, this trial did not find differences in productivity between the pigs given ZnO and those that received no ZnO. This may be attributed to the addition of benzoic and calcium formate, which were not used in previous trials with ZnO.

Results showed no interaction between initial weight and the four protein strategies, neither in terms of productivity nor diarrhoea. There were significantly fewer diarrhoea treatments among small pigs compared with medium and large pigs, which proves that small pigs (approx. 5.8 kg) were not more predisposed to diarrhoea than large pigs.

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Participants

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Other: Anne Sofie Hougesen, trainee

Trial no. 1555
NAV: 1276

//LISH//

Appendix 1: Diet composition

Composition of each diet, %.

Group	1 + Zn	2	3	4	5	6
Phase 1, 6-9 kg	**Standard**	**Standard**	**Low**	**Low**	**Very low**	**Very low**
Wheat	45.5	46.6	53.0	53.0	57.0	57.0
Barley	20.0	20.0	20.0	20.0	20.0	20.0
Soyprotein conc.	7.7	7.5	0.9	0.9	0	0
Soybean meal	7.0	7.0	7.0	7.0	7.0	7.0
Dried whey	6.0	6.0	6.0	6.0	6.0	6.0
Potato protein	4.0	4.0	4.0	4.0	1.6	1.6
Fatty acid distillates	2.5	2.2	1.9	1.9	1.9	1.9
Fishmeal	2.0	2.0	2.0	2.0	0	0
Monocalc. phosphate	1.3	1.1	1.2	1.2	1.4	1.4
Calcium formate	1.0	1.0	1.0	1.0	1.0	1.0
Benzoic acid	0.5	0.5	0.5	0.5	0.5	0.5
Sodium chloride	0.7	0.7	0.7	0.7	0.7	0.7
Premix	0.4	0.4	0.4	0.4	0.4	0.4
ZiCare Premix	0.3	0	0	0	0	0
DSP Microgrits Green	0.05	0	0	0	0	0
DSP Microgrits Blue	0	0	0.05	0.05	0	0
Feed lime	0	0	0	0	0.1	0.1
Lysine sulphate 70 %	0.668	0.676	0.860	0.860	1.327	1.327
Threonine 98 %	0.121	0.123	0.188	0.188	0.364	0.364
Methionine 98 %	0.109	0.108	0.140	0.140	0.258	0.258
Tryptophan 99 %	0.046	0.047	0.073	0.073	0.107	0.107
Valine 96.5 %	0.021	0.022	0.106	0.106	0.307	0.307
Phase 2, 9-15 kg	**Standard**	**Standard**	**Standard**	**Low**	**High**	**Medium**
Wheat	53.1	53.1	53.1	57.6	51.6	55.9
Barley	20.0	20.0	20.0	20.0	20.0	20.0
Soyprotein conc.	3.0	3.0	3.0	0	3.6	0
Soybean meal	14.0	14.0	14.0	14.0	14.0	14.0
Potato protein	3.0	3.0	3.0	1.2	4.0	2.9
Fatty acid distillates	2.0	2.0	2.0	1.8	2.0	1.8
Monocalc. phosphate	1.0	1.0	1.0	1.1	1.0	1.1
Calcium formate	1.0	1.0	1.0	1.0	1.0	1.0
Benzoic acid	0.5	0.5	0.5	0.5	0.5	0.5
Sodium chloride	0.6	0.6	0.6	0.6	0.6	0.6
Premix	0.4	0.4	0.4	0.4	0.4	0.4
DSP Microgrits Green	0.05	0.05	0.05	0	0	0
DSP Microgrits Blue	0	0	0	0.05	0	0
Feed lime	0.2	0.2	0.2	0.2	0.2	0.2
Lysine sulphate 70 %	0.732	0.732	0.732	0.961	0.722	1.046
Threonine 98 %	0.147	0.147	0.147	0.245	0.135	0.266
Methionine 98 %	0.128	0.128	0.128	0.174	0.133	0.207
Tryptophan 99 %	0.041	0.041	0.041	0.059	0.046	0.075
Valine 96.5 %	0.045	0.045	0.045	0.163	0.028	0.178

Phase 3, 15-30 kg	Standard	Standard	Standard	High	High	High
Wheat	50.2	50.2	50.2	49.1	49.1	49.1
Barley	20.0	20.0	20.0	20.0	20.0	20.0
Soyprotein conc.	0	0	0	0	0	0
Soybean meal	21.0	21.0	21.0	21.0	21.0	21.0
Potato protein	1.3	1.3	1.3	2.5	2.5	2.5
Fatty acid distillates	2.4	2.4	2.4	2.4	2.4	2.4
Monocalc. phosphate	0.8	0.8	0.8	0.9	0.9	0.9
Sodium chloride	0.5	0.5	0.5	0.5	0.5	0.5
Benzoic acid	0.5	0.5	0.5	0.5	0.5	0.5
Premix	0.4	0.4	0.4	0.4	0.4	0.4
DSP Microgrits Green	0.05	0.05	0.05	0	0	0
DSP Microgrits Blue	0	0	0	0.05	0.05	0.05
Feed lime	1.5	1.5	1.5	1.5	1.5	1.5
Lysine sulphate 70 %	0.823	0.823	0.823	0.802	0.802	0.802
Threonine 98 %	0.203	0.203	0.203	0.185	0.185	0.185
Methionine 98 %	0.157	0.157	0.157	0.158	0.158	0.158
Tryptophan 99 %	0.041	0.041	0.041	0.047	0.047	0.047
Valine 96.5 %	0.106	0.106	0.106	0.081	0.081	0.081

Appendix 2: Nutrient content

Phase 1, 6-9 kg. Average nutrient content (4 batches, 3 samples from each).

E = Expected, An = Analysed

Digestible amino acid per feed unit is based on analysed amino acid values and the digestibility coefficient included in the feed formulation.

Group	1		2		3 + 4		5 + 6	
	E	AN	E	AN	E	AN	E	AN
Feed units/kg	1.15	1.17	1.15	1.17	1.15	1.18	1.15	1.18
g protein/kg	191	185	191	187	166	169	140	148
g dig. protein/feed unit	145	138	145	139	125	125	105	109
g lysine/kg	13.6	13.2	13.6	13.3	12.7	13.0	12.4	12.6
g dig. lysine/feed unit	10.6	10.1	10.6	10.2	10.0	10.1	10.0	9.9
g threonine/kg	8.6	8.4	8.6	8.3	8.0	8.1	7.9	7.9
g dig. threonine/feed unit	6.5	6.2	6.5	6.2	6.1	6.0	6.1	6.0
g methionine/kg	4.3	4.0	4.3	4.0	4.2	4.0	4.5	4.1
g dig. methionine/feed unit	3.5	3.1	3.4	3.2	3.4	3.1	3.4	3.1
g calcium/kg	7.5	7.8	7.1	7.9	7.1	7.8	6.9	7.8
g phosphorus/kg	6.4	6.1	5.9	5.9	5.9	5.9	6.0	6.0
g dig. phosphorus/feed unit	3.6	3.4	3.3	3.2	3.3	3.2	3.3	3.2
mg zinc/kg*	2,502	2,563	100	144	100	144	100	150
mg copper/kg*	170	156	170	161	170	164	170	166

*zinc and copper: E= amount added

Phase 1, 6-9 kg. Average amino acid profile (4 batches, 3 samples from each), % of lysine based on total amino acid content

Group	1	2	3+4	5+6
Lysine	100	100	100	100
Methionine	30	30	31	33
Cysteine+Cystine	22	22	20	18
Threonine	63	63	62	62
Aspartic acid	124	123	104	80
Serine	66	66	59	49
Arginine	76	76	65	54
Glycine	59	59	54	44
Glutamic acid	266	262	242	224
Alanine	58	58	52	41
Proline	91	91	85	78
Valine	68	67	67	69
Histidine	32	31	28	24
Phenylalanine	68	68	61	50
Isoleucine	55	55	48	39
Leucine	103	103	92	75

Fase 2, 9-15 kg. Average nutrient content (4 batches, 3 samples from each).
E = Expected, An = Analysed
Digestible amino acid per feed unit is based on analysed amino acid values and the digestibility coefficient included in the feed formulation.

Group	1+2+3		4		5		6	
	E	AN	E	AN	E	AN	E	AN
Feed units/kg	1.11	1.13	1.11	1.13	1.11	1.14	1.11	1.12
g protein/kg	184	183	162	167	193	191	174	175
g dig. protein/feed unit	144	141	126	128	152	146	137	136
g lysine/kg	13.1	13.0	12.2	12.5	13.7	13.8	13.5	13.9
g dig. lysine/feed unit	10.6	10.4	10.0	10.1	11.1	10.9	11.1	11.3
g threonine/kg	8.3	8.0	7.7	7.6	8.7	8.5	8.6	8.5
g dig. threonine/feed unit	6.5	6.2	6.1	5.9	6.8	6.5	6.8	6.7
g methionine/kg	4.1	3.8	4.0	3.8	4.3	4.0	4.5	4.3
g dig. methionine/feed unit	3.4	3.1	3.3	3.1	3.6	3.3	3.8	3.6
g calcium/kg	6.7	7.7	6.7	7.7	6.7	7.6	6.7	7.5
g phosphorus/kg	5.6	5.8	5.6	5.9	5.6	5.7	5.6	5.7
g dig. phosphorus/feed unit	3.2	3.3	3.2	3.3	3.2	3.2	3.2	3.2
mg zinc/kg*	100	176	100	153	100	153	100	149
mg copper/kg*	170	160	170	163	170	156	170	165

*zinc and copper: E= amount added

Phase 2, 9-15 kg. Average amino acid profile (4 batches, 3 samples from each), % of lysine based on total amino acid content.

Group	1+2+3	4	5	6
Lysine	100	100	100	100
Methionine	29	31	29	31
Cysteine+Cystine	22	21	22	20
Threonine	62	61	62	61
Aspartic acid	122	105	124	102
Serine	66	60	66	57
Arginine	76	71	76	66
Glycine	57	51	57	49
Glutamic acid	273	266	265	245
Alanine	56	50	56	48
Proline	92	89	90	83
Valine	67	67	66	66
Histidine	32	29	32	27
Phenylalanine	68	60	68	58
Isoleucine	54	47	54	46
Leucine	101	89	101	86

Fase 3, 15-30 kg. Average nutrient content (4 batches, 3 samples from each).
E = Expected, An = Analysed
Digestible amino acid per feed unit is based on analysed amino acid values and the digestibility coefficient included in the feed formulation.

Group	1+2+3		4+5+6	
	E	AN	E	AN
Feed units/kg	1.11	1.14	1.11	1.14
g crude protein/kg	184	187	192	195
g dig. protein/feed unit	144	143	151	149
g lysine/kg	13.0	13.3	13.6	13.8
g dig. lysine/feed unit	10.6	10.6	11.1	11.0
g threonine/kg	8.3	8.8	8.7	8.7
g dig. threonine/feed unit	6.5	6.7	6.8	6.6
g methionine/kg	4.1	3.9	4.3	4.1
g dig. methionine/feed unit	3.4	3.2	3.6	3.4
g calcium/kg	8.4	9.4	8.4	9.5
g phosphorus/kg	5.2	5.7	5.2	5.6
g dig. phosphorus/feed unit	3.0	3.2	3.0	3.1
mg zinc/kg*	100	178	100	159
mg copper/kg*	140	135	140	138

*zinc and copper: E= amount added

Phase 3, 15-30 kg. Average amino acid profile (4 batches, 3 samples from each), % of lysine based on total amino acid content.

Group	1+2+3	4+5+6
Lysine	100	100
Methionine	29	30
Cysteine+Cystine	21	20
Threonine	63	63
Aspartic acid	124	126
Serine	65	67
Arginine	81	80
Glycine	56	57
Glutamic acid	285	280
Alanine	55	56
Proline	91	92
Valine	68	68
Histidine	32	32
Phenylalanine	66	67
Isoleucine	52	54
Leucine	99	101

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