Title: Improving pig performance and economic return by the application of ultra-high doses of phytase in finishing pigs – **NPB #17-106**

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Revised

Industry Summary

This project specifically evaluated the impact of ultra-high doses of phytase on pork production parameters. Past research efforts have demonstrated positive effects of phytase supplementation at approximately 1,500 to 3,000 FTU/kg, but higher inclusion levels have not been adequately tested in a commercial production environment. The cost of phytase has decreased substantially; therefore, inclusion of ultra-high levels of phytase (beyond those required for P release) becomes economically feasible. In the present study with 2,150 pigs, we demonstrated that mega-dosing of phytase (3,000, 4,500, or 6,000 FTU/kg) linearly improved daily gain and feed efficiency and that this improvement was most dramatic during the final finishing phase (95 to 125 kg of body weight), improving feed efficiency from 3.76 to 3.41 (9.3% improvement). The final finishing phase represents a period of increased stress related to decreasing floor space per unit of pig body weight, resulting in a relatively profound reduction in pig performance. These data suggest that a targeted application of mega-doses of phytase during the final phase of production may be economically attractive compared to supplementation of phytase for the entire growth period.

Key Findings:

- Supplementation of fat improved daily body weight gain and feed efficiency, with the largest effect being observed during the last feeding phase before the first marketing cut.
- Supplementation of phytase at up to 6,000 FTU/kg improved daily gain and feed efficiency, especially during the final feeding phase before marketing.
- Supplementation of phytase (3,000 FTU/kg) to diets with added fat (4% choice white grease) did not impact performance of pigs.
- Supplemental phytase reduced the number of viable pigs (representing mortalities, light, and cull pigs), which was not observed in previous studies. This potential impact of phytase needs to be further evaluated.
- Collectively, data indicate that mega-doses of phytase during the final phase of production may be economically attractive compared to feeding phytase for the entire growth period.

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Scientific Abstract:

The objective of the current study was to determine the impact of fat and ultra-high inclusion levels of phytase on growth rate, carcass characteristics, and pig viability. A total of 2,150 gilts and barrows (31.4 ± 0.4 kg; Camborough derivative sows x TR-4 sire) were randomly allotted to 6 dietary treatments within sex and initial body weight blocks. Treatments included a control diet (500 FTU/kg of phytase) with no supplemental fat, the control diet with 3,000, 4,500, or 6,000 FTU/kg of additional phytase, the control diet with 4% choice white grease (CWG), and the 4% CWG diet with 3,000 FTU/kg of phytase. Diet phases were: 31 to 50, 50 to 73, 73 to 95, 95 to 113 kg, and 113 until all pigs had been marketed (4 marketing cuts; target market weight was 130 kg). Pigs fed supplemental fat were 2.3 kg heavier at the end of the study, had lower feed intake (4.4%) and improved feed efficiency (7.2%) compared to control pigs ($P < 0.05$). Similarly, hot carcass weight, carcass ADG, and carcass F:G were improved ($P < 0.05$) with the addition of fat to the diet. Supplementation of phytase (3,000 FTU/kg) to the fat-supplemented diet did not improve whole body or carcass performance parameters. Phytase mega-dosing improved whole body F:G (2.75, 2.72, 2.68, and 2.65 for 0, 3,000, 4,500, and 6,000 FTU/kg of phytase respectively; $P < 0.001$) and tended to improve carcass F:G ($P = 0.076$) in a linear manner. The largest improvement in F:G with phytase supplementation occurred during the 95 to 115 kg feeding period (3.76, 3.67, 3.48, and 3.41 for 0, 3,000, 4,500, and 6,000 FTU/kg of phytase respectively; $P < 0.001$) and this was also the case with fat supplementation (3.76 vs. 3.22 for control vs. fat-added). Fat supplementation increased backfat depth and decreased lean percent ($P < 0.001$). On the other hand, phytase supplementation linearly decreased backfat depth ($P < 0.02$) and increased ($P < 0.03$) lean percent. Phytase linearly decreased the percent of full value pigs ($P < 0.03$). The results of the present study suggest that a targeted application of phytase may be more cost-effective than continuous administration. The reduction in full value pigs (as a result of increased mortality and more light, cull pigs) with phytase supplementation needs to be further evaluated as this effect has not been observed in previous studies.

Introduction

Approximately 60-75% of the P in plant based feedstuffs commonly used in swine diets is found in form of phytic acid (inositol hexakisphosphate (IP6); Kornegay, 2001; NRC, 2012). The P associated with phytate is poorly used by pigs because the lack of significant endogenous phytase activity and low microbial populations in the upper part of the digestive tract (Woyengo and Nyachoti, 2013). Phytic acid is unstable in the free acid form and occurs predominately as a complex with cations such as Ca, Fe, Zn, Mg, Mn, Cu and K (Humer et al., 2015). Phytate is considered an anti-nutritional factor because it is a poly-anionic molecule, with chelating capacity. Phytate can form complexes with minerals, proteins, starch and lipids, making these nutrients less available to the animal (Selle et al., 2000). Phytate can form complexes with amino acids (mainly basic amino acids, such as Arg, His and Lys) at low and high pH conditions, which may results in a reduction of protein solubility, enzyme activity and amino acid digestibility.

Similarly, phytate can form complexes with starch and inhibit α-amylase activity, decreasing starch digestibility and absorption of glucose. Phytase can also associate with lipids to form "lipophytins". Lipid and Ca-phytate may participate in the formation of metallic soaps, limiting the energy utilization from lipid sources (Kumar et al., 2010; Humer et al., 2015). The enzyme phytase (myo-inositol hexaphosphate phosphohydrolase) can dephosphorylate phytate into a series of lower inositol phosphate esters, thereby liberating P and increasing P availability to the pig (Selle et al., 2000).

Numerous reviews and studies have validated the positive effects of using exogenous phytase in monogastric animals (Simons et al., 1990; Cromwell et al., 1993; Radcliffe et al., 1998; Selle et al., 2000; Sands et al., 2001; Omogbenigun et al., 2003; Selle and Ravindran, 2007, 2008; Chu et al., 2009; Adeola and Cowieson, 2011; Woyengo and Nyachoti, 2013). Supplementation of phytase to swine diets has traditionally been focused on improving the utilization of phytate-P, thus increasing P availability and reducing P excretion in manure. However, in some cases, supplementation of phytase in P adequate diets has been demonstrated to improve performance of pigs and chickens, suggesting that improvements in growth performance are not completely explained by enhanced P availability (Selle and Ravindran, 2008). These extra-phosphoric effects of phytase may be related to improvement in Ca, Zn, Fe, Mg and Na utilization, enhanced amino acid and energy utilization, improved activity of gastric enzymes (pepsin, trypsin, and chymotrypsin) and reduced endogenous losses (enzymes or mucin).

More recently, there has been interest in supplementing phytase at levels that exceed commercial levels aimed at releasing P (500-1500 FTU/kg) to take advantage of the potential extra-phosphoric effects of phytase (super-dosing). These relatively extreme levels of phytase aim to degrade at least 85% of insoluble anti-nutritional phytate esters and generate myo-inositol, which presumably plays an important role in facilitating transport of fats and fat soluble nutrients (Cowieson et al., 2011). The effect of super-dosing phytase and generation of myo-inositol have been studied primarily in poultry (Cowieson et al., 2013, 2015; Walk et al., 2014) and to a lesser extent in pigs. Several studies in pigs have demonstrated improved growth performance with high levels of phytase in nursery pigs, grower pigs and finisher pigs (Braña et al., 2006; Cowieson et al., 2006; Kies et al., 2006; Walk et al., 2013; Miller et al., 2016). However, others have observed no improvements in performance from super-dosing phytase (Holloway et al., 2016 using nutrient deficient diets; Miller et al., 2016 in grower pigs). We recently evaluated the impact of phytase supplementation at 3,000 FTU/kg compared to the impact of supplemental fat in finishing pigs (1,946 pigs). As expected, fat supplementation decreased ADFI and marginally improved ADG, resulting in improved efficiency. On the other hand, supplementation of phytase tended to increase ADFI resulting in a slight increase in ADG equivalent to 60 lbs/ton of fat. Others have reported increased feed consumption in pigs fed high doses of phytase (e.g. Miller et al., 2016) and this may be especially relevant under heat stressed conditions.

Most studies included super-doses of phytase at 1,500 to 2,500 FTU/kg. However, there is evidence that phytase continues to improve performance, bone characteristics, and Ca and P digestibility at doses up to 10,000 (Augspurger and Baker, 2004), 12,000, (Shirley and Edwards, 2003), 15,000 (Kies et al., 2006) and 20,000 FTU/kg (Zeng et al., 2014). Given the decreasing costs associated with phytase inclusion in practical diets and rising feed ingredient costs (e.g. cost of fat) higher levels of supplemental phytase above those typically used in super-dosing studies (2,500 to 3,000 FTU/kg) may be justified. However, research in pigs housed under the rigors of a commercial production environment has not been conducted with ultra-high levels of phytase. We propose that improving growth rate of pigs by using phytase that is either independent of fat or additive to supplemental fat (which has not been evaluated) is economically feasible, whereas fat is an expensive means of achieving rapid growth, especially because fat has seemingly become less effective in stimulating growth as pigs have become leaner. In addition, the impact of phytase when it is supplied “on top” (above and beyond nutrient requirements) of the diet needs to be considered to take advantage of potential extra gain that can be accomplished and the economic benefits associated with reduced days to market, reduced feed costs per pig, and increased income per pig space.

Objectives

The goal of this project was to improve growth rate and reduce feed cost per unit of gain in swine through the strategic application of ultra-high levels (above super-dosing levels that have been used in previous studies) of the enzyme phytase. We hypothesized that supplementation of super-doses of phytase will result in the near complete destruction of the anti-nutrient phytate, thereby providing a cost effective means to promoting body weight gain and reducing feed cost of gain, leading to improved efficiency of pig production. We further proposed that super-doses of phytase may be a more cost effective means to promoting growth than supplemental dietary fat and growth promotants, some of which cannot be used in the future. Specifically, our objectives were:

1. Determine the impact ultra-high inclusion levels of phytase on growth rate, carcass characteristics, and production metrics.
2. Determine the impact of ultra-high levels of phytase in diets with or without supplemental fat on growth rate, carcass characteristics, and production metrics.

Materials & Methods

Animals and dietary treatments

All animal protocols were approved and conducted under the supervision of licensed veterinarians. This experiment was conducted in a commercial finisher research facility in two barns equipped with the Howema feed delivery system.

A total of 2,150 gilts and barrows (31.4 ± 0.4 kg; Camborough derivative sows x TR-4 sire) were randomly allotted to 6 dietary treatments within sex and initial body weight blocks. Treatments included a control diet with no supplemental fat, the control diet with 3,000, 4,500, or 6,000 FTU/kg of phytase, the control diet with 4% choice white grease (CWG), and the 4% CWG diet with 3,000 FTU/kg of phytase (Table 1). The control diets (with and without added fat) contained a base level of 500 FTU/kg of phytase, thus supplemental levels above the base level were 2,500, 4,000, 5,500 FTU/kg of phytase for control diets without fat and 2,500 FTU/kg for the fat added diet. The phytase product used was Quantum Blue Phytase (AB Vista, Marlborough, Wiltshire, UK). Diet phases were: 31 to 50, 50 to 73, 73 to 95, 95 to 113 kg, and 113 until all pigs had been marketed. All diets (Table 2) met or exceeded nutrient requirements suggested by NRC (2012). Diets were formulated considering the nutrient release values for 500 FTU/kg of phytase (which represents the control diet); however, super-dosing levels of phytase were added without giving additional release values above 500 FTU/kg of phytase. The release values for Ca and P of 0.12% for 500 FTU phytase were implemented in the diets. Pen weights and number of pigs in each pen were determined at each diet change and after each marketing cut. Feed was provided to pens using an automated feeding system (Howema). The system dispensed the appropriate treatment diet to each pen and maintained records of the amount of feed dispensed. Feed intake by pen was determined from the sum of daily feed additions minus the weight of remaining feed at diet switches and marketing cuts. Strict protocols were in place for individual pig medication and removal. Weight of all removed pigs and dead pigs was recorded with their associated pen number and the reason for removal or death. Pigs were treated individually when necessary and the treatment, reason for treatment, and pen number were recorded. When pigs were removed to sick pens, dietary treatments were maintained to be able to calculate mortality, morbidity, cull pigs, and full value pigs. Pens were marketed over 4 cuts and each cut was weighed within 24 hours of loading onto the trucks for harvest. The target market weight was 130 kg.

Pig weights, ADG, ADFI, and feed:gain (F:G) were calculated for each period and overall. Carcass yield was determined using farm live weights and hot carcass weight from the plant. Fat-O-Meter back fat, loin depth and lean percent was determined at the packing plant. Number of dead pigs, pigs removed, down pigs, pigs dead on arrival, and stressed pigs were recorded.

Data analysis was conducted using the PROC MIXED procedure of SAS using a model that included sex and dietary treatment. Pen was the experimental unit for growth performance data. Observations greater than 3 standard deviations from the mean were removed from the analysis along with relevant associated traits when appropriate. Pig days were used to calculate ADFI, and ADG was measured as the difference between weight of the pig at the end and the beginning of the period divided by the days in the period. Feed conversion was calculated as ADFI divided by ADG. Whole body calculations included dead, light weight, and cull pig weights. Percent of full value pigs that were able to be marketed was calculated. Linear and quadratic orthogonal contrast comparisons were made using the proper coefficients calculated using Proc IML. Differences between treatments were considered significant at $P < 0.05$ and tendencies at $0.05 \leq P < 0.10$.

Results

Pigs fed supplemental fat (4% of choice white grease) were 2.3 kg heavier at the end of the study compared to control pigs (Table 3). As expected, pigs fed supplemental fat had lower feed intake (4.4%) and improved feed efficiency (7.2%) compared to control pigs ($P < 0.05$). Similarly, hot carcass weight, carcass ADG, and carcass F:G were improved ($P < 0.05$) with the addition of fat to the diet (Table 4). Supplementation of phytase (3000 FTU/kg) to the fat-supplemented diet did not improve whole body or carcass performance parameters any further. Phytase mega-dosing improved whole body F:G ($P < 0.001$) and tended to improve carcass F:G ($P = 0.076$) in a linear manner (Table 3 and 4). This response was primarily due to a linear decrease in ADFI with increasing phytase because ADG was not affected by phytase supplementation. The improvement in F:G was 10 points for whole body F:G and 6 points for carcass F:G. Interestingly, the largest improvement in F:G with phytase supplementation occurred during the 95 to 115 kg feeding period (Figure 1) and this was also the case with fat supplementation. For phytase, the improvements in F:G were 5, 0, 3, and 28 points for feeding Phase 1, 2, 3, and 4, respectively (comparing 0 and 6,000 FTU/kg of phytase). For fat supplementation, the improvements in F:G were 15, 20, 20, and 51 points for Phase 1 through 4, respectively. Fat supplementation increased backfat depth and decreased lean percent ($P < 0.001$; Table 4). On the other hand, phytase supplementation linearly decreased backfat depth ($P < 0.02$) and increased ($P < 0.03$) lean percent. Phytase linearly decreased the percent of full value pigs that could be marketed ($P < 0.03$).

IX. Discussion

Both the addition of fat and phytase improved production efficiency and responses were independent. In fact, supplementation of phytase (at 3,000 FTU/kg) to a diet containing 4% added fat did not improve performance. The impact of fat on performance was more pronounced than the impact of phytase. Supplemental fat improved overall feed efficiency through a combination of increased ADG and reduced ADFI, whereas the effect of phytase was primarily due to reduced ADFI at similar ADG. Interestingly, the impact of fat and phytase was most pronounced during the final growth phase. During the feeding period of 95 to 115 kg of body weight, fat and phytase supplementation improved ADG, reduced ADFI and substantially improved F:G. This final growth phase presents a consistent challenge in performance reductions (e.g. F:G deteriorates with increasing pig body weight, from 2.02, to 2.46, 2.84, and 3.76, for Phase 1 to 4, respectively), which may be related to the stress of expanding pig density (kg/ft^2), reduced feeder space and feeder access. This limitation of space may be remedied, in part, by creating space through removal of pigs in the first marketing cut. Thus, this loss in performance may go unnoticed in close-out data, nonetheless creating significant erosion in feed efficiency. The improvement in ADG due to supplemental fat during Phase 4 was at least twice that observed in the prior phases. The results of the present study suggest that a targeted application of phytase may be more cost-effective than continuous administration. The reduction in full value pigs (as a result of increased mortality and more light, cull pigs) with phytase supplementation has not been observed in previous studies and needs to be further evaluated.

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Table 1. Design of experimental treatments

Treatment[1]	Added fat, %	Phytase, FTU/kg	Pens
1	0	500	18
2	0	3000	16
3	0	4500	16
4	0	6000	16
5	4	500	18
6	4	3000	18

[1]Diets for treatment 2 were created by blending 54% of treatment diet 1 with 46% of treatment diet 4 and diets for treatment 3 were created by blending 26% of treatment diet 1 with 74% of treatment diet 4.

Table 1. Composition of experimental diets, as-fed basis

	Finish 1		Finish 2		Finish 3		Finish 4		Finish 5	
Supplemental fat, %:	**0**	**4**	**0**	**4**	**0**	**4**	**0**	**4**	**0**	**4**
Ingredients										
Corn, 7.0 CP	53.52	49.40	63.95	59.56	71.22	67.01	76.77	72.65	77.39	73.31
Soybean Meal 48.5% CP	23.50	23.50	16.75	16.75	16.80	16.80	11.30	11.30	10.80	10.80
Corn DDGS Fat 6.5	19.5	19.5	17.0	17.0	10.0	10.0	10.0	10.0	10.0	10.0
Fat, CWG	0	4	0	4	0	4	0	4	0	4
L-Lysine	0.39	0.50	0.41	0.50	0.22	0.30	0.24	0.30	0.14	0.20
DL-Methionine	0.05	0.10	0.03	0.08	0.00	0.02	0.00	0.00	0.00	0.00
L-Threonine	0.07	0.10	0.07	0.12	0.02	0.06	0.03	0.07	0.00	0.02
L-Tryptophan	0.04	0.06	0.05	0.06	0.02	0.03	0.02	0.03	0.02	0.02
Limestone	1.38	1.32	0.86	0.91	0.73	0.73	0.71	0.71	0.71	0.71
MonoCal 21.0 P	1.06	0.98	0.40	0.48	0.50	0.51	0.45	0.45	0.45	0.46
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Vitamin and minerals	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Phytase premix[1]	-/+	-/+	-/+	-/+	-/+	-/+	-/+	-/+	-/+	-/+
Color dye[2]	-/+	-/+	-/+	-/+	-/+	-/+	-/+	-/+	-/+	-/+
Calculated composition										
Crude protein	21.1	21.0	17.9	17.8	16.3	16.1	14.0	13.8	13.7	13.5
Total lysine	1.27	1.35	1.09	1.15	0.90	0.96	0.76	0.81	0.68	0.71
SID Lysine	1.16	1.24	0.99	1.06	0.82	0.87	0.69	0.73	0.6	0.64
Calcium	0.85	0.81	0.50	0.54	0.47	0.47	0.43	0.43	0.43	0.43
Phosphorus	0.66	0.63	0.48	0.49	0.48	0.47	0.44	0.43	0.44	0.43
Available phosphorus	0.39	0.37	0.23	0.24	0.21	0.21	0.20	0.20	0.20	0.20

[1]Phytase was included at 0.105 to 0.230% replacing corn to achieve targeted levels of 3000, 4500, and 6000 FTU/kg of phytase

[2]Color dye was included at levels of 0.05 to 0.15% replacing corn to color code the experimental diets.

Table 3. Impact of phytase and supplemental fat on growth performance of pigs

Fat , %	0	0	0	0	4	4			Linear	Quad
Phytase, FTU/kg	**500**	**3000**	**4500**	**6000**	**500**	**3000**	**SEM**	**P-value**	**Trt 1-4**	**Trt 1-4**
Pens on test	18	16	16	16	18	18	-	-	-	-
Pigs placed	379	337	341	336	379	378	-	-	-	-
Body weight, kg										
Day 0	31.5	31.4	31.4	31.5	31.4	31.4	0.36	1.000	0.976	0.920
Day 21	50.0	49.9	50.1	50.3	50.5	50.2	0.50	0.963	0.712	0.754
Day 42	72.2	72.1	72.0	72.1	72.7	72.8	0.59	0.909	0.908	0.866
Day 63	94.9	95.1	94.3	94.7	95.8	96.0	0.68	0.478	0.684	0.967
Day 84	113.7	113.9	113.8	114.4	116.5	116.0	0.77	0.026	0.626	0.768
Average daily gain, kg/d										
Day 0 to 21	0.88	0.88	0.88	0.89	0.91	0.89	0.014	0.783	0.738	0.706
Day 21 to 42	1.05	1.06	1.04	1.04	1.06	1.08	0.014	0.462	0.599	0.638
Day 42 to 63	1.08	1.10	1.07	1.08	1.10	1.11	0.014	0.215	0.547	0.742
Day 63 to 84	0.89	0.90	0.92	0.94	0.98	0.94	0.018	0.002	0.048	0.414
Day 0 to 84	0.98	0.98	0.98	0.99	1.01	1.01	0.005	<0.001	0.522	0.741
Average daily feed intake, kg/d										
Day 0 to 21	1.79	1.76	1.77	1.76	1.68	1.68	0.018	<0.001	0.309	0.812
Day 21 to 42	2.58	2.60	2.51	2.55	2.40	2.41	0.027	<0.001	0.304	0.857
Day 42 to 63	3.08	3.04	3.07	3.04	2.92	2.91	0.032	<0.001	0.461	0.828
Day 63 to 84	3.35	3.28	3.21	3.18	3.16	3.08	0.041	<0.001	<0.001	0.999
Day 0 to 84	2.70	2.67	2.63	2.61	2.55	2.52	0.027	<0.001	0.004	0.903
Feed:gain										
Day 0 to 21	2.02	2.00	2.00	1.97	1.85	1.89	0.03	<0.001	0.288	0.862
Day 21 to 42	2.46	2.47	2.41	2.46	2.27	2.25	0.03	<0.001	0.705	0.843
Day 42 to 63	2.84	2.78	2.88	2.81	2.65	2.63	0.04	<0.001	0.993	0.72
Day 63 to 84	3.76	3.67	3.48	3.41	3.22	3.29	0.07	<0.001	<0.001	0.615
Day 0 to 84	2.75	2.72	2.68	2.65	2.51	2.50	0.02	<0.001	0.001	0.693

Table 4. Impact of phytase and supplemental fat on carcass characteristics and carcass growth of pigs

Fat , % **Phytase, FTU/kg**	**0** **500**	**0** **3000**	**0** **4500**	**0** **6000**	**4** **500**	**4** **3000**	**SEM**	**P-value**	**Linear Trt 1-4**	**Quad Trt 1-4**
Pens	18	16	16	16	18	18	-	-	-	-
Pigs Placed	379	337	341	336	379	378	-	-	-	-
Initial weight, kg	31.5	31.4	31.4	31.5	31.4	31.4	0.36	1.000	0.976	0.920
Days to market	100.2	100.3	100.8	100.5	99.8	100.0	0.30	0.352	0.324	0.641
Markey weight, kg	127.3	126.8	127.5	126.6	129.5	129.1	0.73	0.018	0.673	0.852
Whole body										
ADG, kg/d	0.96	0.95	0.95	0.95	0.98	0.98	0.01	0.001	0.563	0.504
ADFI, kg/d	2.82	2.77	2.75	2.74	2.68	2.63	0.03	<0.001	0.004	0.760
Feed:gain	2.94	2.92	2.91	2.88	2.72	2.68	0.03	<0.001	0.030	0.687
Hot carcass Wt, kg	212.0	210.8	212.1	210.3	216.8	216.4	1.10	<0.001	0.49	0.857
Carcass yield, %	75.5	75.5	75.3	75.2	75.8	75.9	0.20	0.176	0.314	0.551
Back fat, mm	15.6	15.4	15.4	15.0	16.1	15.9	0.20	0.001	0.017	0.422
Loin depth, mm	62.6	63.0	62.5	63.1	62.4	62.4	0.20	0.155	0.246	0.909
Lean, %	54.3	54.5	54.4	54.6	54.1	54.1	0.10	<0.001	0.026	0.683
Initial carcass wt, kg	23.3	23.3	23.3	23.3	23.3	23.3	0.27	1.000	0.979	0.915
Carcass ADG, kg/d	0.73	0.72	0.72	0.72	0.75	0.75	0.004	<0.001	0.247	0.949
Carcass feed:gain	3.87	3.84	3.80	3.81	3.55	3.50	0.03	<0.001	0.076	0.832
Full Value Pigs, %	97.63	96.14	95.28	94.64	97.35	96.56	0.99	0.246	0.026	0.887
Cull pigs, %	1.32	0.6	1.19	1.49	1.06	1.59	0.66	0.920	0.817	0.324
Dead pigs, %	1.05	2.07	2.08	2.38	1.59	1.59	0.64	0.723	0.152	0.681
Pigs removed, %	0.52	1.79	2.04	1.49	0.53	0.53	0.53	0.129	0.162	0.188

Figure 1. Relative changes in F:G ratio for each dietary phase.