



The effects of low levels of dietary trace minerals on the plasma levels, faecal excretion, health and performance of pigs in a hot African climate

M.H. BOMA and G. BILKEI*

Veterinary Consulting, Bahnhofstrasse 42, CH - 8600 Dübendorf, Switzerland

ABSTRACT

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The present study was performed in order to evaluate the effects of lower than usual industry levels of dietary trace minerals on plasma levels, faecal excretion, performance, mortality and morbidity in growing-finishing pigs in a hot African climate.

Group 1 ($n=100$ pigs) received a diet with common industry levels of trace minerals.

Group 2 ($n=100$ pigs) received reduced dietary trace mineral levels but were fed the same basic diet as Group 1.

Mortality, morbidity, pig performance and carcass measurements were evaluated.

Two pigs in Group 1 and three pigs in Group 2 died. Thirteen pigs in Group 1 and 27 pigs in Group 2 were medically treated ($P < 0.05$).

Carcass masses, back fat depth, loin depth, and lean percent were not significantly different between the groups. However, the carcasses when evaluated revealed a non-significant higher back fat thickness, lower loin eye area and percentage of fat-free lean in barrows compared to gilts within each group.

Despite lower initial masses, pigs fed diets containing industry levels of trace minerals were heavier ($P < 0.05$) and had a higher ($P < 0.05$) than average daily gains compared to those that received a diet containing lower levels of trace minerals.

Faecal zinc excretion was significantly lower ($P < 0.05$) in pigs fed with lower dietary zinc levels. Copper, manganese and iron excretion were not affected ($P > 0.05$) by the dietary levels of these trace minerals.

Plasma trace mineral concentrations were not affected by the dietary treatment.

Keywords: Climate, mortality, morbidity, performance, pigs, trace element

INTRODUCTION

Higher than usual levels of zinc and copper recommended for the pig production industry by the National Research Council, USA (1998) are often added for disease prophylaxis or growth promotion in

the diets of nursery and growing-finishing pigs in Central and Eastern Europe (Bilkei, Biro, Bölcskei, Clavadetscher, Orban, & Waller 1995). Klasing (2001) suggested that in order to optimize immune function and health, trace mineral requirements may be greater than requirements for growth performance. However, it has also been demonstrated that reducing dietary trace mineral levels does not affect pigs growth performance (Creech, Spears, Flowers, Hill, Lloyd, Armstrong & Engle 2004). Bilkei *et al.*

* Author to whom correspondence is to be directed: E-mail: bilkei.consulting@gmx.net

(1995) suggested, that reduced levels of excreted trace minerals may diminish the negative effects of the environment. The same authors found that in many Eastern European pig units, higher dietary levels than suggested by the National Research Council (1998) regarding zinc (150–3000 ppm), copper (17–80 ppm), manganese (50–136 ppm) and iron (350–601 ppm), were fed.

Accumulation of zinc and copper in soils are of concern in areas where manure from swine facilities is applied to them (Jongbloed & Lenis 1993). It has been shown that when lower than the National Research Council (1998) standard of dietary zinc and copper were fed, there was reduced excretion in the faeces of gilts (Creech *et al.* 2004). In a study (Creech *et al.* 2004), the dietary levels of zinc (from 100 to 25 ppm) and copper (from 15 to 5 ppm) were reduced in grower-finisher pigs diets. In addition, the authors (Creech *et al.* 2004) reduced the levels of iron (from 100 to 25 ppm) and manganese (from 40 to 10 ppm) of the diet in order to minimize the antagonistic effects of these trace minerals on the absorption of zinc and copper, without affecting the pigs' growth performance. Similarly, Van Huegten, O'Quinn, Funderburke, Flowers & Spears (2004) found that reduced levels of trace minerals in growing-finishing pigs diet resulted in lower faecal excretion, without any negative effects on the performance of the pigs. In contrast to this, and according to our (unpublished) experiences in a hot African climate, lower than suggested (National Research Council, 1998) trace element levels decrease fattening performance.

The authors cited (Bilkei *et al.* 1995; Klasing 2001; Creech *et al.* 2004; Huegten *et al.* 2004) did not evaluate morbidity and mortality of their trial animals and did not take climatic factors into consideration.

The objective of the present study was to evaluate the effects of lower than recommended levels of dietary trace minerals on mortality and morbidity, plasma levels, faecal excretion, and performance in growing-finishing pigs in a hot African climate.

MATERIALS AND METHODS

The study was performed in a large Kenyan breeding and growing-finishing unit from April 2007 to April 2008.

In the trial, the herd suffered from a high rate of infections caused by gastrointestinal and respiratory pathogens. Pretrial necropsies revealed a low rate of infection with *Lawsonia intracellularis*, *Brachyspira hyodysenteriae* and beta-haemolytic *Escherichia coli*, while ELISA tests using a Tween-20 detergent-extracted antigen have shown that mycoplasmal infections are present in the herd and an ELISA for the detection bacterial antigen against *Actinobacillus pleuropneumoniae* serotypes 1, 2, 5, 7 and 9 has given positive results. No toxigenic *Pasteurella multocida* strain has been found in this unit, and swine influenza virus immunofluorescent antibody tests were negative. The unit was free from of *Salmonella choleraesuis*.

The study was performed in two groups of pigs which were randomly selected from a computer-generated list within blocks of animals of similar mass (Table 1). Equal numbers of gilts and barrows were represented in each group. The animals were ear-tagged with consecutive numbers at the beginning of the trial.

Group 1 ($n = 100$ pigs, 50 gilts, 50 barrows) received a diet containing higher levels of dietary trace mineral than is suggested by the National Research Council (1998), in four feeding phases (Table 2).

Group 2 ($n = 100$ pigs, 50 gilts, 50 barrows) received a diet containing reduced levels of trace mineral but were fed the same basic diet as those in Group 1.

The trial animals were moved from the nursery "flat-deck" barns at the age of 7–8 weeks to the growing-finishing barn and were housed in pens each of which contained ten animals (0.97 m² per pig, partly slotted floors [1/3 of the pen]). The two rooms of pens in the barn were separated from each other by a central aisle. The pigs were therefore raised under the same management and environmental con-

TABLE 1 Growth performance of growing-finishing pigs in a hot African climate. Group 1 received trace mineral levels suggested by the NRC, USA (1998), while Group 2 received reduced levels

Pig data	Group 1	Group 2	SEM	P value
Initial mass (kg)	19.20	21.10	0.88	> 0.05
Final mass (kg)	118.10	114.10	0.36	< 0.05
Mortality %	2.00	3.00		
Morbidity %	13.00	27.00		< 0.05
Average daily gain (kg)	0.78	0.69	0.01	< 0.05

ditions. The pigs had *ad libitum* access to water, were, apart from the trace element compounds, fed *ad libitum* with an identical commercial diet from the same feeding mill in each phase (Table 2) and were raised in “all-in/all-out” management system. No prophylactic antimicrobial drugs were used.

Initial and slaughter masses for each group were recorded.

Mortality and morbidity data

Mortality data included any death regardless of its cause. Morbidity data included treatments for diarrhoea, skin infections, respiratory diseases and diseases of joints. Mortality and morbidity rates were recorded and evaluated as a percentage of the group, concerned.

Pig performance and carcass measurements

The total number of days in the trial was calculated from the start and end dates of each group. Average

daily gain (ADG) was calculated from the total mass at placement, total mass at marketing, and the total number of days to marketing.

Feed disappearance was calculated from the total feed delivered to each group, corrected for feed remaining at the end of the trial, the number of pigs in each group, and the total number of days in the trial.

Carcass measurements of each individual pig in each group were collected at slaughter, and included gender, hot carcass mass, back fat and loin deposit (by using an optical probe), and percent lean body.

Laboratory procedure

Feed samples were collected and fresh faecal samples (30 pigs per group [3 pigs per pen]) were obtained randomly at the same time upon defaecation from three pigs in each pen during the second week in each feeding phase (Table 2). Samples were dried in an oven at 60 °C, and then ground through

TABLE 2 Experimental diets of the pigs. Group 1 received the trace mineral levels suggested by the NRC, USA (1998), while Group 2 received reduced levels

Diet formula for both groups of pigs weighing from 19–115 kg

Phases	Mass (kg)	Protein (%)	Lysine (%)	Calcium (%)	Phosphorus (%)
1	19–25	17–18	1.1	0.66	0.62
2	25–40	15–16	0.9	0.66	0.67
3	41–60	13–14	0.8	0.65	0.55
4	61–115	13–14	0.8	0.64	0.54

Amino acid patterns for the pigs in relation to lysine for both groups

Amino acid	19–60 kg	> 60 kg
Lysine	100	100
Methionine + cystine	65	65
Threonine	67	70
Tryptophan	18	19
Arginine	30	18
Valine	68	68
Isoleucine	60	60
Leucine	100	100
Phenylalanine + tryptophan	100	100
Histidine	32	32

Analysed trace mineral composition of the diets for both groups

Trace mineral (ppm)	Phase 1		Phase 2		Phase 3		Phase 4	
	Group 1: normal	Group 2: reduced	Group 1: normal	Group 2: reduced	Group 1: normal	Group 2: reduced	Group 1: normal	Group 2: reduced
Zinc	177	78	159	71	148	70	130	79
Copper	18	11	22	9	18	11	19	11
Manganese	69	60	68	53	48	37	57	41
Iron	516	380	487	365	362	271	295	251

TABLE 3 Analysed trace mineral composition of the faeces (dry matter basis) of the pigs. Group 1 received trace mineral levels suggested by the NRC, USA (1998), while Group 2 received reduced levels

Trace mineral ppm	Phase 1		Phase 2		Phase 3		Phase 4	
	Group 1: normal	Group 2: reduced	Group 1: normal	Group 2: reduced	Group 1: normal	Group 2: reduced	Group 1: normal	Group 2: reduced
	ppm \pm SEM							
Zinc	1 187 \pm 108 a	367 \pm 78 b	1 149 \pm 11 a	397 \pm 80 b	1 141 \pm 116 a	371 \pm 78 b	1 031 \pm 102 a	71 \pm 75 b
Copper	131 \pm 15 a	95 \pm 12 a	142 \pm 16 a	91 \pm 11 a	125 \pm 14 a	81 \pm 13 a	118 \pm 13 a	81 \pm 12 a
Manganese	459 \pm 41 a	245 \pm 42 a	428 \pm 38 a	223 \pm 29 a	419 \pm 42 a	231 \pm 45 a	461 \pm 46 a	231 \pm 32 a
Iron	2 511 \pm 169 a	1 381 \pm 141 a	2 580 \pm 131 a	2 333 \pm 145 a	2 261 \pm 129 a	2 273 \pm 131 a	2 291 \pm 148 a	2 233 \pm 121 a

a, b in a row: the difference is significant, $P < 0.05$

TABLE 4 Analysed trace mineral composition of the plasma of pigs. Group 1 received trace mineral levels as suggested by the NRC, USA (1998), while Group 2 received reduced levels

Trace mineral ppm	Phase 1		Phase 2		Phase 3		Phase 4	
	Group 1: normal	Group 2: reduced	Group 1: normal	Group 2: reduced	Group 1: normal	Group 2: reduced	Group 1: normal	Group 2: reduced
	mg/l \pm SEM							
Zinc	0.71 \pm 0.08 a	0.72 \pm 0.07 a	0.69 \pm 0.03 a	0.77 \pm 0.02 a	0.74 \pm 0.06 a	0.78 \pm 0.06 a	0.81 \pm 0.07 a	0.76 \pm 0.07 a
Copper	2.23 \pm 0.5 a	1.84 \pm 0.4 a	1.95 \pm 0.5 a	1.99 \pm 0.2 a	1.98 \pm 0.4 a	1.21 \pm 0.4 a	2.08 \pm 0.4 a	2.11 \pm 0.2 a
Iron	1.31 \pm 0.6 a	1.39 \pm 0.3 a	1.26 \pm 0.3 a	1.30 \pm 0.5 a	1.29 \pm 0.2 a	1.28 \pm 10.3 a	1.29 \pm 0.3 a	1.28 \pm 0.4 a

a 1-mm screen prior to trace mineral analysis. When the faecal samples were collected, blood samples were obtained from the same pigs from the anterior vena cava using Vacutainer heparinized tubes (Becton Dickinson, Zagreb, Croatia).

Feed and faecal samples were digested by wet ashing with nitric acid and hydrogen peroxide using a microwave digestion system (Model MDS-81D; CEM Corp. Matthews, NC, USA) as described by Gengelbach, Ward & Spears (1994). Ashed samples were subsequently analysed for zinc, copper, iron and manganese using an atomic absorption spectrophotometer (model AA-6701F; Shimadzu, Kyoto, Japan). Plasma samples were diluted in nitric acid, then analysed for the same elements by atomic absorption spectrophotometer. All laboratory procedures of feed, faecal and plasma samples were performed in Veterinary Investigation Centre in Zagreb, Croatia.

Statistical analyses

Data were analysed by analysis of variance as a randomized complete block design using the *General Linear Model* (GLM) of Statistical Analytical System (SAS 1999, SAS Institute Inc. Cary, NC, USA). The model for morbidity, mortality, growth performance, trace mineral excretion data, and plasma trace mineral concentrations included blocks and trace mineral inclusion levels (high or low), using a group as the experimental unit. The model for carcass data included block, trace mineral supplementation level and gender, and the interaction of block and trace mineral supplementation level. The latter was used as an error term to test the effect of trace mineral supplementation on carcass characteristics. The experimental unit for this analysis was the individual pig. In addition, carcass data were analysed using carcass mass as a co-variate to evaluate carcass characteristics at a common carcass mass.

RESULTS

Two pigs (1 gilt and 1 barrow) died in Group 1 (that had received higher than recommended levels of the trace elements), and three pigs (one gilt and two barrows) died in Group 2 (that received lower than recommended levels of trace minerals). Owing to the low number of death no statistical analyses were performed. Thirteen pigs (six gilts and seven barrows) had to be medically treated in Group 1, and 27 pigs (11 gilts and 16 barrows) in Group 2 ($P < 0.05$).

Carcass masses (Group 1: 86.9 ± 2.1 kg; Group 2: 86.7 ± 2.5 kg, $P > 0.05$) back fat depth (Group 1: 18.9 ± 2.2 mm; Group 2: 18.7 ± 2.3 mm, $P > 0.05$ mm), loin depth (Group 1: 58.9 ± 2.9 mm; Group 2: 59.3 ± 4.2 mm, $P > 0.05$ mm), and lean percent (Group 1: $54.1 \pm 3.2\%$; Group 2: $53.7 \pm 3.1\%$, $P > 0.05$ kg) were not significantly different between the groups. The carcasses revealed a non-significant higher back fat thickness (gilts: 19.7 ± 2.1 mm; barrows: 17.6 ± 2.3 mm, $P > 0.05$ mm), lower loin eye area (gilts: 60.2 ± 3.0 mm; barrows: 59.1 ± 3.1 mm, $P > 0.05$ mm), and percent fat-free lean (gilts: $55.0 \pm 3.1\%$; barrows: $53.1 \pm 3.0\%$, $P > 0.05$ kg) in barrows compared to gilts within each group.

Despite lower initial masses (19.2 kg vs. 21.1 kg, Table 1), pigs fed diets containing higher than usual "industry" levels of trace minerals were heavier ($P < 0.05$) and had a higher ($P < 0.05$) ADG compared to the pigs that received the diet containing lower levels of trace minerals (Table 1).

Faecal excretion of zinc was significantly lower ($P < 0.05$) in pigs fed with lower dietary zinc levels compared with the pigs that received higher zinc levels. Copper, manganese and iron excretion were not significantly affected ($P > 0.05$) by their dietary levels (Table 3).

Plasma trace mineral concentrations were not affected by the dietary treatment (Table 4).

DISCUSSION

In the present trial the gilt and barrow ratio were identical in the groups. Therefore, the differences in performance observed in the present study cannot be attributed to differences in gender distribution.

During the trial, many of the pigs in the herd suffered from gastrointestinal and respiratory infections, and nearly 30% of the pigs receiving lower dietary trace mineral levels had to be treated. Thus, it seems reasonable to assume that lower dietary trace mineral levels might have contributed to their higher disease prevalence and lower performance. Klasing (2001) suggested that in order to optimize immune function and health, trace mineral requirements may be greater than requirements for growth performance. As the only difference between the groups was the dietary trace mineral concentration, it is reasonable to conclude, that the lower trace mineral content of the diet in Group 2 might have contributed to lower resistance against the present pathogens in this unit, causing higher morbidity

compared to the pigs having received higher dietary trace mineral levels.

Carcass characteristics did not differ significantly between the groups. These findings confirm the findings of Heugten *et al.* 2004. Similarly, Paboeuf, Nys & Corlouer (2000) reported no differences in carcass characteristics for barrows and gilts fed diets with reduced levels of copper or zinc, or both in either the finisher period or the entire grower-finisher period. Consistent with the findings of Goodwin & Burrough (1995), in the present study the carcasses revealed a higher backfat thickness, and a lower loin eye area and percentage of fat-free lean in barrows as compared to gilts.

In contrast to the findings of Paboeuf *et al.* (2000), Creech *et al.* (2004) and Heugten *et al.* (2004) in the present study, pigs fed diets containing higher levels of trace minerals were heavier ($P < 0.05$) and had a higher ($P < 0.05$) ADG compared to the pigs that had received a diet containing lower levels of trace minerals.

Zinc is excreted via the faeces (Weigand & Kirchgessner 1980) while most of the copper is excreted in the bile with only minute amounts being excreted in the urine (Mahoney, Bush, Gubler, Moretz, Cartwright & Wintrobe 1955). According to Underwood (1977), the absorption and excretion of copper and zinc are strictly regulated through homeostatic control mechanisms, and when these trace minerals are consumed in quantities exceeding the requirements, the excess is excreted. Consistent with the present results, Creech *et al.* (2004) suggested that zinc and copper excretion could be reduced by up to 40% by reducing their supplementation to levels recommended by the National Research Council, USA (1998). Paboeuf *et al.* (2000) reported that excretion of copper was lowered by 76% and that of zinc by 14%, when pigs were fed diets containing reduced levels of copper (from 92 ppm to 15–18 ppm) and zinc (from 125 to 90 ppm). In the present study the reduction of these trace elements was different from that of the cited authors as our copper levels were not as high as those in the study of Paboeuf *et al.* (2000) and our zinc levels were generally higher in the Group 1 and lower in the Group 2 as compared to those used by those authors. The higher reduction of zinc excretion in the present study, compared to that of obtained by Paboeuf *et al.* (2000), might be the result of the higher zinc levels fed in our trial. In the study of Heugten *et al.* 2004, pigs fed with reduced trace mineral levels had lower faecal levels of zinc and tended to be lower for copper, iron and manganese compared to pigs

fed with higher levels of these trace minerals. The authors (Heugten *et al.* 2004) concluded that grower finisher pigs' performance was not negatively affected by lower dietary trace mineral levels.

Jongbloed & Lenis (1993) calculated that the total excretion of copper could be reduced from 14.4 g to 4.6 g per pig in pigs weighing 25–106 kg by eliminating growth-promoting levels of copper in the starter phase and reducing dietary copper from 35 ppm to 20 ppm in the grower-finisher phase. Total excretion of zinc could be reduced from 21.6 g to 10.9 g per pig when dietary zinc was reduced by approximately 50%. Copper and zinc may accumulate in soil and cause leaching and diarrhoea of pigs which have access to such pastures (Jongbloed & Lenis 1993). Although, in the present study, the dietary manganese content was similar in the different groups, there was (consistent with the findings of Heugten *et al.* 2004) a tendency for lower faecal manganese excretion. It seems to be reasonable to suggest that the reduction in dietary levels of zinc, copper, and iron might have increased the availability of manganese, resulting in reduced excretion.

In the present trial, plasma concentrations of the trace minerals which were evaluated were within physiological serum concentrations of 0.70 mg/l to 1.50 mg/l, 1.30 mg/l to 3.00 mg/l copper, 1.00 mg/l to 1.50 mg/l iron (Puls 1994).

CONCLUSION

It is suggested that in a hot African climate, higher levels of dietary trace minerals in pigs significantly diminish morbidity, increase performance and result in higher average daily mass gains.

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