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TRACE MINERAL NUTRITION OF PIGS

MEETING PRODUCTION AND ENVIRONMENTAL OBJECTIVES

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SUMMARY

Trace mineral nutrition has been a neglected area of pig nutrition. There is little recent information on the trace mineral requirements of modern pig genotypes and it has become customary to provide levels in the diet much higher than those recommended. Some minerals, such as copper and zinc, are added at 'pharmacological' levels to increase growth, to enhance immunity and to reduce diarrhoea in piglets. There is, however, concern about the large quantities of undigested elements being excreted and causing environmental pollution.

Although inorganic sources of trace minerals have been widely used, there are questions about their availability to the animal and this has created interest in proteinated or chelated (organic) trace elements. These are better absorbed and are more available to the animal. As a consequence, inclusion levels can be reduced while maintaining, or even enhancing performance. Indeed, providing a balance of inorganic and organic minerals may be the most effective way to meet the animal's need and studies with sows have shown improvements in reproductive performance.

In the future, the source of mineral may therefore be of increasing importance in attempting to satisfy both production and environmental demands.

INTRODUCTION

Trace minerals are a commonly forgotten source of nutrients in animal feedstuffs. Their physiological role is often underestimated and their presence in the feed in adequate quantities taken for granted. However, they are necessary to maintain body function, to optimise growth and reproduction and to stimulate immune response and therefore determine the health status. Indeed, it is difficult to realise the impact of insufficient trace minerals, as symptoms of deficiency may not always be evident. However, a slight deficiency of trace elements can cause a considerable reduction in performance.

MINERAL REQUIREMENTS

It is rather difficult to justify the term ‘requirements’ for minerals in the same way as it is for energy, protein or amino acids. Requirements for minerals are hard to establish and most estimates are based on the minimum level required to overcome a deficiency symptom and not necessarily to promote productivity or indeed, to enhance immunity. Most of the work relating to mineral requirements has been carried out in the 1960’s and 1970’s and may not be relevant to the modern animal. This is reflected in the review of NRC (1998) which, with few exceptions, shows only minor differences in the requirements of several minerals proposed by NRC (1988) or ARC (1981) (Table 1). However, the differences in nutrient requirements are the result of different production targets and the differing physiological status of the animal.

Table 1. Dietary requirements for trace elements (per kg diet)*

Body weight (kg)	Piglet - 20		Growing Pig 20 – 50		Finishing Pig 50 – 120		Breeding Sow	
Source	ARC[1]	NRC[2]	ARC[1]	NRC[2]	ARC[1]	NRC[2]	AFRC[3]	NRC[2]
Zinc (mg)	50	100	50	60	50	50	50	50
Manganese (mg)	16	4	16	2	16	2	15	20
Iron (mg)	60	100	-	60	-	50	60	80
Copper (mg)	4	6	4	4	4	3.5	5	5
Iodine (mg)	0.16	0.14	0.16	0.14	0.16	0.14	0.5	0.14
Selenium (mg)	0.16	0.3	0.16	0.15	0.16	0.15	0.15	0.15

*Values represent the highest value quoted
[1] ARC (1981) per kg dry matter
[2] NRC (1998) 90% dry matter
[3] AFRC (1991) 90% dry matter

Indeed, there is a paucity of information on mineral requirements for current pig genotypes and Van Lunen and Cole (1998) have suggested that the mineral needs for growth in the modern fast-growing pig hybrids are about twice the level required by the slower growing pigs of some 20-30 years ago.

In addition, Lindemann and Kim (2006) have shown that the NRC (1998) recommendations for several minerals are based on very few publications.

MINERAL ALLOWANCES

Because of these concerns, minerals are often provided in the diet at levels well above the 'recommended requirements'. These are called 'allowances' and should take account of the class of the animal, its level of performance, as well as the source and bio-availability of the mineral. A survey of the amounts of minerals commonly provided in diets in several European countries has been carried out by Whittemore *et al.* (2002) (Table 2). This shows the wide variation in inclusion levels, with some as high as 3-4 times those recommended in Table 1. These are provided as an insurance for good rates of performance and to meet the animal's needs under the different systems of production and management, as well as to enhance its immune and health status.

Table 2. Range of dietary mineral additions in several EU countries (per kg feed)

Body weight (kg)	Piglet - 20	Growing Pig 20 – 50	Finishing Pig 50 – 120	Breeding Sow
Zinc (mg)	100 – 200	100 - 200	70 – 150	80 – 125
Manganese (mg)	40 – 50	30 – 50	25 – 45	40 – 60
Iron (mg)	80 – 175	80 – 150	65 – 110	80 – 150
Copper (mg)	6 – 18	6 – 12	6 – 8	6 – 20
Iodine (mg)	0.2 – 1	0.2 – 1.5	0.2 – 1.5	0.2 – 2.0
Selenium (mg)	0.2 – 0.3	0.15 – 0.3	0.2 – 0.3	0.2 – 0.4

(Whittemore *et al*, 2002)

When determining mineral supplementation, consideration must be given to the quantity and type of raw ingredients and their inherent mineral content, the processing of the diet, the storage and environmental conditions, as well as the inclusion and content of other minerals.

Minerals do interact and this must be taken into account. A well known example is the interaction between copper, zinc and iron, and if high levels of copper are used for growth-promoting purposes, then the requirements for both zinc and iron increase. Stranks *et al* (1988) proposed that in diets containing 175 mg Cu/kg, the level of iron should be increased to 200 mg/kg diet, whereas that for zinc should be increased to 150 mg/kg diet. These values are higher than those recommended in many national standards and explain the high allowances in commercial practice. Thus, the provision of minerals is not straight forward.

SOURCES OF MINERALS

Customarily, inorganic salts, such as sulphates, carbonates, chlorides and oxides are added to the diet to provide the correct levels to meet the animals needs. These salts are broken down in the digestive tract to form free ions and are then absorbed. However, free ions are very reactive and can form complexes with other dietary molecules, which are difficult to absorb. The availability of the trace mineral to the animal therefore varies considerably and under extreme conditions it may be unavailable for absorption and therefore of little benefit to the animal. Large quantities of undigested minerals are then excreted and cause environmental pollution.

For this reason, there is growing interest in organic, that is proteinated or chelated trace minerals. In this form, the trace elements are chemically bound to a chelating agent or ligand, usually a mixture of amino acids or small peptides. This makes them more bio-available and bio-active and provides the animal with a metabolic advantage that often results in improved performance. They can therefore be included at much lower levels without compromising performance, thus minimising nutrient excretion and environmental impact.

Relative values for the availability of selected sources of copper, zinc and iron for pigs are presented in Table 3.

Table 3. Relative bioavailability values of selected sources of copper, zinc and iron (Ammerman *et al*. 1995)

	Copper	***Zinc***	***Iron***
Sulphate	100		100
Carbonate	85 (2)		19-95 (3)
Oxide	30 (4)	50 (1)	10 (1)
Chloride		100	
Citrate			150 (4)
Lysine		100 (1)	
Methionine	110 (1)	100 (2)	185 (1)
Proteinate			125 (1)

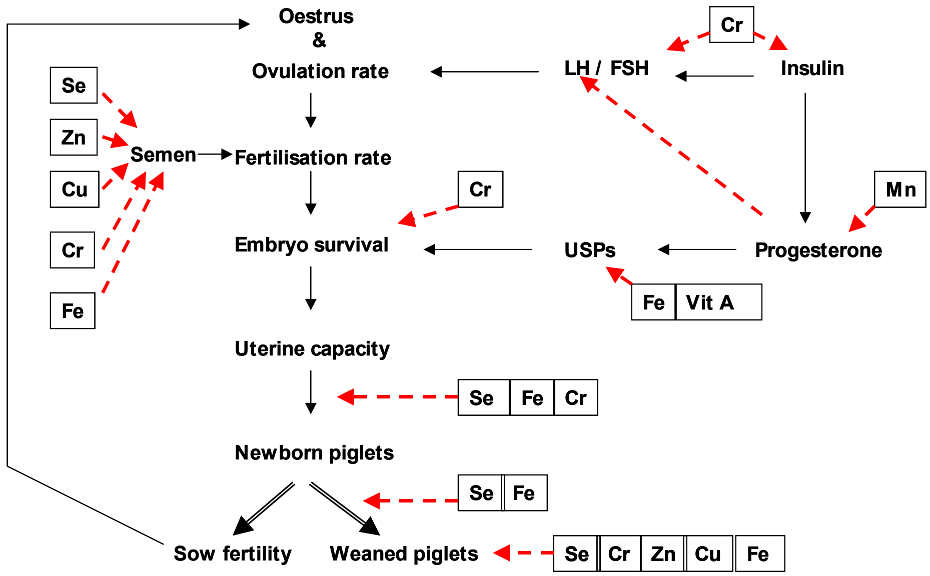
Values are relative to those of sulphate (100)
Values in brackets ( ) indicate the number of observations

The question is: 'Is the performance of pigs improved when organic minerals are added to their diet and what are the environmental advantages?' This is discussed in this paper in relation to the sow and in a corresponding paper in this session by Myers Hill (2006) for the weaner and grow-finish pig.

MINERALS AND REPRODUCTION

The role of minerals in reproduction is often under-estimated and their involvement in the different components that determine litter size and sow productivity has been suggested (Figure 2).

Figure 2. The potential role of trace elements in sow reproduction (Close 1999)



Much of the information on which current recommendations are made are based on work carried out 20-30 years ago when the productivity of sows was much lower than today. In addition, requirements are based on a per kg diet basis and do not take into account the metabolic needs of the sow, which changes with both body weight and level of productivity.

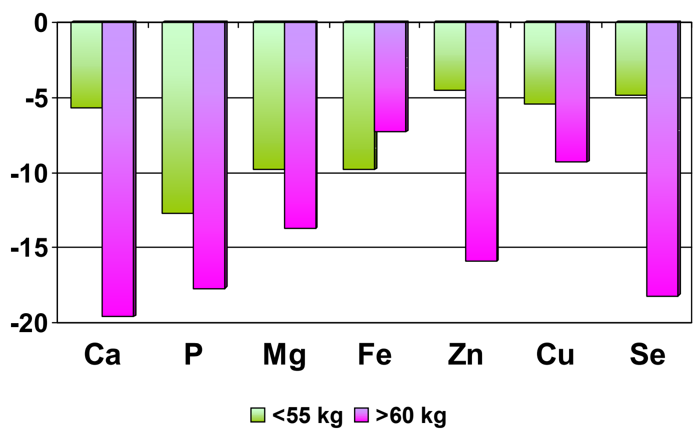
For example, it can be calculated that at the recommended rates of inclusion, and taking account of differences in feed intake, the mineral intake of mature sows is some 22% lower than that of first parity sows, when expressed per kg of body weight (Table 4). Mahan and Newton (1995) reported that the analysed body mineral content of sows after weaning their third litter of piglets was 15-20% lower than that of control, non-bred animals of similar age (Figure 3). Damgaard Poulsen (1993) has also reported a reduction in the mineral status of the sow and in suckling piglets with parity. These studies indicate that the levels of minerals recommended for the modern sow may be below those needed to optimise sow productivity. On the basis of the information presented in Table 4, the mineral content in the diet of the modern sow would need to be increased by approximately 5% with parity.

Table 4. Trace mineral intake in relation to sow body weight and parity

Mineral	Recommended[1] (mg/per kg diet)	Parity 1 (160 kg)[2] Intake (mg/d)	Parity 1 (160 kg)[2] Intake (mg/kg body wt)	Parity 3+ (240 kg)[3] Intake (mg/d)	Parity 3+ (240 kg)[3] Intake (mg/kg body wt)	% Reduction in mineral intake (mg/kg body wt)
Iron	100	300	1.87	348	1.45	22
Zinc	100	300	1.87	348	1.45	21
Copper	15	45	0.28	52	0.22	22
Manganese	40	120	0.74	139	0.58	22
Selenium	0.25	0.75	0.0047	0.87	0.0036	22

[1] MLC (2004)
[2] Animal fed 2.4 kg in gestation and 5.5 kg/day over a 26-day lactation
[3] Animal fed 2.8 kg in gestation and 6.5 kg/day over a 26-day lactation
[4] A 7-day post-weaning period has been assumed, with a feed intake of 3.5 kg/day

Figure 3. Sow mineral content: % Change (Mahan and Newton, 1995)



These results therefore raise questions about the mineral needs of the modern sow, the actual mineral content in the diet and the availability to the animal, as well as the effect of the mineral status of the animal on overall productivity. This is especially pertinent to the sow, and Richards (1999) has shown that already in late gestation, the sow must rely on her liver iron reserves to meet foetal demands for the mineral. Similarly, Mahan (1995) has shown that the milk Se content and tissue Se retention becomes depleted as sows mature and this affects the Se status of the suckling piglet as demonstrated by Damgaard Poulsen (1993).

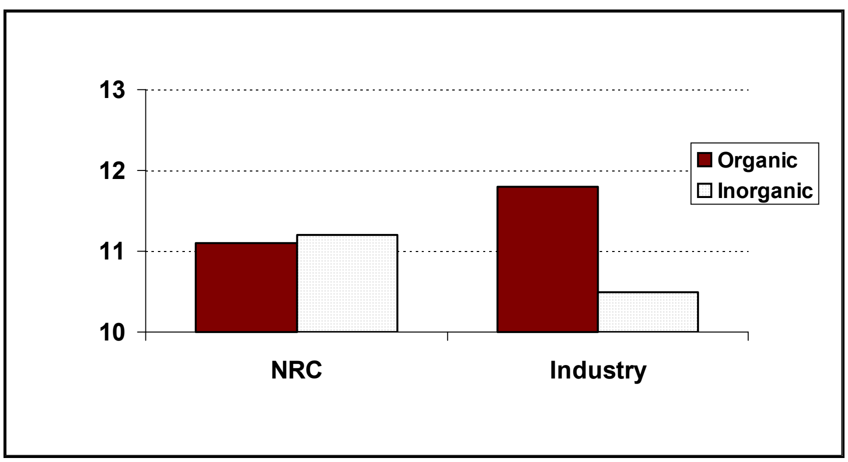
Several studies have been carried out to establish if high level of dietary minerals could maintain the mineral status of the sow with parity and hence enhance sow productivity. For example, Cromwell *et al*. (1993) fed high levels of dietary copper to sows (250 ppm) over six parities and reported that their liver copper concentration increased by more than four-fold. There was no significant effect on reproductive performance, but birth weight and weaning weight of the piglets was increased. More recently, Boyd (2006) increased the mineral and vitamin content of both the gestation and lactation diets by 20-25% of sows from parity 3 onwards and reported an extra 0.6 piglet weaned per litter. This equates to 1.4 extra piglets weaned per sow per year, compared to control sows of similar parity. However, the biggest response was from parity 6 onwards, when there is likely to be no more than 10% of sows in the breeding herd.

Instead of increasing the mineral content of the diet with parity, an alternative would be to use more available sources of mineral, that is organic, rather than inorganic minerals. These are more bio-available and bio-active and have been reported to provide an advantage to the animal (Ammerman *et al.*, 1995).

Fehse and Close (2000) fed highly productive sows a special package of organic minerals additional to the normal level of inorganic minerals over a 2-year period. Over the peak parities (parities 3-6), 0.5 more piglets were weaned per litter from those sows fed the additional organic minerals and pre-weaning mortality was also reduced. Interestingly, it was also observed that a greater proportion of the 'supplemented' sows remained in the trial for a longer period of time compared with the 'control' sows. Similar improvements in sow productivity have been reported by Smits and Henman (2000) and Acda and Chae (2002). More recently, Lima *et al.* (2006) fed additional organic minerals to young sows from selection and reported an extra 0.7 piglets weaned during the first parity.

Mahan and Peters (2006) compared the form (inorganic or organic) and level of trace minerals (NRC (1998) or 'Industry') (Se, Fe, Cu, Zn, Mn) in the diet of sows over 6 parities. Industry levels were 0.5 to 2.0 times higher than the NRC (1998) levels for selected individual minerals. When NRC levels were fed, there was no difference in the number of live piglets born per litter (Figure 4). However, when industry levels were used, there was an additional piglet born per litter when organic minerals were provided compared with inorganic minerals. Performance of the sows fed the inorganic source of minerals at commercial levels was also below that of the NRC (1998) levels of inclusion, regardless of form. This suggests that when the dietary inorganic mineral inclusion may possibly be excessive, there is a reduction in the reproductive performance of sows; a response similar to that reported by Flowers *et al.* (2001). It is possible that increases in inorganic trace minerals, and especially in sulphate form, are linked to an accumulation of free radicals which may impair reproductive performance. In this respect, Mahan (2005) has suggested that organic sources of trace minerals may be more important than previously thought in preventing free radical accumulation and, as a consequence, enhancing reproductive performance.

Figure 4. Effect of level and source of minerals on piglets born alive (Mahan and Peters, 2006)



CONCLUSIONS

Trace mineral nutrition has been a particularly neglected area of pig science and modern genotypes, with higher levels of productivity may require higher levels than are currently recommended. However, it is not just a question of quantity, but very much a question of source and bio-availability. The benefits of including trace minerals at the level required by the modern animal and in the most readily absorbed form are measurable in increased performance, better health and welfare. In this respect it is likely that organic minerals will play an increasing role in pig nutrition, not only for meeting the true requirements of the animal for optimal performance, but also for minimising their excretion and hence better meeting environmental standards, as well as providing healthy meat for the consumer.

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