Organic trace mineral can reduce the environmental burden of poultry manure

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Brief Curriculum vitae

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Introduction

Trace mineral needs of poultry have received little attention over the last 40 years compared to other aspects of nutrition, such as energy and amino acids.

A brief review of information published in scientific journals over the last 15 years indicates only some 1.5% of research effort expended on trace minerals.

The main reason for this lack of interest lies in their relative economic importance. More often than not trace minerals are included in excess of required amounts in the poultry diets, even then they represent less than 0.5% of total diet costs.

This contribution is overwhelmed by the costs of energy and amino acids, and so naturally there is much greater interest in more closely defining the needs for these macronutrients.

However recently there has been increased interest in trace mineral nutrition. This has been brought about by concerns for the environment and particularly the level of all nutrients in manure. Environmental concerns are a major focus for all who are involved in intensive poultry production. Thus it is no surprise this has been a popular topic at a number of recent Poultry Science meetings in the USA and Europe.

Much has been written about the balance of nitrogen and phosphorus in poultry nutrition, and there are ongoing attempts at limiting their concentration in manure. It seems inevitable that regulatory concerns will be raised about the level of other chemicals in manure, one of which will be trace minerals.

Today in the USA, Canada and some European countries, there are reports that rural water supply is testing at or in excess of 0.2ppm zinc. Such relatively high levels are likely a consequence of various agricultural practices, and zinc content of poultry manure will be but one contributor to this situation.

It seems inevitable that trace mineral levels in poultry diets will come under closer scrutiny, and providing amounts excess to requirements will have to be curtailed. There is all likelihood that more attention will be paid to the organic sources of trace minerals that are more bioavailable and environmentally friendly.

Trace mineral requirements and ingredient composition

Many nutritionists base their estimates of requirement on the NRC(1994) Nutrient Requirements of Poultry. This is something of a unique situation since many 'requirement' values within the NRC(1994) are often used as a starting point in formulation, and actual diet levels often provide added 'insurance'. However the NRC(1994) estimates for trace minerals are within the range commonly used in feeding broilers, layers and breeders.

A concern often raised about these values is the somewhat historical data used in their development. All nutrient requirement values within NRC(1994) are based solely on information published in referenced scientific journals.

Since there has been little interest in redefining trace mineral needs of poultry, then the NRC(1994) values are necessarily based on somewhat historic data.

With changes in genetics of broilers and layers, and dramatic changes in performance, the validity of such historic data is often questioned.

Table 1 shows the year of the research data used in defining NRC(1994) trace mineral estimates.

Table 1. Year (19__) of research used in estimate of trace mineral requirements[1].

	Pullets	Layers	Broilers
Magnesium	49, 60, 63	67, 68, 69	47, 60, 60, 61, 63, 75
Manganese	39, 71	39, 69, 71	39, 83
Zinc	58, 59, 61, 72, 72	86	58, 58, 58, 60, 61, 83, 84, 90
Iron	61, 61, 64, 68	81	64, 68, 79, 82
Copper	61	78	79

[1] NRC, 1994

As shown in Table 1, much of our knowledge of trace mineral requirements is based on information gathered prior to 1980, with most of these data coming from the period 1958-1978.

Another point of interest is the type of diets used in these studies (Table 1). Most often semi-purified or purified research diets are used, since the researcher is often unsure as to the content and/or bioavailability of trace minerals in conventional feedstuffs. Also, the mineral under study is invariably one of the highest purity possible obtained at great cost from a chemical supply company.

Table 2 shows recent mineral analyses conducted in spring 2002 on feed ingredients used in some trace mineral studies. The point of interest is the fact that values are quite different to other published values (e.g. NRC, 1994; Leeson and Summers, 1997) and reflects the variable uptake of trace minerals by plants.

Table 2. Trace mineral content of selected feed ingredients (ppm).

	Zinc	Manganese	Iron	Copper
Corn	12	10	107	11
Soybean meal	37	19	184	15
Meat meal	97	7	285	12
Wheat shorts	76	104	203	16

Of even greater importance in estimating trace mineral needs is knowledge of bioavailability of minerals within feedstuffs such as corn and soybean meal. There is very little information available on this topic. O'Dell *et al.*(1972) and Nwokolo and Bragg(1980) show 40-70% availability of Mg, Mn, Cu and Zn in canola meal and 50-78% availability in soybean meal. There is virtually no information available to account for such variability, and so predicting the bioavailability of trace minerals in common ingredients becomes a tenuous exercise.

Some ingredients can contain very high levels of trace minerals. For example, it has been reported that defluorinated phosphates contain up to 10,000 ppm Fe, and that this is up to 50% bioavailable (Henry *et al.,* 1992). At this level, 1% dietary phosphate will supply 50 ppm biovailable Fe, which is close to the requirement for most classes of poultry. Obviously suppliers of phosphates are not likely to guarantee minimum levels of iron, and so the source is likely to be disregarded or discounted when establishing an ingredient matrix.

There is a great deal of information describing the mineral bioavailability from various salts(Ledoux *et al.,* 1991; Smith *et al.,* 1994; Roberson and Edwards, 1994; Pesti and Bakalli, 1996). In general, sulphates are thought to have higher bioavailability than do oxides. Another area of discrepancy in such studies is choice of response criteria. While growth rate and feed efficiency may be the most important from a commercial viewpoint, bone accretion of trace minerals may well be a more sensitive indicator for minerals such as zinc and manganese.

Many requirement studies are conducted under idealized environmental conditions, where birds are subjected to minimal stress. *It is therefore important to realize that factors such as high environmental temperatures seem to influence the need for trace minerals at the dietary level.* Belay *et al.* (1992) indicated that levels of both fecal and urinary magnesium are increased under hot environments, and that needs for this mineral can be increased by up to 50%.

EFFECT OF USING PHYTASE

Phytic acid affects the birds' metabolism of trace minerals as well as that of calcium and phosphorus. Use of a phytase enzyme is therefore likely to increase the bioavailability of trace minerals in ingredients such as corn and soybean meal. The molecular structure of phytate has Zn, Fe and Mg bound much as is calcium.

While the effects of phytase on the liberation of P and Ca from phytate are well recorded, there is less information available on trace mineral release and bioavailability. Theoretically, as much Zn, Mg and Fe should be released as is Ca. However, it is not clear if the increased bioavailability of Ca due to phytase results from Ca release from phytate or from greater bioavailability of diet Ca *per se.*

Roberson and Edwards(1994) conclude that if phytase is used, then it may not be necessary to use supplemental zinc while levels of other cationic minerals such as Mn and Fe can also be reduced.

Yi *et al.*(1996) show improved retention of zinc from 'natural' ingredients when phytase is added to the diet(Table 3). Using regression analyses, they suggested that 100 U of phytase releases about 1mg of zinc. Therefore 600 U phytase will provide around 10% of zinc needs for a young broiler.

Table 3. Effect of phytase on zinc utilization.

Zinc retention	**Zinc (ppm)**	**Phytase (U/kg)**	
		%	**mg/bird**
0	0	37.9	0.77
5	0	35.8	1.06
10	0	35.4	1.25
20	0	34.2	1.49
0	150	39.2	0.82
0	300	44.0	1.02
0	450	43.0	1.00
0	600	44.8	1.03

Yi *et al.*(1996)

TRACE MINERAL PROTEINATES

It seems difficult to predict with accuracy the bioavailability of trace minerals in diets containing inorganic supplements.

To date this has not been a major concern since the obvious solution has been to over-formulate to ensure requirements even under the most stressful situations. However if there is need to minimize trace mineral excretion in manure, then we need greater confidence in bioavailability of 'reduced' diet inclusions.

In this context, the mineral proteinates may be of more use, since their bioavailability is more consistent.

Proteinates are chelates of protein/amino acids containing minerals, whose consistent bioavailability equates more closely to that of amino acids, i.e. 90-95%. Mineral proteinates usually contain amino acids, dipeptides, tripeptides or proteins *per se*, and are thought to enhance digestibility and availability of the mineral sequestered by the ligand.

Improved digestibility may be due to better solubilization, greater stability in the lumen and/or perhaps the ligand serves as an efficient carrier for the mineral across the brush border. Once absorbed, there is also the potential for greater retention, since there is less likelihood of secretion or excretion prior to incorporation in end-product molecules. Proteinates therefore seem ideal choices in formulating diets containing minimal levels of trace minerals.

As an initial step in investigating the role of metal proteinates in reducing trace mineral levels in manure, S. Leeson *et al.,* University of Guelph, Canada, conducted a study with caged broiler chickens. Broiler diets were formulated with mineral sulphates using 100 ppm Zn, 90 ppm Mn, 30 ppm Fe and 5 ppm Cu. These sulphates were assured to be 70% bioavailable. The same level of bioavailable minerals were contributed by Bioplex™ minerals, and then this level further reduced to 80%, 60%, 40% or 20% of this level(Table 4).

Table 4. Trace mineral inclusion levels (ppm).

	Inorganics	Digestible*	Bioplex™ level				
			100%	80%	60%	40%	20%
Zinc	100	70	70	56	42	28	14
Manganese	90	63	63	50	50	25	13
Iron	30	18	18	14	11	7	3.6
Copper	5	3	3	2.4	1.8	1.2	0.6

*assumes 70% digestion

All other trace minerals and vitamin levels were constant across the five treatments. Each treatment was tested with 6 replicate groups of 8 caged birds to 17 days and thereafter, 5 replicate groups of 5 caged birds to 42 days.

Table 5 shows the body weight and feed efficiency of broilers fed the various levels of trace minerals.

There were surprisingly few effects of trace mineral supplementation, where even birds fed just 20% of a normal level of Bioplex™ trace minerals grew quite well considering the cage environment.

There were no overt problems with bird health, and no differences seen in mortality. During the 15-17 day period and the 39-42 day period, a balance study was conducted, and feed and excreta analyzed for trace minerals. Based on this data, trace mineral excretion for a farm housing 100,000 male broilers was calculated for each of the trace minerals under study.

Table 5. Broiler response to diet trace minerals.

		Body weight		Feed gain	
		17 days	42 days	0-17 days	0-42 days
Inorganic		489	2217	1.45	1.75
BioplexTM	100%	470	2351	1.51	1.70
	80%	472	2239	1.47	1.73
	60%	467	2285	1.53	1.72
	40%	444	2185	1.48	1.74
	20%	459	2291	1.50	1.69
	±SD	36	97	.08	.05
		NS	NS	NS	NS

Table 6. Calculated mineral output in manure (kg/year) from a farm growing five crops of 100,000 male broilers annually.

		Zinc	Manganese	Iron	Copper
Inorganic		470^{a}	273^{a}	535	19^{a}
Bioplex™	100%	318^{b}	217^{b}	523	17^{ab}
	80%	294^{b}	185^{b}	491	18^{ab}
	60%	309^{b}	172^{cd}	494	16^{ab}
	40%	299^{b}	156^{d}	487	16^{ab}
	20%	292^{b}	130^{e}	446	15^{b}
	±SD	37	13	50	1.7
		**	**	NS	*

Use of Bioplex™ minerals calculated to be at the same level as contributed by the inorganic salts resulted in reduced mineral output. To some extent this situation reflects the 70% bioavailability assigned to the inorganic salts, and that diets with proteinates therefore contained some 30% less mineral *per se.* The Bioplex™ minerals may be even more bioavailable relative to the inorganic salts, although the trial was not designed to answer this question.

It seems as though trace mineral needs for non-heat-stressed broilers may be substantially less than current industry recommendations, and so there is potential to reduce manure loading of these nutrients. As trace mineral levels are reduced, then proteinated minerals become more attractive, since their bioavailablity is very high, and very consistent. Using proteinated trace minerals at lower levels also makes them more economically attractive.

Adapted from Dr. Steve Leeson's paper given at the Alltech Symposium, May 2003

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