BIOAVAILABILITY OF SUPPLEMENTAL TRACE MINERALS AS ESTIMATED BY TISSUE ACCUMULATION

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Efficient production of livestock and poultry requires that all essential nutrients be provided to the animal in proper amounts and in forms which are biologically available. There are at least seven microminerals (iron, copper, manganese, zinc, cobalt, iodine and selenium) which can be deficient under practical feeding situations. When deficiencies of one or more of these mineral elements occur in the diet for animals, the usual practice is to provide them in an inorganic supplemental form. Thus, it is important to know the bioavailability of the desired elements in the mineral sources which can be obtained for use as dietary supplements. Earlier reviews on the bioavailability of the trace minerals (Ammerman and Miller, 1972) and the macro minerals (Peeler, 1972) are available.

DEFINITION OF BIOAVAILABILITY

The term "bioavailability", as used generally, can be defined as the degree to which an ingested element in a particular source is available for use in metabolism by the animal in question. The value for bioavailability is expressed frequently in percentage units in relation to a standard source as an aid in use of the information in diet or mineral supplement formulation. Various methods have been used over the years for determining bioavailability of the different mineral elements. It is not the purpose of this paper, however, to discuss the various procedures.

DETERMINATION OF BIOAVAILABILITY

Studies have been conducted in recent years at the University of Florida in which bioavailability values for the micro elements have been estimated with relatively short feeding periods and using diets consisting of natural ingredients and containing elevated levels of the mineral element in question. Accumulation of the element in various target organs has been used as the response criterion. There are several potential advantages to the proposed method. Diets containing natural ingredients which are less expensive and more palatable than purified diets can be fed. Greater consumption of the diet by the animal results in more complete expression of genetic growth potential and a more sensitive assay animal. Contamination of either diet or of tissue samples with the micro element in question is of less consequence when high dietary levels of the element are being fed as opposed to having the diet as completely free as possible of the element. Measurements of elements in tissues are quantitative in nature compared with signs of deficiency such as subjective leg scores for perosis in chickens. Fewer observations are required to reach the same level of statistical confidence in the data. This is illustrated in Figure 1 in which it becomes obvious that with a linear response in tissue mineral concentration, fewer observations would be required to detect a difference at the higher mineral intake "B" than at the lower intake "A".

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For purposes of illustration, results from studies with manganese will be discussed. Initially, studies were conducted which indicated that chicks can tolerate high dietary manganese levels without adverse effects. Based on these results, a study was conducted with male broiler-type chicks using tissue uptake of manganese as a measure of biological availability of manganese sources (Black et al., 1984). A basal corn-soybean meal diet (116 ppm manganese) was supplemented with 0, 1000, 2000, or 4000 ppm manganese as either reagent grade sulfate, carbonate, or monoxide and fed ad libitum for 26 days. No toxic effects were noted as expressed by feed intake, weight gain, feed conversion, hematocrit, hemoglobin, or mortality. Analysis of manganese in tissues revealed a highly linear relationship between bone manganese concentration and dietary manganese for all three sources (Figure 2). On the basis of uptake by liver and bone, relative bioavailability values for manganese sulfate, monoxide and carbonate were 100, 69 and 34%, respectively.

Another study was conducted (Henry et al., 1986) in which supplemental levels of 40, 80 and 120 ppm manganese as manganese sulfate or manganese monoxide were added to a natural chick diet containing 35 ppm manganese. Chicks were fed 21 days and the effect of manganese source and level on bone manganese is shown in Figure 3. The results of this study indicated that there was a linear response in tissue manganese at dietary concentrations of the element near the required level and that relative differences in bioavailability were similar to those obtained at the greatly elevated dietary levels. In earlier research, Watson et al. (1971) could not differentiate statistically among the same manganese sources when fed to a larger number chicks at a supplemental level of 10 ppm manganese in purified diets by using either bone manganese concentrations or leg abnormality scores.

BIOAVAILABILITY OF COMMERCIAL SOURCES

Further experiments have been conducted to estimate bioavailability of several feed grade manganese oxides, manganese dioxide and a manganese-methionine complex for broiler chicks. Chicks were fed 1000, 2000 or 3000 ppm manganese as reagent grade manganese sulfate or oxide or three fed grade manganese oxides for 21 days (Wong-Valle et al., 1989). Based on slope ratio comparisons of bone and kidney manganese concentrations with sulfate set at 100%, relative values averaged 81 to 84% for the reagent grade oxide and one of the feed grade sources and 62 to 64% for the other two feed grade oxides.

Reagent grade and feed grade manganese dioxide (pyrolusite) were compared with reagent grade manganese oxide in diets containing 1000, 2000 or 3000 ppm manganese from each source (Henry et al., 1987). Both dioxides were 40% as available as the monoxide. When compared with sulfates used in earlier studies availability was estimated at 29%.

A feed grade manganese-methionine complex was compared with reagent grade manganese sulfate or monoxide in diets containing 700, 1400, or 2100 ppm manganese and also adjusted for methionine concentration (Henry et al., 1989). The manganese-methionine complex was valued at 120% of sulfate and 133% of monoxide when based on bone and kidney manganese concentrations.

Availability of reagent grade sources of manganese sulfate, monoxide, dioxide and carbonate has also been studied in sheep fed 0, 1500 or 3000 ppm manganese (Wong-Valle et al., 1989). Based on manganese concentrations in liver, bone and kidney, relative bioavailability estimates were 100, 58, 33 and 28%, respectively.

SUMMARY

The bioavailability of mineral elements in supplemental mineral sources must be known to make effective use of various products in the formulation of diets or mineral supplements. A method has been studied to determine the biological availability of supplemental trace mineral elements for ruminants and poultry. The element of interest is added to a practical corn-soybean meal-cottonseed hulls diet for sheep or corn-soybean meal diet for chicks at high, graded levels and fed for a short period of time. The highest level offered should be below that which would cause feed refusal. Uptake of the element is measured in tissues such as bone, liver, kidney and plasma. This method has several advantages when compared with those which require highly purified diets and very low supplemental levels of the element being tested.

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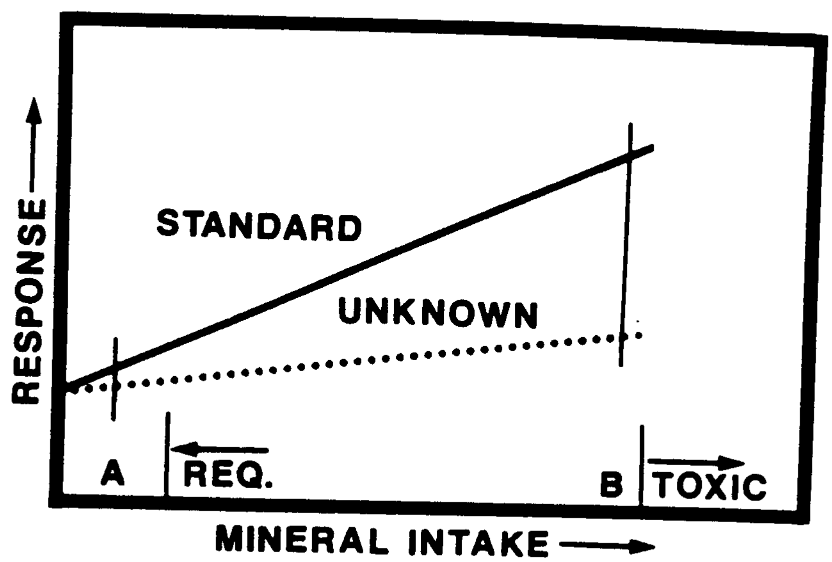

Figure 1. Illustration of linear relationship between mineral intake and tissue mineral response.

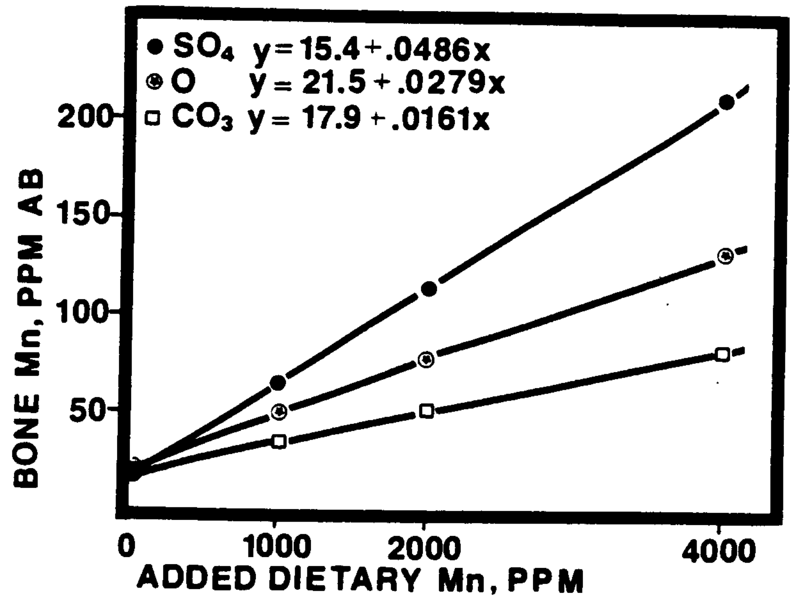

Figure 2. Effect of source and level of dietary manganese on bone manganese concentration (ash weight basis) in chicks fed 26 days.

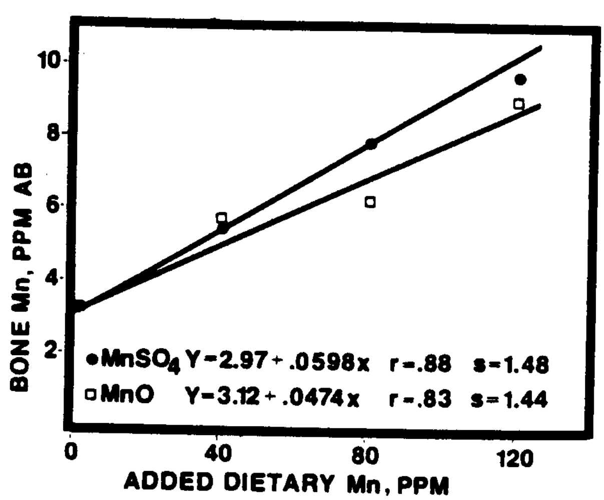

Figure 3. Effect of source and level of dietary manganese on bone manganese concentration (ash weight basis) in chicks fed 21 days.