A Comparison of the Bioavailability of Three Dietary Zinc Sources Using Four Different Physiologic Parameters in Dogs

John A Lowe and Julian Wiseman

Gilbertson & Page Ltd., Welwyn Garden City, Hertfordshire, AL7 1LF, UK and *Nottingham University, Department of Animal Production, Sutton Bonnington, Leicestershire LE12 5RD, UK

EXPANDED ABSTRACT

KEY WORDS: • zinc • bioavailability • chelate • polysaccharide complex • dogs

Although there are a number of bioavailability studies reported in the literature involving farm animals for zinc (Zn) as a function of dietary source (Baker and Ammerman 1995, Wedekind et al. 1994), there appear to have been few quantitative bioavailability studies conducted in dogs. The concept of bioavailability is much discussed and defined (Ammerman and Henry 1994). The most common definitions include reference to the proportion of a nutrient that is digested/absorbed and metabolized through normal pathways (Forbes and Erdman 1983). The latter part of this definition, the utilization of the nutrient by the animal in a structural or biochemical capacity, plays a significant part as to the extent of the “availability” as stressed by Fox et al. (1981). Therefore, the “bioavailability” of a nutrient is perhaps better defined as the proportion of intake that is capable of being absorbed through/by the intestine and made available either for metabolic use or storage in animal tissues. This assumes that the bioavailability of the nutrient is a function of the diet per se. However, it is also a response of the animal and of the animal to the diet as a function of its status. Different requirements and bioavailabilities have been found to be dependent upon the physiologic parameter measured (Wedekind and Baker 1990) and on the age and physiologic state of the animal (Lowe, unpublished data). Thus terms that would quantify under what conditions bioavailability had been established, for example, age of the animal, should be stated. If different dietary sources of a nutrient have different bioavailabilities of that nutrient, then a dietary concentration ceases to be an appropriate definition of the requirement for the nutrient. Nutrient requirements should, therefore, always be expressed as daily amounts available for metabolic use. Such complications infer that no one single parameter is appropriate to define the absolute, or relative bioavailability (RB) of a nutrient, and thus no single dietary inclusion rate can be indicated as the “requirement” without qualification. An examination of these data also leads to the recognition that young, or rapidly growing animals and/or tissues exhibit greater responses to differences in the dietary concentrations and expression of bioavailability of various Zn sources.

Zinc oxide (ZO) is a commonly used source of supplementary Zn in diets for farm animals (Wedekind and Baker 1990) and for dogs in the UK. Zn from ZO, however, has recently been shown to be of relatively low bioavailability relative to other dietary sources and prone to antagonistic reactions with other dietary nutrients (Baker and Ammerman 1995, Lowe et al. 1994, Lowe and Wiseman 1997).

A study was therefore conducted to examine the RB, by slope-ratio assay, of Zn from an oxide source in comparison with Zn from a chelate (ZM), corresponding to 2 mol of amino acids (methionine and glycine) to one of Zn, or a polysaccharide complex (ZP), consisting of zinc sulphate complexed with alkali modified brewers wort. Four physiologic parameters in the adult dog were determined to ascertain to what extent the Zn source influenced the RB values.

Materials and methods. Twenty-seven (27) adult Beagle dogs (13.7 kg, SD 1.93) were randomly assigned to nine groups of three. Dogs were housed in 2.4 m$^2$ (1.7 m x 1.4 m) concrete block pens with an open-metal steel gate to the front allowing them visual access to kennel-mates and the central walkway/exercise area. Bedding was provided in the form of soft-wood shavings. The kennel building was heated and ventilated to maintain a temperature of between 16 and 24°C, 30–70% relative humidity with 12 h of light in a 24-h period. All dogs were monitored throughout the day and pens cleaned once daily. The study protocols were appropriately approved and the animals maintained under the care of a veterinary surgeon for the duration of the study in compliance with the 1986 EC...
TABLE 1

Responses of dogs fed supplemental zinc from a chelate (ZM), polysaccharide (ZP) or oxide (ZO) source in addition to a basal diet for 30 d of supplementary dietary zinc intake by source on the dependent variables plasma AP concentration, hair growth, Zn deposited in hair and \( \text{AUC}_5 \). The RB was then determined by the comparison of the slopes of the regression lines for each parameter after the appropriate statistical analysis (Finney 1978). It was considered, because of the small sample size, to highlight trends in data (0.05 < \( P < 0.10 \)) as well as significant differences (\( P < 0.05 \)).

**Results.** The mean data and SEM for the treatments are shown in Table 1. Both supplemental Zn source and amount affected the variables measured. Alkaline phosphatase (AP) did not respond to zinc supplementation in a consistent manner.

The RB of Zn from the ZM or ZP source, compared with Zn from the ZO source, as the standard, was determined by comparison of the slopes of the regression lines, based on the data from Table 1 for Zn deposited in hair, hair growth and \( \text{AUC}_5 \). The statistical interpretation of the derived slope ratio assays is summarized in Table 2.

For some of the parameters measured, there were large variations among animals; however, with the exception of AP, this did not affect the validity of the regression equation. Linearity of the regression lines was sufficiently poor for the AP data to preclude the analysis of the data by slope ratio assay to determine RB of Zn.

The suitability of the slope ratio assay model as indicated by

### TABLE 2

Relative bioavailability of Zn from a zinc chelate (ZM), or a zinc polysaccharide (ZP) to zinc from an oxide source (ZO) in dogs

<table>
<thead>
<tr>
<th>Physiological parameter²</th>
<th>A</th>
<th>ZM</th>
<th>ZP</th>
<th>ZO</th>
<th>P³</th>
<th>RB⁴</th>
<th>Slope P⁵</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hair growth</td>
<td>244</td>
<td>7.05</td>
<td>n/a</td>
<td>3.37</td>
<td>0.14</td>
<td>2.09</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>244</td>
<td>n/a</td>
<td>2.41</td>
<td>2.41</td>
<td>0.88</td>
<td>1.00</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td>Zinc deposited</td>
<td>43.5</td>
<td>0.91</td>
<td>n/a</td>
<td>0.36</td>
<td>0.09</td>
<td>2.52</td>
<td>0.03</td>
</tr>
<tr>
<td>43.5</td>
<td>n/a</td>
<td>0.69</td>
<td>0.37</td>
<td>0.90</td>
<td>1.87</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>( \text{AUC}_5 )⁶</td>
<td>3.64</td>
<td>0.016</td>
<td>n/a</td>
<td>0.007</td>
<td>0.97</td>
<td>2.29</td>
<td>0.01</td>
</tr>
<tr>
<td>3.64</td>
<td>n/a</td>
<td>0.014</td>
<td>0.008</td>
<td>0.89</td>
<td>1.75</td>
<td>0.11</td>
<td></td>
</tr>
</tbody>
</table>

1 Multiple regression equations for each source for hair growth, zinc deposited in hair and \( \text{AUC}_5 \) on supplemental Zn from either ZM and ZO, or ZP and ZO. The equations take the following form: response variable = A + (test source × d) + (standard source × d) where A is a constant equivalent to the value from the basal diet, d is the amount of supplemental Zn from either the test or standard source and P is the slope of the line.

2 For each parameter, line 1 is the comparison between ZM and ZO and line 2 is the comparison for ZP and ZO.

3 \( \text{P} \) refers to the validity of the equation in terms of the deviations from the regression.

4 RB is the relative bioavailability of Zn from the test source to zinc oxide.

5 Slope P is the significance of the difference between the regression coefficients.

6 Abbreviations: \( \text{AUC}_5 \), the area under the plasma Zn curve for 5 h after feeding the dietary supplemental Zn; n/a, not applicable.
P in column 5 of Table 2 means that a valid comparison of the RB of Zn from the test source, either the ZM or ZP, can be made with the standard ZO. In each case, the Zn from the ZM source had a significantly higher RB, as indicated by slope P in the final column of Table 2, than Zn from the ZO. A direct comparison between the RB of Zn from the ZM and ZP sources is not valid because this was not in the design or analytical interpretation of the experiment. However, the extent of the relative differences in the RB of Zn from the ZM source to the ZO source compared with the Zn from the ZP and ZO sources suggests a ranking in terms of the bioavailability of the Zn, ZM, ZP and ZO. The superiority of the RB of the Zn from the chelate was similar to results from other published studies (Wedekind and Baker 1990).

The Zn deposited in hair, the product of hair zinc concentration and hair growth rate, reflected an increase for the ZM source. On closer inspection, the majority of the response (Zn deposited in hair) was due to an increase in hair growth with a smaller contribution from the hair Zn concentration. The changes in the Zn deposited in hair with the ZP source were almost entirely due to a growth rate effect and not accompanied by an increase in the hair Zn concentration.

**Discussion.** The data suggest that although the absolute numerical values for RB may differ, depending on the physiologic parameter used to determine the RB, there is overall agreement in the general ranking of the bioavailability of the Zn from the three dietary Zn sources across the measurement criteria used. This general agreement between the various parameters measured indicates that, in line with previous studies, dietary supplemental Zn from a chelate is relatively more bioavailable than Zn from an oxide source and probably from the polysaccharide source. There were no significant differences established between the RB of the Zn from the oxide and polysaccharide sources. This is likely due to a greater than expected variation among dogs because previous studies have indicated differences for these two sources (Lowe et al. 1994).

The results of this study support the proposition that rapidly growing tissue, or tissue with a high requirement for a nutrient, provides a sensitive assay for the determination of the RB of Zn by slope ratio methodology. In the adult dog, which is normally considered indifferent to a wide variation in Zn supply, Zn deposited in hair, which combines the effects of Zn on cell differentiation (hair growth) and the concentration of zinc in hair (reflecting an increase in Zn storage), should be considered as a sensitive assay for the determination of the RB of Zn from different dietary sources under controlled conditions. In contrast, AP does not appear to be a useful criterion for the evaluation of differences in the RB of Zn from different dietary sources.

**LITERATURE CITED**


