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Household Harvested Rainwater Run-Off from Galvanized Metal Roofs can Be An Important Dietary Source of Bioavailable Zinc

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Abstract

Rainwater samples harvested off galvanized metal roofs in parts of Jos metropolis were surveyed for zinc content and zinc bioavailability. Zinc content was measured by atomic absorption spectrophotometry while zinc bioavailability was assayed in the rat using serum Zn as an index. Zinc content (mg/l) of rainwater run-off samples was in the range 0.2321-2.8877 with a mean value of 1.1150±0.2113. The zinc in selected samples was readily bioavailable as evidenced by the marked elevation of serum zinc levels in rats given the water samples as drinking water. The results are discussed and it is concluded that rainwater harvested off galvanized metal roof can be an important source of bioavailable zinc in a household relying on it as domestic water source.

Key words: Galvanized metal roof, rainwater run-off, zinc content, zinc bioavailability.

1.0 Introduction

Zinc is an essential micronutrient critical in human nutrition as evidenced by the wide range of reported health benefits of zinc supplementation (Penny, 2000). This is attributable to its wide ranging important roles in body biochemistry: zinc is essential for the proper functioning of more than 300 enzymes, structural proteins and hormones variously playing catalytic, structural and regulatory roles (Cunningham *et al.* 1990). Zinc is needed for diverse physiological processes and metabolic functions, including many aspects of the immune system (Shankar and Prasad, 1998).

Human zinc deficiency syndrome, first recognized in Iranian and Egyptian adolescents eating a staple diet consisting largely of whole meal bread (Prasad *et al.*1963), is characterized by a wide range of clinical manifestations, including growth retardation, male hypogonadism, growth failure, skin changes, mental lethargy, hepatosplenomegaly, iron deficiency anaemia and geophagia. Less overt or subclinical deficiency is more common than the gross deficiency condition and contributes to an increased incidence and severity of common but important infections, such as diarrhoea and pneumonia, which are responsible for much of infant morbidity and mortality (Penny, 2000). Zinc deficiency disease is reportedly prevalent in many populations of the world, including Nigeria (Maziya-Dixon *et al.*, 2004), in some of which it constitutes a serious public health problem (Penny, 2000). Children under 5 years and pregnant and lactating mothers are the most vulnerable group in the population.

Zinc deficiency disease is primarily a consequence of consumption of a zinc deficient staple diet. Thus, the bioavailable zinc content of the staple diet is a major determinant of differences in zinc status within and among populations. Foods of animal origin, such as meat, fish, offals, milk and eggs, are the richest dietary sources of easily assimilable zinc (Penny, 2000). A wide range of foods of plant origin like nuts, beans, pumpkin, okra, peas, and cassava, are also rich in zinc but the bioavailability of their zinc content is reduced by the coexistence of inhibitory substances, such as phytates, and hemicelluloses and lignin (Gibson, 1994). Thus, diets consisting largely of foods of plant origin are considered poor in zinc. Researchers appear not to reckon with the contribution of domestic water to dietary zinc and have tended to explain observed differences in zinc status within and among populations solely from the standpoint of the staple food content of zinc and its antinutritional factors. Consequently, it has been suggested (National Advisory Committee on Micronutrient Deficiencies, 2001) that in certain populations like Nigeria where most communities do not have access to pipe-borne water, alternative

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sources of domestic water supply, such as rainwater harvested off galvanized metal roofs, could be important dietary sources of bioavailable zinc and, thus, may constitute a significant variable in the prevalence or otherwise of zinc deficiency within and among populations.

In many rural and semi-urban (and even some urban) communities in Nigeria, it is common practice for individual property owners with the means to provide for large-scale storage facilities for rainwater run-off from galvanized metal roofs. The storage facilities range from metal or plastic surface tanks to underground concrete tanks. And depending on the capacity of the storage facility, such harvested rainwater may last several months into or throughout the dry season. The objective of this study is to test the hypothesis that rainwater harvested off galvanized metal roofs contains readily bioavailable zinc and so may be an important source of /or supplement to dietary zinc in populations where it is a principal source of domestic water supply.

2.0 Materials and Methods

A survey of rainwater samples harvested off galvanized metal roofs for zinc content was conducted in the suburbs of the Jos metropolis during the 2002 rainy season. For reference purposes, tap water was concurrently surveyed. Samples were analyzed as soon after collection as possible.

2.1 Water Sample Collection

Water samples were collected randomly at different locations in the metropolis using factory fresh 0.5 litre wide neck, white plastic sample bottles with screw caps (purchased from O.K Plastics Nigeria Ltd, Gombe). Prior to use, the bottles were washed and rinsed several times with distilled water.

Rainwater run-off samples were collected directly into sample bottles, during periods of prolonged rainfall, from homesteads using harvested rainwater as source of domestic water supply. Direct collection of rainwater run-off instead of collection from the receptacle was designed to eliminate possible contribution of zinc from the latter some of which were made of metal materials. Tap water samples were also collected directly into sample bottles. In each case, the sample bottle was screw-capped immediately after sample collection and upon return to the laboratory, the samples were stored at room temperature pending analysis.

2.2. Analysis of Water Samples For Zinc

The zinc content of the water samples was determined by atomic absorption spectrophotometry on a UNICAM model 696 atomic absorption spectrophotometer (Pye Unicam Ltd., Cambridge, England) using air-acetylene as fuel. Water samples were analyzed as collected, without further treatment, according to the procedure described in the equipment manufacturer's operational manual. Glass distilled water served as the control for the water samples.

2.3 Assay of Zinc Bioavailability

Rainwater run-off samples with zinc content of 2.0mg/l and above were employed in the assay of bioavailability of zinc. The bioassay was done in the rat model system.

Young adult male Wistar strain white albino rats (b.wt.100-140g) obtained from the Animal House Unit, University of Jos, Nigeria, were distributed evenly and randomly, three rats per cage, into four standard metal-plastic cages. They were fed the standard rat diet pellets (purchased from Grand Cereals Oil mills Ltd, Kuru) Jos Nigeria, *ad libitum* for four days and given drinking water, also *ad libitum*. However, the drinking water source varied with groups as shown in Table 1 below.

In each case, the drinking water was administered via a white plastic bottle with steel nipple. Prior to

Table 1: Treatment of experimental animals

Group	Treatment (drinking water)	mgZn/l
1 (Control)	Distilled water	
2	Rainwater run-off sample containing	208.15×10^{-3}
3	Rainwater run-off sample containing	288.77×10^{-3}
4	Rainwater run-off sample containing	269.07×10^{-3}

use, each bottle was thoroughly washed with brush and detergent under running tap water, and rinsed five times with glass distilled water.

At the end of the four day feeding experiment, the rats were anaesthetized with diethylether and sacrificed by decapitation. Blood sample (3-4ml) was collected separately from each rat into a dry, clean graduated centrifuge tube, allowed to clot at room temperature, and the serum recovered by centrifuging at 3,000 rev/min for 10 min in an MSE benchtop centrifuge. The serum sample (supernatant) was transferred into a dry, clean sample bottle by means of a dry, clean Pasteur pipette, the bottle screw-capped and stored in the refrigerator pending analysis. The serum samples were analyzed as soon after preparation as possible.

Serum zinc was determined by atomic absorption spectrophotometry as described earlier for water samples except that the serum samples were diluted 1:20, v/v, with glass distilled water prior to analysis.

2.4 Statistical Analysis

Statistical analysis of differences between sample means was done by the Student's t test (Steele and Torrie, 1960).

3.0 Results

The results of the determination of the zinc content of the water samples and of the assay of bioavailability of zinc in selected rainwater run-off samples are summarized on Tables 2 and 3, respectively.

The zinc content of rainwater samples harvested off galvanized metal roofs (See Table 2) varied widely, a fact reflected in the very high coefficient of variability. Both the zinc content and its sample variability are generally much higher in rain water run-off samples than in the public tap water, the highest zinc level in tap water being about the same as the least level observed rainwater run-off samples. The mean zinc content of rainwater run-off samples is significantly higher than that of tap water ($p<0.05$) as determined by Student's t test (n_1 ‚„ n_2).

Serum zinc levels were elevated in rats given rainwater run-off samples as drinking water when compared to the control given distilled water (See Table 3). In each case, the difference from the control was highly significant ($p<0.01$) as determined by the Student's t test for sample means ($n_1 = n_2$). However, the highest serum zinc level was observed not in rats given the rainwater sample with the highest concentration of zinc but in rats given a rainwater sample with a lower zinc content.

4.0 Discussion and Conclusion

The extreme variations observed in the level of zinc in rainwater samples harvested off galvanized metal roofs can be attributed to the wide divergence in the age or state of rusting of the galvanized metal roof off which rainwater samples were collected. Although no deliberate attempt was made during sample collection to relate sample to the state of corrosion of the galvanized metal roofs. A recall suggests that rainwater run-off samples obtained from heavily rusted galvanized metal roofs contained higher levels of zinc than those collected off the relatively newly constructed roofs.

Table 2: Zinc content of rainwater samples collected off galvanized metal roofs

	Zinc concentration (mg/l)		Coefficient of variability (%)
Water source	Mean ± S.E.M	Range	
Rainwater run-off	$111.50\text{x}10^{-3} \pm 21.13\text{x}10^{-3}$*	$23.21\text{x}10^{-3}$–$288.77\text{x}10^{-3}$	711.87
Tap water	$16.94\text{x}10^{-3} \pm 2.88\text{x}10^{-3}$	$9.39\text{x}10^{-3}$–$23.23.86\text{x}10^{-3}$	38.03

Zinc content of glass distilled water = 0.00, Significantly different from tap water ($p>0.05$). For rainwater run-off, n = 15; for tap water, n = 5

Table 3: Effect of administration of rainwater samples harvested off metal roofs as drinking water on rat serum zinc levels.

Treatment Group	Serum Zinc (mg/dl)
Distilled water (Control; Group 1)	$91.31x10^{-3}±0.18x10^{-3}$
Rainwater run-off 1 (Group 2)	$93.85x10^{-3}±0.18x10^{-3}$**
Rainwater run-off 2 (Group 3)	$96.91x10^{-3}±1.02x10^{-3}$**
Rainwater run-off 3 (Group 4)	$97.14x10^{-3}±1.11x10^{-3}$**

Tabulated values are means ± SEM for three rats. Significantly differentrom the control (p<0.01). Rainwater run-off samples 1, 2 and 3, contained $208.15x10^{-3}$ $288.77x10^{-3}$ and $269.07x10^{-3}$mg zinc/l, respectively. Zinc content of glass distilled water = 0.00.

The range of zinc content (mg/l) values obtained for rainwater run-off samples is expectedly generally much lower than those reported for rich dietary sources of zinc (i.e., meat, liver, poultry, fish, milk and dairy products, whole grain legumes) which are also rich dietary sources of protein (Veillon, 1990). The range of values obtained for zinc content is also generally much lower than the values reported for various ready-for-table local Nigerian prepared foods (Agbon *et al.*, 2010).

However, the three highest zinc concentrations (>2.0mg/l) obtained for rainwater run-off samples compare favourably with values reported for some local staple plant foodstuffs, such as yam, sweet potato, plantain and Amaranth leaf (Gibson and Ferguson, 1999) and cocoyam flour (Oyenuga, 1968). One advantage of household harvested rainwater run-off would appear to have over plant foodstuff sources of zinc is that of being devoid of the highly potent inhibitors of zinc bioavailability associated with the former. Besides, in a situation where it is used both in food preparation and as drinking water, harvested rainwater run-off may contribute substantially to the consumer's daily requirements for zinc. With human adult daily zinc requirement of about 15mg (Trusswell, 1985) and recommended water intake of 2.5l/day (Burton, 1976), harvested rainwater run-off zinc at the levels observed in this study could contribute up to 48.13% of the adult daily requirement for zinc.

The observed significant elevation of serum zinc levels in rats fed selected samples of harvested rainwater run-off is a confirmation that their zinc contents are readily bioavailable, being as readily absorbed from the gut lumen as the zinc in the rat standard diet. This is more so as the samples bioassayed were those collected off highly rusted galvanized metal roofs. Thus, although the level of zinc in the rainwater run-off samples may be relatively low compared to zinc rich foodstuffs, even the small quantity is readily bioavailable and would effectively supplement the zinc from foods. It therefore follows that in communities and households relying on rainwater harvested off galvanized metal roofs as a principal source of domestic water supply, domestic water could be a biologically significant source of dietary zinc.

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