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Zinc Content and Bioavailable Zinc of Run-off Water from Roofing Sheets in Jos Metropolis, Nigeria

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Abstract Zinc, a micronutrient, a nutritionally essential trace element, plays important biochemical roles as a component of many metalloenzymes and proteins. Zinc deficiency leads to compromised immune function and hence illnesses from a range of diseases. In this study, bioavailable zinc from water collected under roofs in Jos, Nigeria, was assessed using animal models. The aim of the study was to determine whether this water has as much zinc as the tap water commonly used by the inhabitants. Rats in the experimental group were fed rain water samples, collected as run-off, having the highest zinc content. Rats in control group were fed water from tap. All feedings were done normally for 21days *ad libitum*. Plasma was collected and analysed for their zinc content using atomic absorption spectrophotometer. Statistical analysis of the result showed that, there is no significant difference ($p > 0.05$) between the two groups. Therefore, rain water collected as run-off under roofs in Jos is as good as the normal tap water consumed in the city in terms of zinc content and bioavailable. Further research is still needed to determine whether these zinc sources can meet up the RDA.

Keywords: *rainwater, bioavailable zinc, Jos, metalloenzymes, deficiency*

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1. Introduction

Zinc is a micronutrient, a nutritionally essential trace element necessary for many biological functions. It plays important biochemical roles as a component of zinc metalloenzymes and proteins such as DNA polymerase, carbonic anhydrase, lactate dehydrogenase, and protein chain elongation factor [1]. Table 1 lists some examples of these enzymes.

Table 1. Some zinc metalloenzymes and their functions

Enzyme	Function
Carboxypeptidase	Hydrolysis of C-terminal peptide residues
Leucine aminopeptidases	Hydrolysis of leucine N-terminal peptide residues
DNA polymerases	DNA replication
Peptidases	Hydrolysis of peptides
Superoxide dismutase	Antioxidant activity
Phospholipase C	Hydrolysis of phospholipids
Alkaline phosphatase	Hydrolysis of phosphate esters
Carbonic anhydrase	Hydration of CO_2/Maintenance of acid-base balance
α-Amylase	Hydrolysis of glucosides
Alcohol dehydrogenase	Hydride transfer from alcohol to NAD^+ in alcohol metabolism

Thus, in deficiency cases may result in definite disease conditions [2] characterized by stunted growth, delayed wound healing, altered protein synthesis at a number of different points, changes in the nature of RNA polymerase and the base composition of mRNA among others. Zinc deficiency disease is prevalent in many parts of Nigeria [3] including Kanam Local Government Area, north-central Nigeria [4].

Zinc deficiency diseases can be prevented by eating Zn rich foods such as eggs, liver, and kidney of animal, seafood, milk, cheese, nuts, meat, poultry, whole grain cereal (Rice, wheat, maize and millet among others) and refined cereals grains. However, while the staple diets are rich in anti-zinc constituents, sources other than staple foodstuffs may be important alternative sources. Onions, pumpkin seeds, dark chocolate, garlic, watermelon seeds are also rich sources of zinc [5], nuts spinach, seafood such as cooked oysters, mushrooms, legumes and grain cereals (especially bran and germ) have relatively high zinc content, while tubers, refined cereals, fruits and vegetables have less [6]. Zinc from foods of animal origin has higher bioavailability than from food of plant origin due to the presence of fibre and phytate that inhibit zinc uptake by the intestine [7].

Other possible source of dietary Zn are domestic water sources, but the extent of its contribution to human Zn requirement/needs does not appear to have been objectively and systematically assessed or evaluated. More importantly, water sources may be explored as complements to the diet in terms of zinc nutriture. Therefore, with cereals as staple foodstuffs of north-central Nigeria, it is advisable to explore

the extent to which domestic water supplies contributes to the intake of zinc. This is the aim of this research project.

2. Materials and Methods

2.1. Materials

2.1.1. Chemicals and REAGENTS

All chemicals and reagents used were of analytical grade and included: EDTA (Ethylenediamine tetraacetic acid), deionized water, sodium citrate, nitric acid, zinc metal, hydrochloric acid, perchloric acid.

2.2. Methods

2.2.1. Collection of Water Samples and the Feeding Experiment

The research was an experimental survey design. Samples were collected and processed using zinc-free equipment (mostly plastics, stainless steels, and ceramics). All laboratory devices used in the test were sterilized to prevent contamination, and plastic products were soaked in a 0.4% EDTA (BDH, Poole, England) solution. Glass products were placed in a 10% hydrochloric acid (EMD Chemicals, NJ, USA) solution for 24 h before being washed with deionised water three or more times and then dried in a drier. Water samples were collected randomly using plastic bottles that had screw cap. Run-off water from roofs was collected from seven different locations: namely Abuja Hostel, Etobaba, Tudun Wada, Bukuru, Dadin Kowa, Lamingo, and University of Jos Main Campus, all in Jos metropolis, Nigeria. These water samples were screened for zinc content using atomic absorption spectrometer, AAS (AA6800, Shimadzu Instruments, Tokyo, Japan).

The sample with the highest zinc content was chosen and fed, *ad libitum*, to white albino rats of both sexes for 21days. The rats were sacrificed at the end of the feeding period. A control group, using tap water, was also set up under the same condition for the same period of time, and sacrificed alongside the experimental group.

2.2.2. Collection of Blood Samples

Eight hours prior to the termination of the feeding experiments, the feeds were removed (i.e. starved overnight). At the end of day 21, the rats were anaesthetized with ketamine/xylazine mixture (0.01ml/g body weight), and sacrificed by decapitation. Blood was collected, for each rat, in trace element-free, EDTA-coated collection tube. Plasma was obtained, for each blood collected, by centrifugation at 5000 x g for 15 minutes at 4°C. The aliquots, measuring about 1.0 ml, were each taken in vials and kept frozen until analysis.

2.2.3. Plasma Zinc Analysis

Plasma samples were prepared for atomic absorption spectrophotometry, AAS, analysis according to a procedure based on the methods of Halvin and Soltanpour [8] and Clegg *et al*. [9]. An aliquot of plasma sample (1.0 ml) was transferred to a Pyrex beaker and mixed with 5ml of digestion solution composed of a 6:1 v/v mixture of nitric acid and perchloric acid. The sample was then very slowly brought to boiling on a hot plate and heated to dryness in a fume cupboard. If sample blackening occurred during the fuming stage, the digestion mixture was added dropwise and heated again until dry white ash was obtained. The ash so obtained was dissolved in 5ml of distilled water and transferred accurately to a new trace element-free plastic vessel with a cap. More distilled water (5ml) was used to rinse the beaker free of all traces of the ash and to make up the volume to 10ml. This solution was stored at -10^{o}C until AAS analysis.

2.2.4. Preparation of Zinc Standard Solution

1g portion of zinc metal was dissolved in 10ml of concentrated HNO_3 solution in a 1 litre standard volumetric flask and the solution was made to mark with deionised water. A serial dilution of 1, 2 and 3mg/l was prepared. From these standard solutions, a standard curve was prepared for the validation of the method.

2.2.5. Preparation of Water Sample for AAS Analysis

The water was filtered through a membrane filter. The first 50-100ml of the sample was used to rinse the apparatus and the required volume of sample was collected. Acidification with nitric acid was used to stabilize the content. The pre-treatment process was carried out before the analysis was done on AAS machine.

2.2.6. AAS Instrumentation

The readings for the samples for zinc content determination were obtained in an atomic absorption spectrophotometer, AA–6800, Shimadzu Instrument®, (Shimadzu Corporation, Chiyoda-ku, Tokyo, Japan) set up at 213.86 nm wavelength, 0.7 slit width, 7.5 mA lamp current, and atomization with air-acetylene flame at 2,300°C. The AAS was equipped with a hollow cathode lamp, graphite furnace heating system, and argon gas was used as the nebulizer gas. The calibration curve was prepared with standard solutions for atomic absorption. Zero reference reading was prepared for all reagents with the same procedures as for sample digestion. The linearity of the curve for zinc indicated outstanding precision. Zinc was determined by direct aspiration of the sample into an air-acetylene flame.

3. Results

3.1. Results

The preliminary water analysis showed that run-off water from Etobaba has the highest zinc content (Table 2).

Table 2. Preliminary screening of run-off water zinc content

Water Location	Sample Code	Zinc Content[a] (mg/l)
Abuja Hostel	A	0.176±0.007
Etobaba	B	0.592±0.048
Dadin Kowa	C	0.412±0.069
Lamingo	D	0.366±0.105
Bukuru	E	0.273±0.079
Tudun Wada	F	0.520±0.088
Main Campus	G	0.407±0.145

[a] Results are means of 3 replicates per sample±SD.

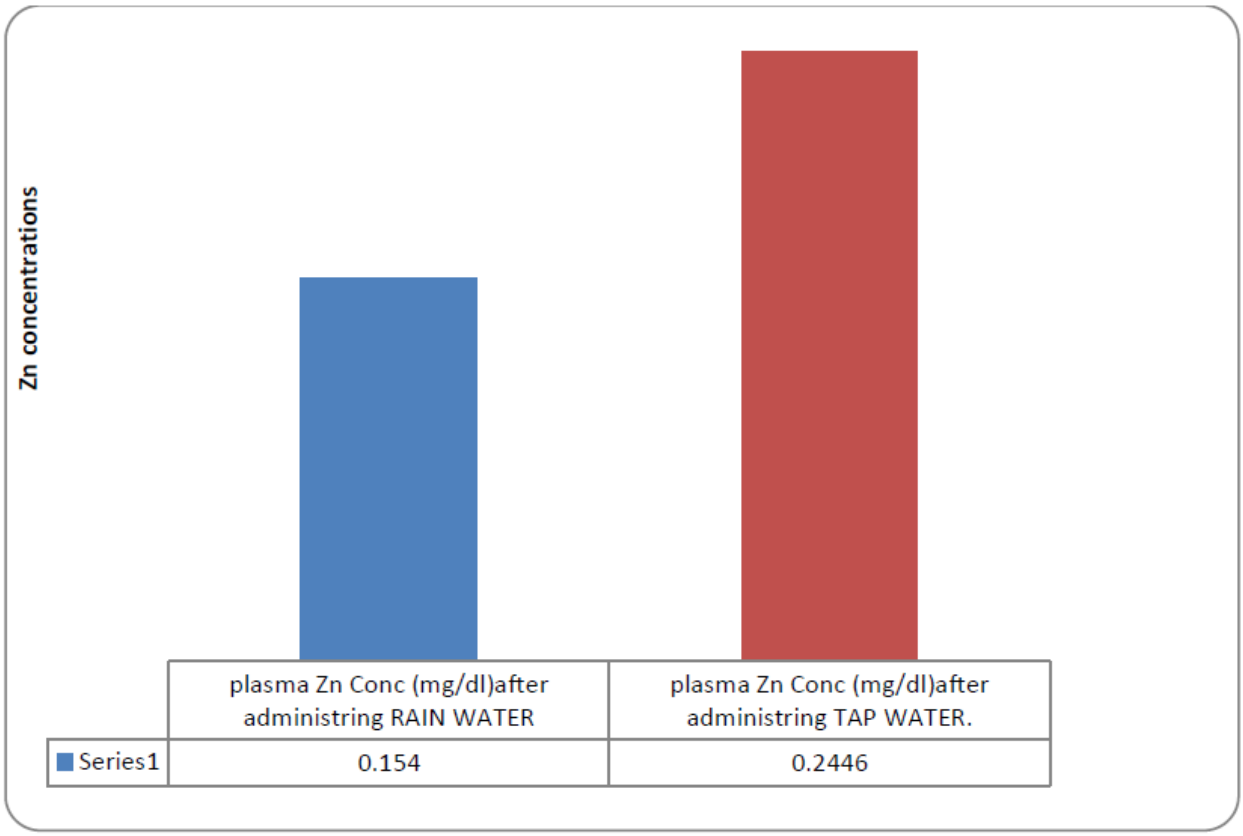

Figure 1. Concentration of Zinc in Plasma of Rat Place on Rain water (Experimental) and Tap Water (Control)

The results of the study showed that zinc is present in both water and rat plasma collected (Table 3).

Table 3[b]. Bioavailable zinc in experimental and control groups of rats

S/N	Plasma Zn Conc. (µg/dl) Experimental	Plasma Zn Conc. (µg/dl). Control
1	0.067	0.338
2	0.142	0.156
3	0.11	0.081
4	0.149	0.374
5	0.302	0.274

[b] Results are means of 3 replicates per sample.

Zinc concentration of rain water from roofing sheets that is absorbed by rats (sample) is lower than, the concentration of zinc in tap water absorbed by rats in the control (Figure 1).

Overall, the results indicate that, there is no significant difference ($p > 0.05$) between the experimental (Test) and Control groups (Table 4).

Table 4. Mean zinc concentration in plasma of rat placed on run-off water (experimental) and tap water (control)

	Plasma Zn Conc. (mg/dl) Experimental	Plasma Zn Conc. (mg/dl) Control	p – value	Remark
MEAN	0.15±0.08	0.25±0.11	0.0792	p > 0.05

p > 0.05 not significant.

This means that the rain water harvested in Jos metropolis contain zinc that is available to consumer.

4. Discussion

Rainwater harvesting has been suggested as the most sustainable solution to be included in the urban water management system [10]. This is because of its potential to reduce the burden on traditional water sources, alleviate nonpoint source pollutant loads, control water logging problems, prevent flooding, and help in controlling climate change impacts [11]. Water scarcity and the limited capacity of conventional sources in urban areas promote rainwater harvesting as an easily accessible source of water [12].

Although, zinc occurs naturally in our diets, most zinc finds its way into the environment because of human activities. Mining, smelting metals (like; zinc, lead and cadmium), steel production, as well as burning coal and certain wastes can release zinc into the environments [13]. A common use of zinc is to coat steel and iron used in making tap water valves in other to prevent rust and corrosion and in making roofing sheets [13]. When rain falls on these galvanized roofs, it carries some zinc along with it as it runs off. The amount of zinc dissolved in a given run-off water is depends on the nature of rain water falling on it and, in turn, on the nature of the atmosphere through which the rain water passes through.

Overall, all the water samples analysed had zinc content below 5.0mg/l, the WHO Interim Standard for Drinking-Water Quality [14]. In natural surface waters, the concentration of zinc is usually below 10 µg/litre, and

in ground waters, 10-40 µg/litre [15]. Based on a 1981 national survey of trace metals in drinking water supplies in Canadian, it was estimated that the average daily intake of zinc from drinking water for Canadian adults is ≤13.0 µg/day [16]. In another study in 1984, this value ranged from 33.8 to 97.5µg/day and was found to be highly dependent on the sampling strategy [17]. Although drinking-water makes a negligible contribution to zinc intake, the concentrations of zinc in run-off waters of the research area are 100 times lower than the usual range for underground waters. On the average, the zinc concentration of the water samples in this study is far less than those reported by [18] of 2.0mg/l for rainwater run-off from galvanised metal roofs. As explained above, this variation could be due to different environmental factors associated with run-off waters.

The concentration of zinc in blood plasma is currently the best available biomarker of the risk of zinc deficiency in a population [19]. However, bioavailability of zinc in plasma may differ due to other dietary factors like phytate and oxalate [20]. Pooled dose responds relationship between zinc intake and zinc status indicated that a doubling of the zinc intake increased the serum/plasma zinc status by 9%, this evidence can be utilised together with currently used balance studies and repletion/depletion studies, when setting zinc recommendation as a basis for nutrition policies [21]. Our research is therefore, consistent and in line with other research on plasma zinc level and bioavailability of zinc.

5. Conclusion

The results showed that, bioavailable zinc in run-off water from galvanized sheets (sample) in Jos metropolis is lower compared to tap water (control). However, the run-off water from galvanized sheets (rain water) in Jos metropolis is a good source of bioavailable zinc for the populace, because statistical analysis of the experimental groups indicates there is no significant difference ($p > 0.05$) between the two groups (sample and control).

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Conflict of Interest

We do not have any conflicts of interest to declare.

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