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*Full Paper*

# Magnesium, Iron, Copper and Zinc in Vegetable Roots from Mato Grosso do Sul, Brazil

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**Abstract:** The inorganic components, especially magnesium, iron, copper and zinc contained in vegetable roots are of major importance, but seldom taken into account, either by general practitioners or by dietitians. The goal of this work is to report on magnesium, iron, copper and zinc in potatoes, sweet potatoes, cassava, yam and taro produced, and consumed in Campo Grande, the capital of Mato Grosso do Sul state, Brazil. After previous determination of humidity, the vegetables were digested with a mixture of $HNO_3$ and $H_2O_2$ in the microwave digestion system Speedwave®, Berghof, Germany. The levels of trace elements were measured using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES, iCap 6000® - Thermo Scientific, USA). Most of the elements analyzed occur at levels within the range reported from international and Brazilian sources. However, iron in common potato, sweet potato and cassava was at the lowest level, while magnesium was very low in taro samples. The bioelements studied cannot pose any serious health risks and the edible tuberous roots widely consumed in Mato Grosso do Sul may represent an important source of essential micronutrients. The data show exclusively the population exposure to these minerals, no assumptions made as to their real absorption or bioavailability.

**Keywords:** analytical measurements; biometals; trace elements; tuberous roots

## 1. INTRODUCTION

Understanding of the inorganic compounds of foodstuff is important from nutritional and toxicological points of view. According to the Paracelsian maxim, dose makes poison and every element can become a human health hazard if its concentration in food is high enough. On the other scale, lack of inadequate quantities of metal ions such as magnesium, iron, copper and zinc can cause health problems for consumers.

The mineral components, especially trace elements contained in natural vegetables are seldom taken into account, either by general practitioners or by dietitians when advising their patients on matters related to balanced nutrition or the need for supplementation. Primarily, this is due to the paucity of reliable analytical data on the subject, although knowledge of the total concentration of a chemical element in food is not sufficient for evaluating how well this element will be absorbed or metabolized when consumed [1]. Living organisms store and transport magnesium, iron, copper and zinc for use in metalloproteins and metal cofactors. These studies belong to the large area if bioinorganic chemistry. The form of the metals is always ionic, but the oxidation state can vary, depending on biological needs.

Although metabolically active agents are mainly associated with organic compounds such as glycosides or alkaloids, the above elements can have a major impact. Their levels depend on the mineral composition of the soil from which they originated, the composition and pH of the irrigation water, the weather conditions, agricultural practices such as the

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use of different types and amounts of fertilizers and other factors [2]. The absorption of metal ions by roots can be both passive (non-metabolic) and active (metabolic), but there are some disagreements reported in the literature as to the particular method of absorption applicable to each individual metal. Despite controversies, in each case the rate of the mineral uptake will positively correlate with its available pool at the root surface [3].

Concerted efforts have been made to evaluate the level of trace elements and magnesium in foodstuffs as a helpful adjunct to establishing local dietary requirements and related legislation. It is notable that vegetables and tubers in particular, are most widely consumed as part of the habitual diet in tropical countries, and especially in Brazil. Their roots are physiological energy reserves; thus, their contribution to the total diet cannot be neglected. This paper is part of our investigations into the presence of mineral components in food samples [4, 5], reporting, in particular, on magnesium, iron, copper and zinc in potatoes, sweet potatoes, cassava, yam and taro produced and consumed in Campo Grande, the capital of Mato Grosso do Sul state, Brazil.

## 2. MATERIAL AND METHODS

### *Samples*

The roots regularly consumed by the inhabitants of Mato Grosso do Sul state were subjected to analysis. Good quality fresh samples of common potatoes, sweet potatoes, cassava, yam and taro were purchased from the wholesaler CEASA (Central Supply of Mato Grosso do Sul state). This company is linked to the Agricultural Development and Rural Extension Agency of Mato Grosso do Sul, which provides vegetables to supermarkets, small markets and trade in general located in the capital and other cities of the state. Such centralized distribution ensures the homogeneity of samples and the randomization of their collection. The general characteristics of five common tubers are given in Table 1.

**Table 1**. General characteristics of tuberous roots selected for analysis.

| Common name | Botanic name | State of origin, Brazil |
|---|---|---|
| Potato | *Solanum tuberosum* | Paraná |
| Sweet potato | *Ipomoea batatas* | Mato Grosso do Sul |
| Cassava | *Manihot esculenta Crantz* | Mato Grosso do Sul |
| Yam | *Dioscorea ssp* | São Paulo |
| Taro | *Colocasia esculenta* | São Paulo |

### *Samples Preparation and Analysis*

The concentrations of magnesium, iron, copper and zinc were determined by Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES, iCap 6000® - Thermo Scientific, USA), using routine conditions for analysing the aforementioned bioelements in plants. Working standard solutions used for the construction of calibrating curves were purchased from Aldrich. All glassware was of Pyrex® glass. All materials, plastic or glass, were previously immersed for 24 h in a solution of Extran 5% (Merck), rinsed and immersed for at least 24 h in nitric acid (10%, Merck) solution for decontamination from any metal residue. Then they were washed with ultrapure water and dried at 40 °C prior to analysis. The analytical measurements were run in duplicates. All procedures were performed in the Laboratory of Mineral Metabolism and Biomaterials belonging to the Medical School of the Federal University of Mato Grosso do Sul.

The samples of each tuber were washed thoroughly with double distilled water, peeled with a plastic peeler and washed again with ultrapure water (Milli-Q, Millipore, Bedford, USA). To determine the humidity, the samples were first grated, then, after the wet weight (*ca* 2 g of the edible part of each vegetable) had been recorded, the matter was dried in an oven at the temperature 65 °C until attaining constant weight, and thereafter maintained at 105 °C for 72 h, according to the published analytical technique [6]. These samples were accurately weighed on a microanalytical balance and processed with a mixture of 5 mL of nitric acid (65%, Merck) and 3 mL of hydrogen peroxide (35%, Merck Millipore) in the microwave digestion system Speedwave®, Berghof, Germany. The vegetables were digested according to the program presented in Table 2. After digestion, the solutions were cooled down to room temperature, diluted with ultrapure water to a final volume of 100 mL and analyzed.

**Table 2**. Parameters of sample digestion[1].

| Step | Temperature (°C) | Pressure (bar) | Stop (min) | Time (min) | Energy (%) |
|---|---|---|---|---|---|
| 1 | 145 | 30 | 2 | 10 | 80 |
| 2 | 190 | 35 | 5 | 15 | 90 |
| 3 | 50 | 25 | 1 | 10 | 0 |

1) In accordance to manufacturer`s scheme; from [7] with modifications.

## 3. RESULTS AND DISCUSSION

The moisture content of the samples, with the exception of taro, was shown to be similar to previously published Brazilian averages, reflecting the stable conditions of previous storage (Table 3).

**Table 3**. Moisture content of tubers studied (% wet weight).

| Tuberous roots | Present work | Brazilian (average*) |
|---|---|---|
| Common potato | 85 | 82.9 |
| Sweet potato | 74.9 | 69.5 |
| Cassava | 58.6 | 61.8 |
| Yam | 68.1 | 73.7 |
| Taro | 85.8 | 73.3 |

* Tabela Brasileira de Composição de Alimentos. 4th ed. NEPA-UNICAMP: Campinas. 2011.

As for the chemical elements, they are considered separately for each root in the order of increasing atomic masses, and their concentrations are listed in Table 4. At present, there is no legislation regarding maximum limits of magnesium and iron in foods, while for copper and zinc they are 30 and 50 mg/kg, respectively [8]. It is worth noting that the negative term "inorganic contaminants" used in Brazil does not seem appropriate when applied to maximum limits. A more neutral expression would be "inorganic components", as they are a normal part of plant metabolism. These bioelements can be considered contaminants only when present in excessive or toxic amounts. The results shown in Table 4 are discussed separately for each root.

### *Common potato*

The maximum amount for magnesium in common potato had not been evaluated so far. The Brazilian average corresponds to 150 mg/kg, while the French potato contains 208 mg/kg and the potato in Central America 230 mg/kg. According to our findings, the magnesium concentration was 158 mg/kg, which is within reasonable limits. As for the iron content, we showed that the average value in Campo Grande (2.52 mg/kg) is almost the lowest in comparison with the published data, barely exceeding the values for Saudi Arabia (0.88 mg/kg). The copper concentration is also low (0.55 mg/kg) compared to the average Brazilian values (0.9 mg/kg) and European data. Unlike copper, zinc concentration found in the present work (2.43 mg/kg) is within the reasonable range of 2 – 2.6 mg/kg characteristic for Brazil and Central America.

### *Sweet potato*

The maximum amount for magnesium in sweet potato had not been evaluated. The Brazilian average is 170 mg/kg, while in Japan magnesium content corresponds to 270 mg/kg. According to our research, magnesium concentration was 135 mg/kg, which is within reasonable limits. As for the iron content, the Brazilian average is 4 mg/kg while our data for Campo Grande correspond to 2.25 mg/kg. This is the lowest level in comparison with the published data, especially those provided by Japanese researchers (22.7 mg/kg). The concentrations of copper and zinc, 0.70 and 1.5 mg/kg, respectively, are within acceptable limits when compared to the levels published for Brazil as a whole. There are no data available for Central America.

### *Cassava*

The Brazilian average for magnesium corresponds to 440 mg /kg, while in Central America and the United States its concentration is 210 mg/kg. Our data are practically identical (201 mg/kg). The only results from Africa are available for Nigeria. The magnesium concentration there is only 154 mg/kg . These data had been originally given as dry weight. Therefore, for purposes of qualitative comparison they have been recalculated on the basis of moisture content found for Brazilian cassava. The error should not exceed 2-4%. The iron levels in our samples are lower than in Brazil as a whole, in the United States, Central America and Mozambique. As for copper there are no data reported for Central America. Our data (0.78 mg/kg) are almost identical to the Brazilian average and similar to those from the United States. It is to be noted that the copper levels in other Brazilian states (e.g. Rio Grande do Sul) also happen to be considerably higher than the mean value. The zinc concentration found in this work (2.13 mg/kg) is consistent with values reported by other sources.

### Yam

The Brazilian average for magnesium corresponds to 110 mg/kg. Our values are higher (210 mg/kg) and are practically identical as reported for Central America. The iron content 3.7 mg/kg is within the range of 2 and 5.4 corresponding to the Brazilian average and values found for Central America. As for the copper concentrations, our data show levels (1.4 mg /kg) higher than the Brazilian average and lower in comparison to those published by Chinese researchers. The zinc concentration found in the present work (3.43 mg/kg) is close to the levels for Brazil and Central America. In a work dedicated to the chemical evaluation of the yam from Mato Grosso do Sul researchers have reported higher values for iron, copper and zinc. These differences may be due to the specific origin of vegetables grown on newly drained marshland in the Pantanal region.

**Table 4.** Trace elements concentrations (mg/kg of wet weight) in edible tuberous roots.

| Roots/ Elements | Magnesium | Iron | Copper | Zinc |
|---|---|---|---|---|
| *Common potato* | | | | |
| Our data | 168 ± 0.2 | 2.52 ± 0.01 | 0.55 ± 0.001 | 2.43 ± 0.002 |
| TACO[1] | 150 | 4 | 0.9 | 2 |
| CA[2] | 230 | 7.8 | - | 2.6 |
| Other sources | 208 France [11] | 0.66 Saudi Arabia [12]; 6 Spain [13] | 0.74 Serbia [14]; 0.94 France [11] | 1.49 Serbia [14]; 5.8 Slovakia [15] |
| *Sweet potato* | | | | |
| Our data | 135 ± 0.02 | 2.25 ± 0.01 | 0.70 ± 0.001 | 1.5 ± 0.001 |
| TACO | 170 | 4 | 1.1 | 2 |
| CA | - | - | - | - |
| Other sources | 267 Japan [16] | 7.19 Spain [17]; 22.7 Japan [16] | 1.26 Spain [17]; 1.88 China [18] | 8.65 China [18]; 2.4 Japan [16] |
| *Cassava* | | | | |
| Our data | 201 ± 0.1 | 1.65 ± 0.01 | 0.78 ± 0.001 | 2.13 ± 0.002 |
| TACO | 440 | 3 | 0.7 | 2 |
| CA | 210 | 2.7 | - | 3.4 |
| Other sources | 210 USA [19]; 164 Nigeria [20] | 2.7 USA [19]; 3.1 Mozambique [21] | 1.0 USA [19]; 5.3Brazil/RS [22] | 3.4 USA [19]; 2.6 Mozambique [21] |
| *Yam* | | | | |
| Our data | 210 ± 0.3 | 3.7 ± 0.01 | 1.4 ± 0.003 | 3.43 ± 0.001 |
| TACO | 110 | 2 | 0.6 | 2 |
| CA | 210 | 5.4 | - | 2.4 |
| Other sources | - | - | 2.8 China [18] | 13.2 China [18] |
| *Taro* | | | | |
| Our data | 80 ± 0.001 | 2.28 ± 0.006 | 0.65 ± 0.001 | 2.13 ± 0.001 |
| TACO | 290 | 4 | 1.7 | 2 |
| CA | 330 | 5.5 | - | 2.3 |
| Other sources | 395 Spain [23]; 325 Brazil [24] | 4.64 Brazil [24] | 2.8 China [18]; 3.13 Brazil [24] | 30.6 China [18]; 4.78 Brazil [24] |

[1]Brazilian Table of Food Composition [9]. [2]Table of Food Composition for Central America [10].

### Taro

In the case of magnesium, data obtained in this research show a level of concentration surprisingly lower than those for Brazil as a whole, Central America and Spain (80 mg/kg *vs* 290 – 395 mg/kg elsewhere). At the same time, the concentrations of iron, copper and zinc, although slightly lower, are comparable to Brazilian averages and Central American values. An excessive level of zinc in taro roots reported by Chinese researchers may be due to the fact that the vegetable was grown in the vicinity of the Dabaoshan mine operating with sphalerite (Zn, FeS and zinc had been leached from the ore.

The present research was not intended to evaluate the nutritional capacity of tubers consumed in Brazil. So, the data obtained here for biometal levels shows exclusively the population exposure to these minerals, concretely in Mato Grosso do Sul, Brazil, no assumptions made as to their real absorption or bioavailability.

## 4. CONCLUSION

The results indicate that most of the inorganic components analyzed occur at levels within the range reported from other sources or close to them. However, iron in common potato, sweet potato and cassava was at the lowest level, while magnesium was very low in taro samples. Thus, the metals studied cannot pose any serious health risks and the edible tuberous roots widely consumed in Mato Grosso do Sul may represent an important source of essential micronutrients. These results can serve as a contribution to the nutritional databases.

## 5. ACKNOWLEDMENTS

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