



## Significance of Mineral Bioavailability in Food Containing Antinutrients, *Tacca leontopetaloides* L. (Taccaceae) versus *Cochlospermum tinctorium* A. Rich (Bixaceae)

Collinlaw Joseph Ndouyang 

Department of Agricultural Engineering and de Food Security,  
University of Pala, Mine Road of Baore, BP 20 Pala, Chad

Tidjani Abdelsalam 

Department of Public health, Faculty of Sciences for Human Health,  
University of N'Djamena, BP 1117 N'Djamena, Chad

### Abstract

*Tacca leontopetaloides* (Taccaceae) and *Cochlospermum tinctorium* (Bixaceae) are herbaceous plants that are used as non-conventional food in period of famine. *T.leontopetaloides* tuber and *Cochlospermum tinctorium* root transformed into powder in order to evaluate bioavailability of essential minerals contained in these vegetable organs versus antinutrients. Current methods of chemical analysis were used in laboratory to determined mineral and antinutrients content, and statistical software used to plot discrimination between data. Results indicated differences between mineral and antinutrient contents in two herbaceous plants. Major antinutrients in tacca tubers are saponins ( $4.08 \pm 0.24\%$ ) and phytate ( $0.46 \pm 0.02\%$ ); but *C. tinctorium* contained an enormous amount of phenolic compounds equivalent gallic acid ( $4,46 \pm 0.12\%$ ) and phytate ( $0.62 \pm 0.07\%$ ). Only Ca and Mg were found bioavailable in tacca and in *C. tinctorium*. Mineral bioavailability depends on mineral content versus antinutrient one.

### Introduction

Food security is a major problem in sub-Saharan African countries. Chiefly, when climate changing occurs, people use many non-conventional plants to sustain life, avoiding disasters in poor households. *Tacca leontopetaloides* (Taccaceae) and *Cochlospermum tinctorium* (Bixaceae) are two under- utilized herbaceous plants that grow in wet tropical regions of Africa [1, 2]. In Chad, *T. leontopetaloides* and *C. tinctorium* used as food of replacement in case of unavailability of staple food. These herbaceous plants are also employed as medicinal [3]. Recently, many authors were interested in studying tubers and root respectively of *T. leontopetaloides* and *C. tinctorium*. According to Ndouyang *et al.* [4] and Zaku *et al.* [5] on the one hand, *T. leontopetaloides* is an important source de nutritive sugars constituted mainly of starch; but on the other hand, *C. tinctorium* root contains mainly carbohydrates from 59.3% to 76.8% [6] and ashes up to 7.8% [7]. These data show the importance of under-utilized plants during famine period.

However, before using *T. leontopetaloides* tubers and *C. tinctorium* root, prior operations are necessary. Raw *T. leontopetaloides* tuber is bitter [8] so it must be transformed into a flour made essentially of starch; and, raw *C. tinctorium* root contains high phenolic compounds content, i.e. antinutrients [7]. Research by many authors [9, 10, 11, 12] indicated ways of pretreatment of these vegetable organs before eating by humans. Pretreatments are soaking, leaching or boiling.

Litterature cite *Tacca* genus as a toxic one containing compounds which stop microbes developpment [8, 13, 14]. That is why taccalonolides are antimitotic [13, 15]. For example, *Tacca chantrieri* contains compounds called taccalonolids which are more oxygenated steroids that inhibit *mitosis* process or a process of cell duplication, or reproduction, installing the formation of thick microtubules net. Taccalonolids are a new class of vegetal compounds, which differ structurally and biologically from the others classes of microtubules stabilizers, e.g taxol. In this ways, taccalonolids are

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antinutrients, minerals, herbs, bioavailability.



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antimitotic and they induce cellular death by apoptosis [13, 15]

Meanwhile, *Cochlospermum* genus appear as a set of non-toxic vegetable species ([16, 17, 18, 19, 20]. Eating these vegetable organs is beneficial for humans. That is why food engineering for our environment is essential to preserve our life from disasters of any kind, leading to food insecurity. According to FAO in 2012 [21], food security is based on the quantity and quality. The present study aim at mineral bioavailability of *T. leontopetaloides* tuber & *C. tinctorium* root.

### Materials and Methods

The biological materials are tuber of *T. leontopetaloides* (L.) Kuntze (Taccaceae) and root of *C. tinctorium* A. Rich. (Bixaceae), two non-conventional plants. Their nutritive organs were harvested from Chad respectively at Binder (Mayo-Kebbi Western Region) where *T. leontopetaloides* is called « *Cii* » by Mundang and Tupuri people, and at Mindaore/Fianga (du Estern Mayo-Kebbi Region) where *C. tinctorium* is called « *Belyewn* » by Tupuri people. Tacca tubers and young *C. tinctorium* root. Samples were collected in a large bag and transported to Laboratory of Biophysic, Food Biochemistry and Nutrition of ENSAI/University of Ngaoundere within 48 hours after harvesting. In laboratory, tubers and roots were washed abundantly with tap water, and then grated. The powder of *T. leontopetaloides* was obtained from tacca tubers as described by Kunle *et al.* [11] and by Ndouyang *et al.* [22]. In addition, the inner matrix and the skin of *C. tinctorium* were used to produce powders. All the powders were kept at 4 °C for analysis.

Antinutrients and minerals in powder of *T. leontopetaloides* tubers and *C. tinctorium* root were determined according to documented methods. The following antinutrients: phenolic compounds, tanins, saponins, oxalates, phytates, cyanides were determined described by Ndouyang *et al.* [12]. Calcium, magnesium and zinc contents were determined by application of sequential extraction and the ICP-AES method for study of the partitioning of metals in fly ashes as reported by Smeda and Zyrnicki [23]. Briefly, the metal fractions were acid-soluble, reducible, and oxidisable. Metal concentrations (here the calcium content) in the extracts were measured by inductively coupled plasma atomic emission spectrometry (ICP-AES).

The iron content was evaluated by using the method of o-phenanthroline reported by Serra-Mora *et al.* [25]. The mass of iron, in milligrams, present in sample of food powder, was assessed by the reddishbrown color of ion complex. Iron determination in powders was performed by measuring the absorbance of the complex formed between this element and o-phenanthroline, after dry mineralization of the sample and treatment with HCl 2 M. Using a

spectrophotometer at 510 nm, the absorbance of the resulting reddishbrown solution was compared to previously prepared standards.

### Statistical analysis

Means and standard deviations ( $X \pm SD$ ) were calculated from individual values. One-way analysis of variance was tested to detect the effect of treatment on the antinutrients. The significance of an effect was observed for  $p < 0.05$ , and the Duncan multiple test range was used to compare two means. The software Statgraphics Plus 5.0 was used for the statistical analysis. Principal component analysis and Pearson correlation was done using the Statbox 6.4 statistical software (Paris, France).

### Results

#### Antinutritional factors of *T. leontopetaloides* and *C. tinctorium*

Antinutrients content of *T. leontopetaloides* (or tacca) and *C. tinctorium* are presented in Table 1 (Appendix). Statistical analysis revealed antinutritional factors content varying positively and significantly ( $p < 0.05$ ) according to each plant. *T. leontopetaloides* flour contains cyanide, oxalate, phytate and saponins that are major antinutritional factors. Nevertheless, starchy flour of *T. leontopetaloides* tuber was almost without antinutrients.

In *C. tinctorium* root flour, the major antinutritional factors in raw flour, on one hand, are total phenolic compounds, oxalate and phytate. In addition, on the other hand, flour obtained by soaking raspings inner matrix of *C. tinctorium* root, the level of leaching was 21.5% for total phenolic compounds. However, three (03) antinutrients have been concentrated during the operation of soaking of raspings of *C. tinctorium* root; i.e. oxalate (+30.34%), phytate (+74.20%) and cyanide (+110%) by chelating. Such reaction would have been prevented using technique of soaking with agitation, of bleaching or biomolecules. Then, the skin flour of *C. tinctorium* root contains more oxalate and phytate.

### Discussion

Globally, secondary metabolites of plants revealed accumulation by chelating between antinutrients, mainly oxalate, phytate, cyanide and other food constituents such as minerals, fibers, and lignine. Oxalate content of *T. leontopetaloides* tuber flour and *C. tinctorium* root flour are beyond the threshold of 0.78% [26]. Beyond these values, oxalates chelates calcium, leading to a deficient of  $Ca^{2+}$  during digestion; digestives enzymes necessitating ion  $Ca^{2+}$  are bioactivators [27]. Oxalates effects are frequently strengthened by phytate in food. Root and tubers are constantly consumed, phytate is 0.62 % manihot; 0.86% for taro and 0.64 % for yam [28], or in cereales (0.8% à 2.2%), rice (0.8 à 1.0%) ou sorghum (0.7 à 1.4%) [29] or consumer 0.1% à 6% de phytate [30].



In nutrition, antinutrients diminish the growth of young animals [22]. The imbalance due to soaking of *C. tinctorium* resulted from hydrosoluble soaked nutrients by reacting against chelated compounds. Furthermore, reaction by antinutrients involves also cyanide, which is toxic. The bitter manihot yields cyanide. The increase of cyanide content during *C. tinctorium* root soaking can be explained by negative charge of cyanide  $CN^-$ , which attracts molecules, or positive charge. Normally, 1 mg  $CN^-$  per 100g of food has negative effect on nutritional status.

The bitter taste of food is also linked to saponins which have toxic effects at high level (3 à 7%) and irritate mucuous membrane. However, tubers of *D. alata*, *D. esculenta* and *X. sagittifolium* have high saponins level from 12,98±0,61 to 20,01±0,26 mg/100g [30]; they are viewed as nontoxic. Saponins in tacca (4.1%) are hydrosoluble [4]. Soaking of tacca tuber reduce cyanide and saponins. Recently, researchers demonstrated that phenolic compounds are reductibles by soaking up to 8.5% phenols and 19.0% tanins in *Caryocar brasiliense* Camb. [31]. In tacca tuber, molecule of taccaline, a bitter and hydrosoluble flavonoid, was revealed [32]. Hydrosoluble character of this molecule constitute a key for reducing bitterness of this tuber powder. However, for *C. tinctorium*, according to Diallo [33], the

taste of the plant is due to gallic and ellagic acids, ellagitannins, flavonoids, who are responsible of astringent et low bitter taste.

Briefly, the present research exhibited a high antinutrient content tacca tuber and *C. tinctorium* root. The effects of such antinutrients on the nutritional quality of these powders cannot be ignored, chiefly when considering the divalent metal chelators, e.g phytate and oxalate. For a good utilization of these divalent metals by animal body, their bioavailability must be assured in any way. However, usual threshold values of antinutrients admitted for foods are listed below (Table 2). Therefore, by soaking or cooking, else by the both, antinutrients in foods can be reduced or eliminated and induce food safety. Otherwise, antiutrients are chemically linked between them (Table 3). These compounds create, on one hand, acute nutritional disasters ou crisis such as anemia, trouble of growth, respiratory problems in young and adult animals; and on the other hand, they are used in the treatment of diarrhea, dyslipidemia, parasitoids by tacca [22], or jaundice, free radicals, hyperlipidemia [19, 20]; and Ndouyang et al. [4] explain how *C. tinctorium* protect liver from damage by secondary metabolites [34].

**Table 2: Threshold of Some Antinutrients in Foods**

| Antinutrients      | Threshold (mg/100g) | References |
|--------------------|---------------------|------------|
| Phenolic compounds | 2700                | [35]       |
| Tanins             | 2000                | [35]       |
| Saponins           | 1000                | [36]       |
| Oxalate            | 780                 | [27]       |
| Phytate            | 30-100              | [37]       |
| Cyanide            | 1                   | [38]       |

**Table 3: Correlation between antinutrients of raw flour of *T. leontopetaloides***

| Variables          | Oxalate      | Phytate      | Phenolic compounds | Tanins       | Cyanide  | Saponins |
|--------------------|--------------|--------------|--------------------|--------------|----------|----------|
| Oxalate            | <b>1</b>     |              |                    |              |          |          |
| Phytate            | 0.986        | <b>1</b>     |                    |              |          |          |
| Phenolic compounds | <b>0.999</b> | 0.992        | <b>1</b>           |              |          |          |
| Tanins             | 0.973        | <b>0.998</b> | 0.981              | <b>1</b>     |          |          |
| Cyanide            | <b>1.000</b> | 0.986        | <b>0.999</b>       | 0.973        | <b>1</b> |          |
| Saponins           | 0.987        | <b>1.000</b> | 0.992              | <b>0.998</b> | 0.987    | <b>1</b> |

**Note:** Values of r that are in bold are significant at  $p < 0,05$ ;  $n=3$ .

#### Bioavailability of minerals versus antinutrients

The bioavailability of divalent ions ( $Ca^{2+}$ ,  $Mg^{2+}$ ,  $Fe^{2+}$  and  $Zn^{2+}$ ) is presented in table 4. Study revealed  $[Oxalate]/[Ca]$  and  $[Oxalate]/[(Ca+Mg)]$  ratios are below critical level of 2.5. In the same way,  $[Phytate]/[Ca]$  ratio which is below critical level of 0.5. Over this value, bioavailability of calcium is affected in tacca or *C. tinctorium*. However,  $[Phytate]/[Fe]$ ,  $[Ca][Phytate]/[Zn]$  and  $[Phytate]/[Zn]$  ratios were

respectively higher than critical level in *C. tinctorium*. These data indicate that phytate content is higher in *C. tinctorium* showing the bioavailability of ion and zinc affected [39, 40, 41]. These ratios are efficient tools used to predict bioavailability of minerals. By this research, calcium Ca and magnésium Mg are bioavailable in tacca and *C. tinctorium* powders, but ion and zinc are not. Lack of ion bioavailability in food can lead to anemia, suggesting the use of variation in food



intake. Finally, if minerals content is higher, minerals are bioavailable versus antinutrients.

**Table 4: Mineral Bioavailability According to Antinutriments/Minerals**

| Antnutrients/minerals               | Tacca flour |               | <i>C. tinctorium</i> root flour |            | Threshold value<br>[40, 41] |
|-------------------------------------|-------------|---------------|---------------------------------|------------|-----------------------------|
|                                     | Raw flour   | Starchy flour | Inner matrix flour              | Skin flour |                             |
| [Oxalate]/[Ca] <sup>1</sup>         | 4.74        | 0.72          | 0.36                            | 0.39       | 2.5                         |
| [Oxalate]/ ([Ca]+[Mg]) <sup>2</sup> | 2.18        | Nd            | 0.43                            | 1.05       | 2.5                         |
| [Phytate]/[Ca] <sup>3</sup>         | 0.33        | 0.33          | 0.04                            | 0.10       | 0.5                         |
| [Phytate]/[Fe] <sup>4</sup>         | 20.16       | Nd            | 252.28                          | 1080.30    | 1.0                         |
| [Ca][Phytate]/[Zn] <sup>5</sup>     | 0.06        | Nd            | 1.16                            | 104.77     | 0.5                         |
| [Phytate]/[Zn] <sup>6</sup>         | 28.36       | Nd            | 45.38                           | 2642.83    | 15                          |

**Note:** \*Nd=Not detected. <sup>1</sup>(mg oxalate/MW of oxalate : mg Ca/MW of Ca); <sup>2</sup>(mg oxalate/MW of oxalate : mg (Ca+Mg)/(MW of Ca+ MW of Mg); <sup>3</sup>(mg phytate/ MW of phytate : mg Ca/MW of Ca); <sup>4</sup>(mg phytate/MW of phytate : mg Fe/MW of Fe); <sup>5</sup>(mol/Kg of phytate × mol/Kg of Ca : mol/Kg of Zn); and <sup>6</sup>(mg phytate/MW of phytate : mg Zn/MW of Zn).

### Conclusion

Bioavailability of divalent ions (Ca<sup>2+</sup>, Mg<sup>2+</sup>, Fe<sup>2+</sup>, Zn<sup>2+</sup>) in food with antinutrients is according to antinutrients content. Therefore, at higher minerals content, mineral bioavailability increases versus antinutrients. Furthermore, we need purchasing research to develop such understanding of interaction between minerals and antinutrients.

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### Availability of data and materials

All data will be made available on request according to the journal policy.

### Conflicts of interest

The authors declare no conflict of interest.

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## Appendix

**Table 1: Minerals and antinutrients content of *T. leontopetaloides* and *C. tinctorium* (mg/100g.DW)**

|                    | <i>Tacca leontopetaloides</i> |                         | <i>Cochlospermum tinctorium</i> |                             |                            |
|--------------------|-------------------------------|-------------------------|---------------------------------|-----------------------------|----------------------------|
| Antinutrients      | Raw powder                    | Extracted powder        | Raw powder                      | Extracted powder            | Powder of skin             |
| Phenolic compounds | 419.26±14.34 <sup>b</sup>     | 9.13±1.30 <sup>a</sup>  | 4458.63±122.44 <sup>e</sup>     | 3499.90±43.36 <sup>d</sup>  | 2487.52±82.23 <sup>c</sup> |
| Tanins             | 355.19±7.21 <sup>ab</sup>     | 6.29±0.59 <sup>a</sup>  | 3400.33±98.10 <sup>d</sup>      | 2076.75±101.35 <sup>c</sup> | 1433.36±90.95 <sup>b</sup> |
| Saponins           | 4081.19±237.39 <sup>b</sup>   | 67.90±6.17 <sup>a</sup> | Nd*                             | Nd*                         | Nd*                        |
| Oxalate            | 870.00±16.20 <sup>c</sup>     | 16.21±1.56 <sup>a</sup> | 799.81±18.47 <sup>b</sup>       | 1043.42±17.72 <sup>d</sup>  | 1365.34±17.92 <sup>e</sup> |
| Phytate            | 457.97±18.41 <sup>b</sup>     | 55.68±3.48 <sup>a</sup> | 622.84±76.67 <sup>c</sup>       | 1084.96±18.40 <sup>d</sup>  | 2667.08±29.0 <sup>e</sup>  |
| Cyanide            | 1.59±0.02 <sup>c</sup>        | 0.17±0.03 <sup>a</sup>  | 0.31±0.03 <sup>a</sup>          | 0.65±0.06 <sup>b</sup>      | 0.72±0.03 <sup>b</sup>     |
| <b>Minerals</b>    |                               |                         |                                 |                             |                            |
| Calcium            | 83.65±2.26 <sup>c</sup>       | 10.19±0.68 <sup>a</sup> | 1025.92±6.69 <sup>a</sup>       | Nd*                         | 1589.71±1.12 <sup>b</sup>  |
| Iron               | 1.38 ± 0.3                    | Nd*                     | 0.15±0.02 <sup>a</sup>          | Nd*                         | 0.15±0.02 <sup>a</sup>     |
| Mg                 | 56.80±0.63 <sup>c</sup>       | 8.34±0.04 <sup>a</sup>  | 398.5±1.74 <sup>a</sup>         | Nd*                         | 697.23±1.70 <sup>b</sup>   |
| Zn                 | 1.60±0.5 <sup>c</sup>         | Nd*                     | 1.36±0.04 <sup>b</sup>          | Nd*                         | 0.10±0.03 <sup>a</sup>     |

**Note:** The mean values on a line with different letters in exponent are significantly different in Duncan test ( $\alpha=0,05$ ;  $p<0,01$ ). \*Nd = not detected. The results are mean ± standard deviation; n=3.

