



Characterization of leaves used in infusion preparation grown in northeastern Brazil by chemometric methods based on their multi-elemental composition

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Abstract

In many places of the world, medicinal plants represent the only form of treatment for various diseases. This work aimed to determine and correlate minerals of infusions and leaves of medicinal plants grown in Northeastern Brazil. Principal component and hierarchical cluster analysis and Pearson correlation were performed. The higher content of Na was for *Ocimum basilicum* L. (94.3 mg/100g) and *Datura stramonium* L. (91.6 mg/100g). The plants examined had low levels of K in infusions. All samples contain Mg at significant levels. The cluster analysis divided the medicinal plants into three groups, associated with *Passiflora edulis*, *Capraria biflora* and *Phyllanthus amarus*. Ca and Al were the minerals that contributed most to an association between the plants in principal component 1; while K, Na and Mg contributed most in principal component 2. Furthermore, the high percentage of extraction, mainly Ca and Mg, suggests these plants could be used as potential mineral supplements.

Keywords: clusters; infusion; minerals contents; multivariate analysis.

Practical Application: The higher content of K over Na (4-8 times) makes these plants from Northeastern Brazil aids in controlling blood pressure. Same plants leaves from Northeastern Brazil have high content of Ca or high levels of Fe, Mn and Zn, can be recommended as a potential supplement of this mineral.

1 Introduction

Interest has been shown in research related to studies of the mineral composition of medicinal plants, given the importance that minerals have in the proper functioning of the human body (Gezgin et al., 2006).

The functional role of trace elements is described in terms of their nutritionally essential role or their potential toxicity. Such a distinction is not absolute, since several elements are in categories, depending upon the dosage, route of administration and the form of the chemical species. Likewise, the excess or absence of minerals has important consequences for the organism (Jyothi et al., 2003).

For most of the world's population, medicinal plants are the only means of treatment in curing various diseases. Almost 80% of people in marginal communities rely on medicinal plants for treatment of their various diseases (Agra et al., 2007). However, the safe use of herbs has not yet been fully established. Sometimes allergic and toxic reactions occur, as well as drug interactions. Some herbs could be hepatotoxic (Stickel et al., 2005). Such a high dependency on medicinal plants or their herbal formulations means it is important to analyze their metal composition. Since various medicinal plant species are also used as food along with

their medicinal benefits, evaluating their metal content can help to understand the suitability of these plants species.

It has been reported that trace elements play a vital role in the formation of the active chemical constituents present in medicinal plants and are therefore responsible for their medicinal as well as toxic properties (Gjorgieva et al., 2010). However, a direct correlation between the elemental composition of the medicinal plants and their curative properties has not yet been established. Therefore, the quantitative estimation of various minor and trace element concentration is important for determining the effectiveness of medicinal plants in treating various diseases and to understand their pharmacological action (Nomita Devi & Nandakumar Sarma, 2010). The mineral contents of some herbal teas have been determined in several previous publications. These studies have usually used univariate methods such as analysis of variance, i.e., comparing the concentration of one element with another or one sample with another. However, multivariate methods can provide further interpretation (Kara, 2009). The two best known multivariate analysis techniques are hierarchical cluster analysis (HCA) and principal component analysis (PCA) (Moreda-Pineiro et al., 2003; Fernández-Cáceres et al., 2001).

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The aims of this paper are 1) to determine the content of Na, K, Ca, Mg, Fe, Al, Mn and Zn in mineralized samples and of (Na, K, Ca, Mg) in infusions of medicinal plants grown in Northeastern Brazil; 2) to evaluate the correlation between minerals of mineralized samples and infusions; 3) to use multivariate analysis (PCA and HCA), to assess whether there is a relationship between the mineral content of the analyzed plants and other plants from previous works.

2 Materials and methods

2.1 Plant material

The medicinal plant species used in the study were collected from the Medicinal Plants Garden Prof. Francisco de Abreu Matos, Universidade Federal do Ceará and authenticated at the Prisco Beserra Herbarium at the same University, where a voucher specimen of each plant species is deposited. The leaves were washed with deionized water and then shredded, air dried for 12 hours and subjected to acid digestion, and, for obtaining teas, extraction with boiling water.

2.2 Sample collection and digestion

Plant leaves (10 g) were placed in a pre-cleaned silica crucible and heated over a flame for about 10 minutes to remove moisture and volatile matter. Then the crucible was heated to a high temperature in a muffle furnace at 600°C for about 10-12 hours which converted the samples into ash. The ash was dissolved in concentrated HCl 1:1 (v / v) by gradually adding the acid. The clear solution obtained was filtered, and then the total volume was made 100 mL and was used for the analysis.

Teas were obtained by weighing 2.0 g of a sample from plant species which was added into boiled ultrapure water (50 mL) in a clean glass for 10 minutes. Aqueous extracts were filtered through filter paper and collected in flasks of 100 mL and the volume was made up with ultrapure water (Almeida et al., 2002).

2.3 Instrumentation

A Flame Atomic Absorption Spectrometry (ATOMICA-GBC 933 PLUS) to analyze Mn, Zn, Fe, Ca and Mg in mineralized samples and tea, was calibrated in terms of specific wavelength, and a mixture of gases for each element. Molecular Absorption Spectrometry (UV-visible, Micronal, model B582) for Al and

Fe, and Flame Photometry (Analyser, 910M) for Na and K. The experimental conditions of analysis are described in Table 1.

All experiments were done in triplicate, and the data were reported as mean \pm SD in mg/100 g for mineralized samples.

2.4 Statistical analysis

Mineral data were also treated by the Pearson correlation test, Principal Component Analysis (PCA) using the Pearson's correlation coefficient method (normed-PCA, variance with 1/n) and Cluster analysis, the similarities were calculated based on the squared Pearson correlation using unweighted pair-group average method (Everitt & Dunn, 2001), and the Ward hierarchical agglomerative method was used to establish clusters (Ward, 1963). Pearson correlation, Cluster, and PC analysis were performed using the software program XLSTAT (2017) (Addinsoft, New York, USA), version 2017.2.

3 Results and discussion

The higher concentrations of sodium in the investigated leaf samples were observed for *Ocimum basilicum* (94.3 mg/100 g) and *Datura stramonium* (91.6 mg/100 g). However, it was found that the infusions had low sodium levels, and the maximum extracted from the raw material was 7.93% from *Acmella uliginosa*. Infusions of *Passiflora edulis*, showed the highest level of extraction for Na (29.3%) (Table 2).

Sodium acts in combination with potassium, the principal cation of intracellular fluid, to maintain proper body water distribution and blood pressure. This element is also important in maintaining the proper acid-base balance and in the transmission of nerve impulses (Alam et al., 2007). In general, the plants examined had low levels of potassium in infusions. However, these percentages were above those found for sodium, which guarantees a ratio Na/K below the unit. The Na/K ratio is important in determining the health status of an individual. A ratio of less than one has been recommended to prevent high blood pressure (Institute of Medicine, 2005). Research on the control of immune response by calcium ions suggests that Ca^{2+} controls the mechanisms involved in antibody formation by an antagonistic action on cell proliferation and cell differentiation (Diamantstein & Odenwald, 1974). Walleczek (1992) reviewed the roles of Ca^{2+} in the immune system including the regulation of leukocytes and lymphocytes. *Senna alata*, *M. pulegium* and

Table 1. Operating conditions used in analytical methods for the determination of minerals.

Element	Technical	λ_{nm}	Linear range (mg.L ⁻¹)	References
Na	FP	589.0	-	Association of Official Analytical Chemists (2005)
K	FP	766.5	-	Association of Official Analytical Chemists (2005)
Ca	FAAS	422.7	1.0-5.0	Welz (1999)
Mg	FAAS	285.2	0.1-0.5	Welz (1999)
Fe	FAAS	248.3	1.0-5.0	Christian (2003)
Al	MAS	525.0	0.2-2.0	Association of Official Analytical Chemists (2005)
Mn	FAAS	279.5	1.0-5.0	Welz (1999)
Zn	FAAS	213.9	0.1-0.4	Welz (1999)

FAAS = Flame Atomic Absorption Spectrometry; MAS = Molecular Absorption Spectrometry; FP = Flame Photometr.

Table 2. Macro mineral levels in raw material and infusions of leaves of medicinal plants (mean \pm sd) and literature data.

Scientific Names	Macrominerals							
	Na		K		Ca		Mg	
	Raw material (mg/100g)	Infusion (% of total amount)	Raw material (mg/100g)	Infusion (% of total amount)	Raw material (mg/100g)	Infusion (% of total amount)	Raw material (mg/100g)	Infusion (% of total amount)
<i>Acmella uliginosa</i> (Sw.) Cass.	17.2 \pm 0.2	7.9	44.6 \pm 0.6	12.4	172 \pm 2	4.7	46 \pm 1	69.8
<i>Capraria biflora</i> L.	51.5 \pm 0.8	1.9	225.2 \pm 0.6	3.5	113 \pm 1	3.3	199 \pm 2	38.4
<i>Symphytum officinale</i> L.	28.6 \pm 0.6	1.5	256.3 \pm 0.6	3.9	229 \pm 1	17.5	87 \pm 0	20.8
<i>Kalanchoe brasiliensis</i> Camb.	37.1 \pm 0.1	1.3	87.0 \pm 0.5	5.7	127 \pm 1	3.1	139 \pm 1	24.4
<i>Mikania glomerata</i> Spreng.	24.9 \pm 0.1	2.0	144.6 \pm 0.5	4.3	297 \pm 0	2.2	159 \pm 1	27.1
<i>Nerium oleander</i> L.	57.3 \pm 1.1	2.8	470.9 \pm 1.1	2.6	224 \pm 0	9.5	28 \pm 0	35.5
<i>Ocimum basilicum</i> L.	94.3 \pm 0.7	1.1	203.5 \pm 0.5	6.9	305 \pm 1	41.0	65 \pm 1	77.2
<i>Senna alata</i> Irw. Et Barn	53.6 \pm 0.5	1.0	118.2 \pm 0.8	7.7	1326 \pm 29	6.6	119 \pm 1	20.1
<i>Mentha pulegium</i> L.	88.4 \pm 0.8	6.5	181.6 \pm 0.5	5.6	943 \pm 1	8.6	107 \pm 1	93.9
<i>Datura stramonium</i> L. var. <i>tatula</i> Moor	91.6 \pm 0.5	4.8	171.9 \pm 0.1	6.4	1035 \pm 1	7.2	297 \pm 0	37.8
<i>Lippia sidoides</i> Cham.	87.9 \pm 0.5	1.0	331.4 \pm 2.4	1.2	577 \pm 1	4.6	271 \pm 1	7.2
<i>Psidium guajava</i> L. var. <i>pomifera</i> L.	64.9 \pm 0.1	10.9	230.5 \pm 1.3	3.1	551 \pm 1	2.5	178 \pm 0	5.3
<i>Passiflora edulis</i> Sims.	50.3 \pm 0.3	29.3	172.3 \pm 1.5	17.3	652 \pm 2	10.0	89 \pm 1	12.7
<i>Brassica integrifolia</i> O. E. Schulz	62.5 \pm 0.5	2.2	479.8 \pm 2.7	0.2	462 \pm 2	53.6	181 \pm 1	20.1
<i>Cecropia adenopus</i> Mart.	45.1 \pm 0.4	20.4	183.4 \pm 0.9	15.4	543 \pm 0	9.9	207 \pm 0	12.1
<i>Ocimum gratissimum</i> L.	59.5 \pm 0.7	0.3	181.8 \pm 1.1	3.3	742 \pm 2	12.0	58 \pm 1	67.9
<i>Spondias aff. Tuberosa</i>	57.6 \pm 0.6	0.6	123.7 \pm 0.7	3.3	679 \pm 2	42.8	56 \pm 0	50.1
<i>Eucalyptus tereticornis</i> Smith	104.6 \pm 0.6	0.4	83.6 \pm 0.6	2.4	636 \pm 1	2.2	197 \pm 0	12.4
<i>Phyllanthus amarus</i> Schumet Thorn	104.1 \pm 0.6	1.9	390.5 \pm 1.0	1.8	245 \pm 0	30.4	178 \pm 1	20.3
<i>Sambucus australis</i> Chem. And Schelecht	80.5 \pm 0.7	0.2	254.9 \pm 0.8	1.2	174 \pm 1	21.7	261 \pm 1	13.1
<i>Justicia pectoralis</i> Jacq.	3.7 \pm 0.1	2.2	40.0 \pm 0.7	21.6	941 \pm 18	17.2	156 \pm 3	47.6
<i>Cymbopogon citratus</i> Stapf.	32.0 \pm 0.5	0.2	212.0 \pm 4.0	9.9	278 \pm 5	92.6	90 \pm 2	62.5
<i>Lippia alba</i> Mill.	40.0 \pm 0.6	0.2	248.0 \pm 5.0	7.8	1388 \pm 25	11.9	170 \pm 3	26.5
<i>Alpinia speciosa</i> Schum.	24.0 \pm 0.4	6.7	88.0 \pm 1.2	10.1	159 \pm 3	6.9	37 \pm 1	59.4
<i>Costus aff. discolor</i> Roscoe	30.0 \pm 0.6	0.0	82.0 \pm 1.0	6.1	134 \pm 2	0.0	42 \pm 1	78.6
<i>Mentha villosa</i> Huds	82.0 \pm 1.1	0.0	267.6 \pm 6.0	5.1	207 \pm 4	88.8	108 \pm 2	77.6
<i>Plectranthus barbatus</i> Andr.	19.8 \pm 0.4	0.0	12.1 \pm 0.2	51.8	409 \pm 8	29.6	132 \pm 2	35.8
<i>Plectranthus amboinicus</i> (Lour.) Spreng.	24.0 \pm 0.4	0.0	72.0 \pm 1.4	15.6	344 \pm 6	57.8	81 \pm 1	42.3
<i>Ageratum conyzoides</i>	24.0 \pm 0.3	0.0	74.0 \pm 1.3	6.8	854 \pm 16	37.0	244 \pm 5	45.1

D. stramonium showed high amounts of calcium, with levels of 1326, 1035 and 943 mg/100 g, respectively. These plants are used for diseases directly related to the immune system, such as herpes, influenza, and inflammatory diseases. Therefore, the high content of calcium found could be useful for these illnesses.

All herbs analyzed contain significant levels of magnesium, with the percentage of extraction in infusions ranging from 20.8 to 93.9%. The highest concentrations of magnesium were found in the leaves of *Capraria biflora* (199 mg/100 g), *Mikania glomerata* (159 mg/100 g) and *Datura stramonium* (297 mg/100 g), plants used in folk medicine as an anti-inflammatory. Studies have shown that oral Mg supplementation to heart failure patients significantly reduces blood levels of C-reactive protein, a biomarker of inflammation (Almoznino-Sarafian et al., 2007).

Considering the size of the sample used (2 g), it was found that the macro minerals extracted in infusions do not meet the daily needs of all elements investigated; nevertheless, some of these species may be important as food supplements. According to dietary reference intakes - DRI for selected minerals (Institute

of Medicine, 1997, 2004) the following medicinal plants are good sources: *Mentha pulegium* (Ca: 943 mg/100 g), *Nerium oleander* (K: 470.9 mg/100 g), *Datura stramonium* (Mg: 297 mg/100 g).

Trace elements such as manganese, iron, and zinc are essential in enzyme metabolism. The concentrations of these elements in the plants are quite important. *M. pulegium* is used in folk medicine to treat diarrhea. Manganese contents in this plant (4.73 mg/100 g) represent the highest concentration of this element in the samples investigated in this study, which is lower than other previously studied plants, for example, *Eucalyptus tereticornis* (14.03 mg/100 g), as can be seen in Table 3. Mn activates several important enzyme systems and in this capacity is required for the synthesis of acid mucopolysaccharides, used to control diarrhea (Verschoor & Christensen, 1990).

Zn plays a vital role in protein synthesis and digestion (Soetan et al., 2010). *M. pulegium* showed abundant levels of zinc (13.55 mg/100 g). This could explain the widespread use of the plant in popular medicine for illnesses associated with the digestive tract.

Iron is an essential nutrient required for the well functioning of the brain and other parts of the body. Metal deficiencies and imbalances are known to be involved in disorders of the cardiovascular system, gastrointestinal, muscular, skeletal, neurological, immune and endocrine systems (Chandrachood et al., 2009). Research has revealed that iron deficiency, which may be a common occurrence in chronic obstructive airways disease, is at least a contributory factor in the production of abnormal red cell indices in such patients (Child et al., 1973). The highest levels of iron were found in *Acmella uliginosa*, *Ocimum basilicum*, *Mentha pulegium* and *Mikania glomerata* which are species used in folk medicine to aid respiratory diseases, in addition to others, such as stomach ache, influenza, infant colic and influenza, as well as being anti-rheumatic and anti-inflammatory (Agra et al., 2008; Ong et al., 2011).

Aluminum concentration ranged between 1.64 and 12.43 mg/100 g in the herbal samples investigated. These values are lower than those reported by Basgel and Erdemoglu (2006) which showed levels ranging from 8.7 to 59.6 mg/100 g. *Capraria biflora* showed the highest content of this element and should, therefore, be used sparingly.

In relation to all micro-nutrients, it should be emphasized that *M. pulegium* showed elevated levels of iron (7.89 mg/100g), manganese (4.73 mg/100 g) and zinc (13.55 mg/100 g) when compared with previously studied plants (Table 3) and dietary reference intakes for selected minerals (Institute of Medicine, 2001).

The positive and negative correlation coefficients (r) indicate positive and negative correlations, respectively, between two elements. When r is close to 1.0, the two variables are more similar and when r is close to 0 there is no relation between the variables (Kolasani et al., 2011). A small number of significant correlations ($P \leq 0.05$) between the total contents of elements were observed, which are between the Na and K (0.50); Na and Mn (0.47), as well as Ca and Al (0.55), and Fe and Zn (0.61). Negative correlations were also observed, although these were not significant ($P > 0.05$). Similarities between some correlations were observed in the study of Kolasani et al. (2011) with Chinese medicinal herbs, where only the values of r greater than 0.5 were taken into consideration. Few studies on the correlation of minerals in medicinal plants are available in the literature.

Table 3. Micro minerals contents in leaf herbal (mean \pm sd) and literature data.

Scientific Name	Micro mineral (mg/100g)			
	Fe	Al	Mn	Zn
<i>Acmella uliginosa</i> (Sw.) Cass.	3.83 \pm 0.01	NP	0.24 \pm 0.02	0.05 \pm 0.01
<i>Capraria biflora</i> L.	0.25 \pm 0.02	12.43 \pm 0.49	0.12 \pm 0.01	0.05 \pm 0.02
<i>Symphytum officinale</i> L.	0.53 \pm 0.02	3.07 \pm 0.15	0.24 \pm 0.02	0.48 \pm 0.01
<i>Kalanchoe brasiliensis</i> Camb.	1.25 \pm 0.03	1.64 \pm 0.05	0.04 \pm 0.01	0.03 \pm 0.01
<i>Mikania glomerata</i> Spreng.	4.53 \pm 0.28	5.59 \pm 0.52	0.49 \pm 0.02	0.26 \pm 0.02
<i>Nerium oleander</i> L.	0.76 \pm 0.01	NP	0.20 \pm 0.01	NP
<i>Ocimum basilicum</i> L.	5.75 \pm 0.23	NP	NP	NP
<i>Senna alata</i> Irw. Et Barn	NP	NP	0.10 \pm 0.02	NP
<i>Mentha pulegium</i> L.	7.89 \pm 0.02	NP	4.73 \pm 0.14	13.55 \pm 0.49
<i>Datura stramonium</i> L. var. <i>tatula</i> Moor	NP	NP	NP	NP
<i>Lippia sidoides</i> Cham.	3.24 \pm 0.24	4.66 \pm 0.13	0.22 \pm 0.02	0.81 \pm 0.03
<i>Psidium guajava</i> L. var. <i>pomifera</i> L.	0.24 \pm 0.01	1.16 \pm 0.03	0.45 \pm 0.01	0.66 \pm 0.01
<i>Passiflora edulis</i> Sims.	0.65 \pm 0.01	1.25 \pm 0.02	0.60 \pm 0.02	0.74 \pm 0.02
<i>Brassica integrifolia</i> O. E. Schulz	2.05 \pm 0.07	2.89 \pm 0.20	0.05 \pm 0.01	0.68 \pm 0.02
<i>Cecropia adenopus</i> Mart.	0.69 \pm 0.01	2.55 \pm 0.01	0.05 \pm 0.01	0.34 \pm 0.02
<i>Ocimum gratissimum</i> L.	3.18 \pm 0.19	NP	6.82 \pm 0.04	0.21 \pm 0.01
<i>Spondias aff. Tuberosa</i>	NP	2.21 \pm 0.15	0.65 \pm 0.01	0.72 \pm 0.02
<i>Eucalipitus tereticornis</i> Smith	1.80 \pm 0.02	NP	14.03 \pm 0.35	0.34 \pm 0.01
<i>Phyllanthus amarus</i> Schumet Thorn	NP	NP	2.42 \pm 0.03	0.17 \pm 0.01
<i>Sambucus australis</i> Chem. and Schelecht	0.28 \pm 0.01	NP	0.24 \pm 0.01	0.05 \pm 0.01
<i>Justicia pectoralis</i> Jacq.	*ND	33.20 \pm 0.60	0.27 \pm 0.01	0.50 \pm 0.01
<i>Cymbopogon citratus</i> Stapf.	0.03 \pm 0.021	3.17 \pm 0.07	0.04 \pm 0.01	0.04 \pm 0.01
<i>Lippia alba</i> Mill.	0.13 \pm 0.01	47.9 \pm 0.10	0.30 \pm 0.01	0.34 \pm 0.01
<i>Alpinia speciosa</i> Schum.	0.15 \pm 0.00	2.92 \pm 0.05	1.13 \pm 0.02	0.28 \pm 0.01
<i>Costus aff. discolor</i> Roscoe	2.15 \pm 0.04	3.76 \pm 0.07	0.09 \pm 0.00	0.02 \pm 0.00
<i>Mentha villosa</i> Huds	0.24 \pm 0.01	3.36 \pm 0.06	0.16 \pm 0.03	0.40 \pm 0.01
<i>Plectranthus barbatus</i> Andr.	*ND	2.79 \pm 0.05	0.10 \pm 0.02	0.03 \pm 0.00
<i>Plectranthus amboinicus</i> (Lour.) Spreng.	0.38 \pm 0.01	**ND	0.15 \pm 0.00	0.07 \pm 0.00
<i>Ageratum conyzoides</i> L.	3.47 \pm 0.07	11.68 \pm 0.21	0.23 \pm 0.00	0.19 \pm 0.00

*ND: Not detectable (<0.02 mg/100 g); ** ND: Not detectable (<0.06 mg/100 g). NP-Analysis not performed.

The correlation study on the potential for mineral extraction in the herbal infusions evaluated did not show any consistent behavior for all samples. Only the minerals K (0.52) and Mg (0.56) showed significant correlations, but with low values.

The Hierarchical Cluster Analysis has the objective of incorporating, according to some criteria of classification, a body of t sample units (treatment, progenitors, individuals etc) in groups through the evaluation of p variables in such a way that homogeneity occurs inside each group and heterogeneity between them (Johnson & Wichern, 1998). The process of grouping involves basically two steps. The first is related to an estimation of one measure of similarity between the treatments, and the second with the adoption of a technique of grouping for the group formation. In this study, Ward's method of the cluster was applied with the square Euclidean distance measuring. Three groups were obtained (Figure 1). These results, when visualized through diagrams known as dendrograms indicate similarity between samples, in such a way that a minor distance between points

indicates larger similarity between them. The cluster analysis divided the medicinal plants into three groups: *Passiflora edulis*, *Capraria biflora* and *Phyllanthus amarus* associated with the clusters 1, 2 and 3, respectively. The other medicinal plants were associated with each one of these clusters.

The first dimension (PC1) separated two groups, one with 13 plants on the right side, and the other with 16 plants on the left side (Figure 2B). The highest Ca contents were observed in samples *Lippia alba* (1388 mg/100g) and *Senna alata* (1326 mg/100 g). It can be clearly observed that these samples are separated from the remaining ones by the first dimension (PC1) and are in the opposite direction from all samples (Figure 2).

A greater homogeneity of the samples in PC2 was verified, with many samples close to the central point, which explains the low data variability in PC2 (9.77%). *Brassica integrifolia*, *Nerium Oleander*, *Phyllanthus amarus* and *Lippia sidoides* had a higher content of K than other samples and hence appear more dispersed in the score loadings in PC2 (Figure 2).

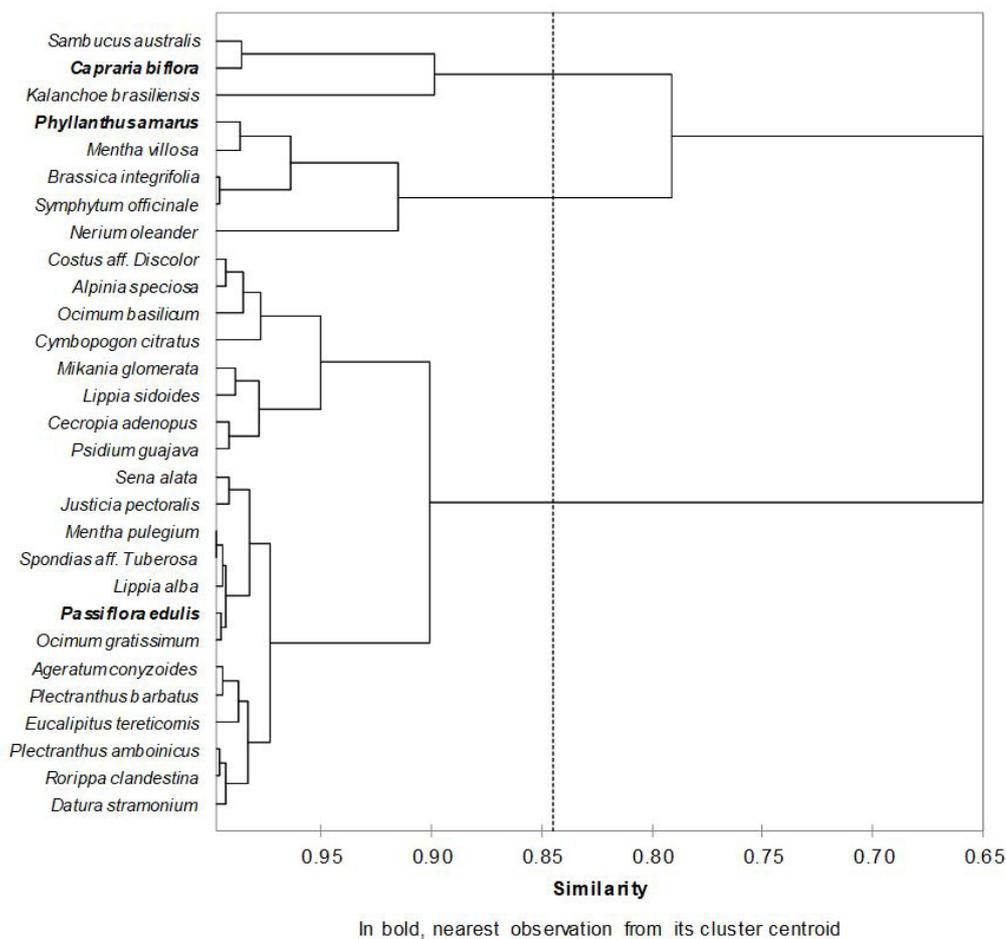


Figure 1. Dendrogram of hierarchical cluster analysis for the medicinal plants of Northeast Principal component analysis is a technique for reducing the number of variables by finding a linear combination of variables that explains the variance in the original variables. Principal Component Analyses (PCA) highlights the relationship between minerals (Kara, 2009; Kolasani et al., 2011; Oliveira et al., 2014). PCA produces a multidimensional space represented by dimensions which explain the total variation among the samples. In this study, only the first and second dimensions were used, that together explained 96.33% of the data variability. Figure 2 show the bi-plot graphic, where the scores of total mineral contents are represented by vectors and the clusters loadings represented by points. The loadings indicate the association between the minerals. The minerals with bigger loadings affect the separation of the samples.

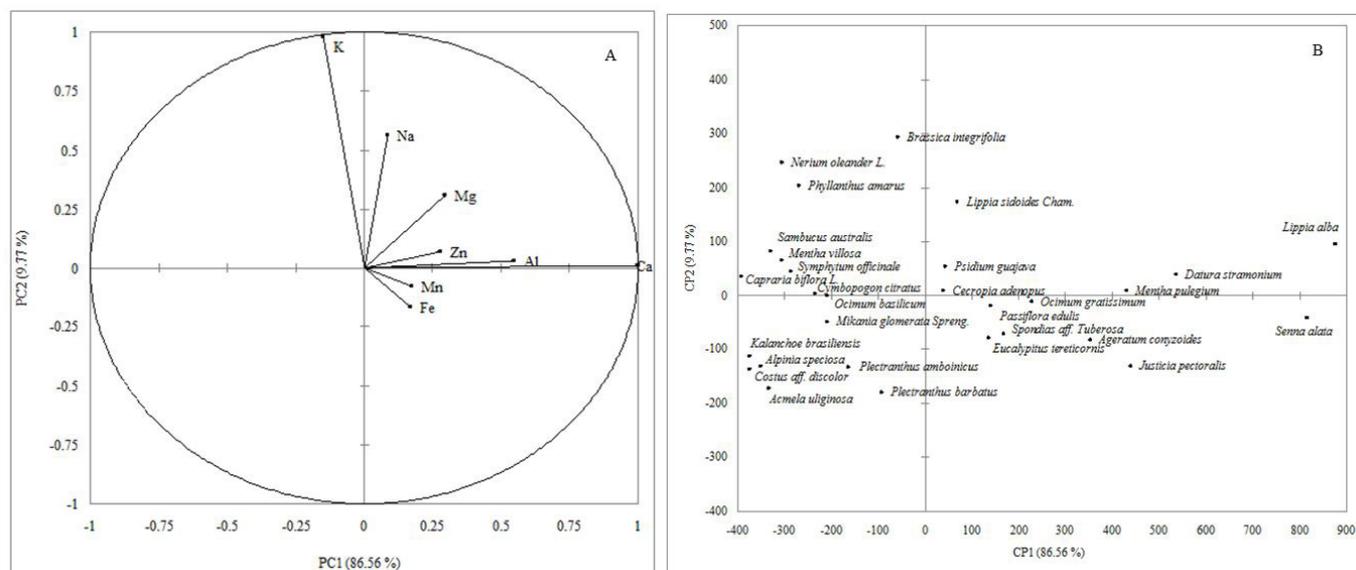


Figure 2. A) Component principal (PC) loading, PC1 versus PC2, of mineral content and B) component principal scores, CP1 versus CP2, of medicinal plants of Northeast Brazil. Fe, Mn, Zn, and K were located near the center of the graph meaning that these minerals were equally present in the plants. Ca and Al were the minerals that contributed most to the association between the plants in PC1; while K, Na, and Mg presented the most significant relationship between the plants in PC2 (Figure 2A).

4 Conclusion

This work attempts to contribute to the body of knowledge about the nutritional properties of herbal tea prepared from different medicinal plants from Northeastern Brazil. The results of this study show that these plants contain elements of vital importance for the human metabolism and necessary for the prevention and healing of diseases. *B. integrifolia*, *N. oleander*, *P. amarus* and *L. sidoides* showed up next in the PC2 region of the high level of K. The higher content of K over Na (4-8 times) makes these plants possible aids in controlling blood pressure. Furthermore, considering the high content of Ca in the leaves of *L. alba* and *S. alata*, and high levels of Fe, Mn and Zn in leaves of *M. pulegium*, as observed in PC1, these plants can be recommended as a potential supplement of this mineral.

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