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Minerals Composition of the Cashew Apple Juice (*Anacardium occidentale* L.) of Yamoussoukro, Cote D'ivoire

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Abstract: The mineral composition of six (6) samples of cashew apple juice, (*Anacardium occidentale* L.) from Yamoussoukro (Cote d'Ivoire) was studied. The objective of this study was to evaluate the mineral profile of the different species of apples grown in this area of Cote d'Ivoire, given the specific soil and climate in the various producing regions. Cashew apples harvested in production area were transported to the laboratory, crushed and the juice collected was analyzed by Scanning Electron Microscopy (SEM) by the method of Energy Distribution Spectroscopy (EDS) with a resolution of 0.1. The juices contain 10 minerals analyzed with seven (7) macro-minerals and three (3) trace elements. The macro-minerals in order of size K>P>Mg>S>Na>Si>Cl. The values (mg/L) of these items range from 33.7-43.3 for Na; from 152.9-215.1 for Mg; from 16.9-28.8 for Si; 211.3-239.7 for P from 43.5-57.3 for the S, 14.6-28.2 for Cl and from 2043.8-2241.4 for K. As for the three trace elements, their distribution is not uniform in all juice samples analyzed. Thus the Al content of juice samples were: 12.2±2.0 mg/L for YA_1 and 12.6±4.7 mg/L for RA_2. The Br is present in the sample PR_1 up to 22.9±1.3 mg/L and finally the Cu in sample PR_2 up 5.1±0.8. In addition, SEM analysis revealed that the minerals are not free in the juices and then ricocheted through the apples, but in the oxidized state with oxide contents above that of minerals.

Key words: Cashew, minerals, juice, ecological zone, SEM

INTRODUCTION

The cashew tree (*Anacardium occidentale*, *Anacardiaceae*) is a tree from the northeastern coast of Brazil. It is a tree resistant to high temperature but very sensitive to low temperature (Christian, 2001). The value of this tree is multifaceted. However it is the cashew nut that is the subject of international trade and giving the cashew notoriety (Lacroix, 2003). The pseudo fruit is three to six times richer in vitamin C than oranges (Franco and Janzantti, 2005; Soares *et al*., 2007; Sivagurunathan *et al*., 2010). In addition, the nutritional composition of the apple is the subject of many studies. So, regardless of its high vitamin C, studies have demonstrated the richness of the cashew apple in polyphenols and other beneficial compounds (Akinwale, 2000; Assuncao and Mercadante, 2003; Lautie *et al*., 2001). The beneficial effects of polyphenols have been inconclusive on diseases such as arteriosclerosis (Johnson and Fenwick, 2000; Pfannhauser *et al*., 2001). The cashew apple is an important source of volatile substances consisting of esters and aldehyds majority (Garruti *et al*., 2003; Franco and Janzantti, 2005). The cashew apple, been a by-product is one of many fruits grown in Cote d'Ivoire. Yet it is generally shown that fruit play and important role in human nutrition, especially as sources of vitamins and minerals (Craig and Beck, 1999; Wargovich, 2000). Minerals are necessary for the balance of the human organism (Goldman *et al*., 1999). Furthermore, the mineral content of fruits and vegetables depends on various factors including the species, climate, soil, stage of maturity (Ismail *et al*., 2011). Thus, the overall objective of this study is to assess the mineral profile of different species of cashew apples harvested.

MATERIALS AND METHODS

The plant material consists of red and yellow cashew apple from Yamoussoukro (Center of Cote d'Ivoire). In addition to these two colors of apple, have been associated red and yellow apples with greenish tasks. Ripe and intact cashew apples harvested in these regions were transported to the laboratory refrigerated for juice extraction and analysis. The city of Yamoussoukro (Lake District), located in the center of the country at 380 km from Abidjan is a region regarded as unfavorable to the cultivation of cashew. The apples

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Table 1: Origin of cashew sample

N°	Origin	Samples	A
1	Yamoussoukro	Yellow apple (1st taking)	YA_1
2	Yamoussoukro	Yellow apple (2e taking)	YA_2
3	Yamoussoukro	Red apple (1st taking)	RA_1
4	Yamoussoukro	Red apple (2e taking)	RA_2
5	Yamoussoukro	Yellow apple with greenish tasks	YAGT
6	Yamoussoukro	Red apple with greenish tasks	RAGT

A = Abbreviation

were harvested in two different dates. It has also been collected a ripe apples which greenish tasks. The aim is to study the impact of the maturity period, the grade of maturity and inter-varietal variations on the mineral content (Table 1).

Juice extraction: Cashew apples transported to the laboratory, are detached from the nuts. The apples are washed thoroughly with clean water. Then the apples are cut and ground to Mixer (Blender LB20E, Torrington, USA, 2002). The juice obtained by pressing the mash is filtered through a 0.5 mm mesh sieve and then stored frozen at-80°C for different analysis.

Equipment testing: The analysis of minerals is carried out using the Scanning Electron Microscope (SEM) type FEG (Field Emission Gun) variable pressure of D.C.AR (SEM/FEG Zeiss Supra 40 VP, Germany, 2008) at a magnification x 1000 000 and resolution 2 nm. This SEM is equipped with an X-ray detector (Oxford Instruments) connected to a platform with a micro-analyzer Spectrometry Diffusion of Energy (EDS) (INCA/30 mm^2, OXFORD, Zurich, Switzerland) of resolution 0,1. The SEM allows shooting environment catch of sight that is to say without metallization. The X-ray detector in turn allows for a one-time elemental chemical analysis.

Sample preparation: A volume of 15 ml sample is poured into a pre-weighed crucible. The assembly is weighed and placed in muffle furnace at 550°C for 4 h. The crucible is then cooled in a desiccator and then weighed again. The ash obtained is used for the analysis of minerals. The ash from mineralization is widespread on a slide wipe sterile. The ash from the mineralization is widespread on a slide wiped and sterile. With the help of a double-sided adhesive pad, the sample is collected by dabbing the face of the magnetic strip on the pad. The ash adheres well and is packed on the wafer which is then sprayed to clear the ash particles free. The pellet containing the ash is then mounted on a plot (stand) and deposited in the chamber of SEM for analysis.

Analysis of minerals: The qualitative and quantitative analysis of the different minerals was carried out by the method of Energy Distribution Spectrometry (EDS). The analysis conditions (calibration) are 25 keV with a working distance of 8 mm. Thus beam energy of 25 keV is bombarded on the sample mounted on the ash plot. In response to this received energy atomic layers (K, L, M) will experience a disruption. The departure of the inner layers will be offset by the migration of the outer layers. This transition will be accompanied by the emission of an energy transition (X-ray) specific of the sample and of each atom. To identify the chemical elements, the X-ray detector (EDS) measure the transition energy of the electron in the electron clouds of the series K, L and M atoms of the cashew. The SEM then provides a spectrum of chemical composition of minerals (Fig. 1) from the 5th element of the table of Mendelief and the concentration of these elements. The acquisition of chemical composition is performed on at least three different areas which allows for a medium with a standard deviation. The results are transported on regular file (Word or Excel) for processing.

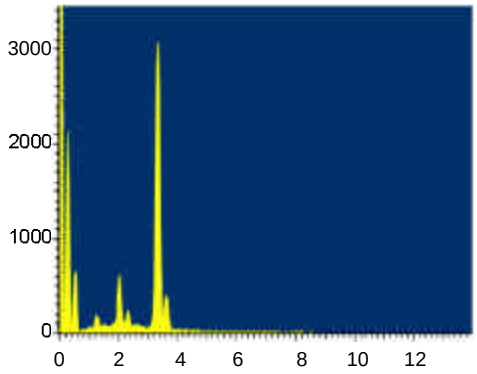

Fig. 1: Spectrum of minerals, example of apple juice YA_1

Statistical analysis: The statistical analysis was done by SPSS 11.5. The significance of change in mineral content of different cashew apple juice was calculated with Duncan's test at significance level $p<0.05$.

RESULTS AND DISCUSSION

In total 6 samples of cashew apple juice from Yamoussoukro were analyzed. The cashew apple juice was found to contain a total of 10 minerals whose 7 macro-minerals and 3 trace elements (Table 2 and 3). Elsewhere Figure 1 shows a model of the spectra of minerals, because they are virtually identical. The values of the macro-nutrients (Na, Mg, Si, P, S, K, Cl) contents in the different juices are given in Table 2. The values (in mg/L) of these items range from 33.7-43.3 for Na; 152.9-215.1 for Mg; 16.9-28.8 for Si; 211.3-239.7 for P; 43.5-57.3 for S; 14.6-28.2 for Cl and from 2043.8-2241.4 for K. There is no significant difference ($p<0.05$) for contents of Na, Mg, Si, Cl, P and K between color of apple an sampling period. As against the S, the difference is significant ($p<0.05$) for the S content of juice from the

Table 2: Contents in macro-elements of yellow and red cashew apples juices

Minerals	YA_1	YA_2	RA_1	RA_2	RAGT	YAGT
Na	34.8^a±5.04	39.0^a±5.4	37.5^a±4.7	43.3^a±9.61	33.7^a±4.3	33.9^a±11.8
Mg	195.6^a±27.2	215.1^a±56.3	152.9^a±23.9	179.8^a±9.7	178.6^a±14.4	205.3^a±46.6
Si	28.8^a±5.4	23.9^a±1.3	23.9^a±8.6	22.6^a±3.8	16.9^a±1.0	19.1^a±3.8
P	215.8^a±18.3	213.9^a±12.1	211.3^a±6.47	231.2^a±37.3	239.7^a±16.6	214.7^a±25.1
S	44.2^a±9.6	46.6^a±4.4	43.5^a±6.2	48.9^a±4.3	55.3^b±1.9	57.3^b±13.1
Cl	26.6^a±2.3	24.6^a±6.4	14.6^a±1.2	15.6^a±12.8	28.2^a±1.0	24.6^a±6.8
K	2189.5^a±122.2	2043.8^a±225.4	2154.5^a±105.0	2128.9^a±270.5	2241.4^a±107.9	2168.2^a±58.02

Value with similar superscripts arranged vertically is not significantly different from each other ($p<0.05$) in the same variety of mineral, value are expressed as mean ± SEM (n = 3 determinations), YA_1: Yellow Apple 1; YA_2: Yellow Apple 2; RA_1: Red Apple 1; RA_2: Red Apple 2; RAGT: Red Apple with Greenish tasks, YAGT: Yellow Apple with Greenish tasks

Table 3: Contents in micro-elements of yellow and red cashew apples juices

Minerals	YA_1	YA_2	RA_1	RA_2	RAGT	YAGT
Al	12.2^a±2.0	nd	nd	12.6^a±4.7	nd	nd
Fe	nd	nd	nd	nd	nd	nd
Br	nd	nd	22.9^a±1.3	nd	nd	nd
Cu	nd	nd	nd	5.1^a±0.8	nd	nd

Value with similar superscripts arranged vertically is not significantly different from each other ($p<0.05$) in the same variety of mineral, value are expressed as mean ± SEM (n = 3 determinations), nd = no detected YA_1: Yellow Apple 1; YA_2: Yellow Apple 2; RA_1: Red Apple 1; RA_2: Red Apple 2; RAGT: Red Apple with Greenish tasks, YAGT: Yellow Apple with Greenish tasks

Table 4: Content in oxides (mg/L) of yellow and red cashew apples juices

Oxides	YA_1	YA_2	RA_1	RA_2	RAGT	YAGT
Na_2O	119.88±7.02	73.48±6.8	50.62±5.99	58.39±12.38	46.18±5.68	85.91±6.35
MgO	428.46±63.22	324.34±44.33	250.19±34.36	298.15±16.37	373.85±77.33	296.50±23.49
Al_2O_3	nd	23.53±3.79	nd	228.22±36.83	nd	nd
SiO_2	51.73±3	232.43±54.72	243.31±17.57	45.29±7.05	40.63±7.68	36.19±2.77
P_2O_5	673.55±27.62	494.17±42.42	483.96±14.69	770.56±66.18	491.51±49.38	595.63±38.63
SO_3	141.64±10.41	110.56±23.71	108.78±15.51	121.66±10.66	187.59±32.42	138.08±4.33
Cl	0	0	0	0	0	0
K_2O	3666.77±71.54	3239.42±47.07	2591.18±26.57	3407.48±36.07	5455.43±70.12	3904.54±30
FeO	nd	nd	4.88±0.45	nd	nd	nd
Br	nd	nd	0	0	nd	nd
CuO	nd	nd	nd	6.44±1.15	nd	nd

nd = no detected; YA_1: Yellow Apple 1; YA_2: Yellow Apple 2; RA_1: Red Apple 1; RA_2: Red Apple 2; RAGT: Red Apple with Greenish tasks; YAGT: Yellow Apple with Greenish tasks

apples of plain color (YA_1, YA_2, RA_1, RA_2) and those of the juice from the apples of tasks (YAGT and RAGT). In other word, apples with tasks contain more S than apples with plain color.

Table 3 gives the values of trace elements (Al, Cu and Br) detected and quantified by SEM. The distribution of trace elements is not uniform in all juice samples analyzed. Thus the Al content of juice sample was: 12.2±2.0 mg/L for YA_1; 12.6±4.7 mg/L for RA_2. The Br is present in the sample RA_1 up to 22.9±1.3 mg/L and finally Cu in the sample RA_2 up to 5.1±0.8 mg/L. the small amounts of these minerals in the juice is probably due to the fact that the soil where the cashew apples were harvested does not contain large amounts of these minerals. According to Vesk and Allaway (1997), a large amount of Fe and probably Al, Br and Cu in a plant is commonly attributed to the environment (air and water) and the soil where the plant grows. Table 4 gives the oxidized forms of minerals in the samples. Indeed, the analysis of minerals by Scanning Electron Microscopy (SEM) revealed that the minerals are not in the free state in juice (by then ricocheted into apple) but the form of oxide. As against the Cl and Br are free forms and does not combine with oxygen. This information is crucial in that it provides a track for agricultural and other phyto-chemists in the design of fertilizer to fight against cashew trees that have abundant foliage but do not bloom in some area.

In general, the minerals content of juice samples in this study are higher than Lowor and Agyente (2009) who worked on the apple juice from three areas of Ghana. Indeed, these authors found the levels (mg/l) following minerals: 119-1562 for K; 18-127.5 for Mg; 0.2-4.5 for Na; 6-9.8 for P and 0.1-1.2 for Cu. However, in this study the K is the mineral majority in all the juices analyzed and this is consistent with the result of these authors. Moreover, the K content of this study is consistent with those apples in general (Eisele and Drake, 2005). Minerals belong to the family of micronutrients. Trace elements do not provide calories but they play an important role in the metabolic processes of the human body. The increased consumption of fruits and

vegetables can improve mineral regulation and reduce cardiovascular disease and certain cancer risks (Ismail *et al*., 2011). The number of malnourished people in the world is estimated at 2 billion related to micronutrients (Johns *et al*., 2006). Pregnant women and nursing mothers like young children are the first victims of the deficiencies. Because their needs for vitamins and minerals are important they suffer more adverse consequences of these deficiencies (Black *et al*., 2003; FAO, 2004). Intakes of vitamins and minerals are provided for most by fruits and vegetables (Quebedeaux and Elsa, 1990; Craig and Beck, 1999; Quebedeaux and Eisa, 1990; Wargovich, 2000). The cashew apple juice appears to be, from the present study, an important source of minerals. Because the 10 minerals put forward play for the majority a significant role in the body. Thus:

Potassium (K) is used to maintain the balance of electrolytes in the body and can help prevent bone demineralization by preventing calcium loss in urine (Tucker *et al*., 1999; He and MacGregor, 2001). It can also lower blood pressure, especially when used as a substitute for Na in patients Na-sensitive (Appel, 1999). The K is used for muscular contraction and has excitability of nervous fibers. It is useful to maintain the automatic heart and muscular activity in general (Jacotot and Parco, 2000). The Accepted Daily Intake (ADI) permitted for an adult is 4700 mg/days (Viarengo *et al*., 1996; Institute of Medicine, 2005). K requirements are covered to the tune of 43.5-47.7 of the ADI by consuming a liter of cashew apple juice.

Magnesium (Mg) plays an important role in the stability of the nervous system, in muscular contraction as an activator of alkaline-phosphatase and as well as it used as an alternative of Calcium (Ca) in the body (Cowan, 2002; Ismail *et al*., 2011). Epidemiological studies have shown that Mg could reduce the phenomenon of sudden death (Garzon and Eisenberg, 1998). Mg requirements of adult's human between 19 and 50 old are from 310-420 mg/days (Azoulay *et al*., 2001), this interval is included in the Accepted Daily Intake (ADI) of between 300 to 420 mg/days (Pennington *et al*., 1986). Mg requirements are covered to the tune of 50.9-51.2 of the ADI by consuming a liter of cashew apple juice.

Sodium (Na) regulates blood pressure and osmotic. It is a major extracellular cation that stabilizes the extracellular fluid and its concentration is regulated by the kidneys and nervous hormonal stimulation. The ADI is between 2400 and 5175 mg/day (Sagnella *et al*., 1989). Na requirements are covered up to 0.84-1.33% of the ADI by consuming a liter of juice. Intakes of apple cashew juice are small but the Na is largely covered by food salt. Phosphorus (P) is contained mainly (700 g) in bones and teeth, combined with calcium ions, but also participates in the formation of basic molecules such as nucleic acids (DNA and RNA), the ATP and phospholipids membranes. The P is necessary for the functioning of nerves and muscular. It is involved in the absorption and transformation of certain nutrients. Dietary intake, which is about 1600 mg/day, is usually enough to cover the needs of the organization witch are in the range of 700-900 mg per day (Jacotot and Parco, 2000).

Sulfur (S) is a component of sulfur amino acids, while the chloride the Chlorine (Cl) is against a sodium ion in the extracellular fluid and the gastric juice. The needs of the human body in these minerals are at more than 50 mg/day (Ismail *et al*., 2011). The contents in S and Cl of this study provide respectively 72.2-114.5% and 29.3-56.4% of needs in relation to the value brought about. Regarding trace elements, the Cupper (Cu) is essential and beneficial to human metabolism. Cu is an essential cofactor for the enzyme system (cytochrome C-oxydase). It stabilizes the membrane, hormones and nucleic acids (Norziah and Ching, 2000).

The ADI of Cu is estimated respectively at 2 mg for adults and 0.05 mg/kg for children (Browing, 1969). Cu concentration of the juice from apples RA2 is almost two times the required dose for an adult. According to Ismail *et al*. (2011), the Al and Br are essential the body point of view beneficial. The disparity of trace elements such as Al, Cu and Br in the juice studied is influence by several factors. Indeed, several factors such as species, growing region, climate, cultural practices, maturity at harvest time (Drake and Eisele, 1997), the storage atmosphere (Drake and Eisele, 1994), storage conditions (Drake *et al*., 2002; Drake and Eisele, 1999) are know to affect the chemical composition of apple juice. The cashew tree is now one of perennial crops in Cote d'Ivoire (Anonyme 2008a). The value of this tree has focused on the cashew nut witch became the main export product. The cashew apple (or pseudo fruit) is fairly values except in India and Brazil particularly in the form of juice (Lautie *et al*., 2001). The cashew apple juice is a very popular juice in Brazil with an estimated production of 200 million liters per year. Regardless of the minerals, the cashew apple juice is rich in vitamin C and polyphenols. This juice has properties for cancer prevention, antimicrobial activity against the bacterium *Helicobacter pylori*, responsible for entero-gastritis. In the same order, antioxidant properties of this fruit have been reported (Sampaio, 1990; Kubo *et al*., 1999; Wharta *et al*., 2004). Cote d'Ivoire following the example of Brazil can set up a policy of promotion of this fruit. Because Cote d'Ivoire exported 330,000 tons of cashew nuts (Anonyme, 2008b), witch means that amount of rotten apples in the fields as a by product.

Conclusion: The analysis of six samples of cashew apple juice showed the richness of the apple mineral quality and quantity. The colors of the apple and the sampling period have almost no influence on the

mineralogical composition. Minerals such as K, Na, P, S, Cl, Mg and Cu have physiological role undeniable rights. At a time when the micronutrients deficiency makes populations in Africa and particularly in Cote d'Ivoire vulnerable, the cashew apple juice is an interesting solution for people in general but more specifically for vulnerable people. Indeed, despite its value there are tons and tons of rotting product unnoticed in our plantations. When strategies are developed at a cost of millions of francs for micronutrient supplementation enhancing, the value of cashew apple could be used to improve the population's health. Although the apple seems to be rich, the astringent side of the juice seems to be the limiting factor for its acceptance by the population. To solve this problem, one way would be to associate the cashew apple juice with other fruit juice available in Cote d'Ivoire.

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