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Physicochemical characterization of Sudan baobab fruits (Pulp, Seeds and Oil)

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Abstract
This work was conducted to measure the physicochemical characteristics of baobab fruits (pulp, seeds and oil). Baobab fruit samples were obtained from El-obeid markets (Sudan). Moisture and ash contents were determined for fruit pulp powder and crushed seeds samples. Minerals concentrations were measured for fruit pulp and seeds using inductively coupled plasma spectroscopy (ICP). Vitamin C content was measured titrimetrically. Baobab seeds oil was extracted by petroleum ether using Soxhlet system. pH value, density, viscosity, refractive index, acid value, peroxide value, saponification number and ester value of the extracted oil were determined. The chemical constituents of the extracted oil were investigated by GC-MS spectroscopy. The ash content was found to be (9.37%) for pulp and (4.93%) for seeds. The moisture content was (18.39%) for pulp and (7.74%) for seeds. inductively coupled plasma analysis showed that, the fruit pulp and seeds were very rich with essential macro and micro minerals (K, Ca, Mg, P, Cu, Mn and Zn). The hazardous minerals showed very low concentrations, except Strontium (Sr) and lead (Pb) which, showed relatively high concentrations in fruit pulp and seeds. The GC-MS characterization indicated the presence of 33 components. The major components were Linoleic acid (25.10%), Palmitic acid (21.14%), oleic acid (17.34%), stearic acid (7.92%), methyldihydrosterculate (4.81%), methyle archisate (1.47%) and Behenic acid (1.23%).

Keywords: adansonia digitata l, vitamin c, macronutrients, tebaldi tree, GC-MS spectroscopy

1. Introduction

1.1 Tebaldi Tree (*Adansonia digitata* L)

Adansoniadigitata L. or Baobab tree in Sudan, is known as Tebaldi tree and the fruit is known as (Gonglase). The fruit pulp powder is very popular traditional food in Sudan, where, it is used for natural juice preparation, almost in every house, especially in the fasting month (Ramadan). Tebaldi juice is normally consumed in markets and restaurants. The pulp powder is sometimes directly eaten by children. Tebaldi juice is used for treating gastrointestinal tract disturbances, such as, diarrhea. Tebaldi is one of the most famous trees in Sudan especially in Kordofan region, where it is sometimes used as a reservoir for water storage.

1.2 African Baobab

Adansonia digitata L., (Malvaceae) is an important indigenous tree species for food security, nutrition and income generation for the rural population in Africa (Muthai K.U. *et al*; 2017) [25]. Baobab occurs in the dry lands of Sub-Saharan Africa, as a representative of the wooden (big five trees) which, include Tamarindous, Zizyphus mauritiana, Sclerocarya birrea, Mangifera indica and Adansonia digitata (Jama *et al*; 2008) [12]. According to Ibrahima *et al*; (2013) [10], Baobab is a big tree that, grows principally in Africa and can live up to 1000 years. Baobab tree is believed to be originated from tropical Africa with a wide distribution range. Baobab species are described as characteristic of Sahelian prairies and Sudano-Sahelian savannas, as well as the semi-arid tropical zone of the western part of Madagascar (Wickens and Lowe, 2008, Ibrahima *et al*, 2013) [24, 10]. African Baobab was reported as a long lived with multiple purposes trees, which tolerant the high temperature and long spans of drought (Rahul Jitin *et al*; 2015) [13]. African Baobab tree has been introduced to areas outside Africa and grown successfully (Rahul Jitin, 2015) [13]. Baobab has an extensive root system and high water holding capacity. It is annual temperature range is 20-30ºC, but it can tolerate temperatures up to (40- 42 ºC), and it is drought tolerant and host sensitive (Zahra, U.B.*et al*; 2014) [26]. This adaption allow it to grow in zones with 100-1000 mm annual rain fall. The trees sometimes stunted in low rain fall areas (Zahra, U B.*et al*; 2014) [26]. African Baobab is known by different local names such as, Monkey bread tree, Ethiopian sour gound, Cream of tartar tree, Senegal calabash fruit, Upside down tree, Baobab, Tebaldi, Dead rat tree. The name Adansonia digitatal L. was given after Michel Adanson, who had, been to Senegal in the eighteen century and discovered baobab tree (Zahra U. B *et al*, 2014) [26]. Adansonia digitata L. is the most widely spread of Adansonia species in the African continent, which belong to the family of Bombaceae, a sour family of Maluaceae (Mohammed A. S. *et al*, 2014) [26]. Adansonia species are described as nine different species, six of them are native to Madagascar, two native to main land Africa and the Arabian Peninsula and one is native to Australia (Wickens and Lowe 2008, Gardener Simon *et al*, 2011; Pettigrew J. P *et al*, 2012) [24, 8, 19].

1.3 Nutritional Importance

The tree parts, tender root, tubers, twigs, fruit pulp, seeds, leaves, flowers and oil are all edible and form common ingredients in the traditional dishes in the rural areas in Africa. It was reported that, the fruit pulp is very rich with vitamin C and the leaves have high minerals content and pro-vitamin A (Codja *et al*; 2001, Assoghajdo *et al*; 2006, Ibrahima *et al*; 2013, Mohammed *et al*; 2014) [5, 1, 10, 26].

1.4 Chemical Composition
Most of the previous studies concerning Baobab have been dealing with Adansonia digitata species, particularly in relation with it is botanical, agronomical and biochemical characteristics (Smedt 2010, Ibrahima *et al*; 2013, Munthai *et al*; 2012, Assogbadjo 2005, 2012) [21, 10, 2, 3]. The fruit pulp was reported to be rich in dietary fibers, carbohydrates and vitamin C (Chadare *et al*; 2009, Soloviev *et al*; 2004, De Caluwe *et al*; 2010) [6, 22, 7]. Ibrahima (2013) [10] reported moisture content of the dried pulp ranging from (11.7 to 13.5%), lipid content from (0.5 to 2.1 g/100g) protein content from (2.5 to 6.3 g/100g). Lockett (2000) [14] and Osman (2004) [18] reported protein content as (5.3g/100g). Ibrahima *et al*; (2013) [10] reported fiber content of different baobab species ranging from (17.2 to 27.0 g/100g). Carbohydrates content was reported to be more than 60% of the dry matter, dominated mainly with soluble sugars, glucose, fructose and sucrose (Soloviev *et al* 2004, Nour A. *et al*; 1980, Murray *et al*; 2001 and Ibrahima *et al* 2013) [22, 17, 15, 10]. According to Murray *et al*; (2001) [15] and Lockett *et al*; (2000) [14], the ash content was (5.2 to 7.8%) and the starch content was very high in some species (60.8% to 71.7%). Ibrahima *et al*; (2013) [10] reported vitamin C content, ranging between (60 and 138 mg/100g), Polyphenol ranging from (329 to 1906mg/100g), and antioxidant capacity of the fruit pulp between (109 and 195µmolTE/g). Mohammed A. S. *et al*; (2014) [26] reported considerable occurrence of the main essential amino acids in Baobab leaves, fruit pulp and seeds. The fruit pulp was described by Rahul Jitin *et al*; (2015) [13] to be very rich in vitamin C, Calcium, Phosphorus, Carbohydrates, soluble and insoluble fibers. Muthai K.U.*et al*; (2017) [25] characterized Baobab fruit pulp and seeds from different African regions, showing highest ash content as 4.59%, highest moisture content as 9.94%, highest crude protein as 2.44%, and highest crude fiber as 9.61%. For Baobab seeds Muthai K. U *et al*; (2017) [25] reported highest ash content as (4.39%), highest moisture content (7.04%), highest crude protein (16.02%), highest fibers (26.25%), highest fat content (13.35%), and the highest carbohydrates as (67.44%). Muthai K.U. *et al*; study (2017) [25] showed that Baobab fruit pulp and seeds are rich with Ca, Mg, K, Na, P, Cu, Fe, Mn and Zn. Potassium was considered to be the most abundant mineral in the fruit pulp and seeds. The study described the accumulation of the macro and microelements at country level as: K>P>Mg>Ca>Na>Fe>Cu>Zn>Mn.

2. Methodology
Newly harvested Baobab fruit samples of different sizes were obtained from Northern Kordofan markets (Sudan). The hard outer shells of the fruits were carefully broken. The white pulp powder and the black fruit seeds were separated. Standard analytical procedures were applied. Minerals contents were measured for Baobab fruit pulp and seeds by inductively coupled plasma spectroscopy. Baobab seeds oil was extracted by Soxhlet extraction system using petroleum ether as a solvent. The physicochemical properties of the extracted oil were measured using the appropriate standard methods. The chemical composition of Baobab seeds oil was determined by GC-MS spectroscopy. The chemicals used were all of analytical grade.

3. Results and Discussion

Table 1: Moisture and Ash contents of baobab fruit Pulp and seeds (mean)

Property	Pulp	Seeds
Moisture content	18.39%	7.47%
Ash content	9.37%	4.93 %

In this study the mean moisture content was 18.39% for baobab pulp and 7.47% for baobab seeds. The ash content mean was 9.37% for pulp and 4.39% for seeds (table 1). Alia Mutasim (2016) reported moisture content as 23.7% and ash content as 2.99% for baobab fruit pulp.

Table 2: Macronutrients content of baobab pulp and seeds

Mineral	pulp (ppm)	seeds (ppm)
Na	33.77	15.49
K	17,406	10,995
Ca	2,282	1,919
Mg	1,707	3,212
P	537.3	4,623

The macronutrients concentrations of baobab fruit pulp in this study were characterized with high potassium (17,406ppm), calcium (2,282ppm), magnesium (1,707ppm), and phosphorous (537.3). Baobab seeds showed potassium content as (10,995ppm), Calcium (1,919ppm), Magnesium (3,212ppm) and phosphorous (4,623ppm), table (2). Magnesium and phosphorous content of baobab seeds were found to be higher than that, of the pulp. Sodium concentrations were low for the pulp (33.77 ppm) and seeds (15.49ppm). Isaac Kwasi Baidoo (2016) [11] reported macro minerals content of baobab fruit pulp as K (2,135ppm), Ca (3,170ppm), Mg (3,210ppm), Na (52.06ppm), and for seeds as, K (12,240ppm), Ca (2,360ppm), Mg (4,720ppm) and Na (23.53ppm). Jitin Rahul *et al*; (2015) [13] reported Ca (3,950µg/g), Mg (3,520µg/g), P (6,140µg/g), and Na as (19.6µg/g) in baobab seeds. The obtained results, were strongly agree with the findings reported by Muthai K.U. *et al*; (2017) [25], where, the minerals content of baobab pulp and seeds in the most African countries were in the order: K>Ca>Mg>P>Na. Osman M. (2004) [18] showed sodium content of baobab pulp as (27.9mg/100g) and seeds as (28.3mg/100g) compared to higher concentrations of potassium, calcium and magnesium. Rayan Hassan study (2018), showed similar availability of the macro minerals in baobab fruit pulp, K (16,081ppm), Mg **(**1,370 ppm), Ca **(**2,629 ppm), P (638.5 ppm), and Na (122.3 ppm).

Table 3: Micro minerals content of baobab fruit (pulp and seeds)

Element	In pulp (ppm)	In seeds (ppm)
Co	$<2x10^{-3}$	$2x10^{-6}$
Cu	4.657	10.45
Fe	939.5	64.37
Mn	13.20	9.656
Mo	$<2.77x10^{-4}$	$2.7x10^{-8}$
Ni	5.285	0.8197
Se	$<4.993x10^{-3}$	0.2799
Zn	9.672	25.19

Inductively coupled plasma (ICP) analysis (table 3), showed significantly high iron content in baobab pulp and seeds (939.5ppm and 64.37ppm respectively). Baobab pulp and seeds may be described as rich with manganese, zinc, nickel and copper. The elements cobalt, molybdenum and selenium were of trace levels in baobab pulp and seeds. These findings agree with those obtained by Marafi Abdallateef (2018) [16] and Muthai KU *et al*; (2017) [25].

Table 4: The undesired minerals in baobab fruit (pulp and seeds).

Mineral	In pulp (ppm)	In seeds (ppm)
Al	988.5	41.18
As	1.339	$<2.547x10^{-3}$
Ba	8.533	4.938
Be	$<3x10^{-5}$	$<3x10^{-5}$
Cd	$<2x10^{-3}$	$<2x10^{-3}$
Cr	4.426	$<5.83x10^{-4}$
Li	$<1.279x10^{-3}$	$<1.279x10^{-3}$
Pb	0.3	6.198
Sb	$<4.72x10^{-3}$	$<6.078x10^{-3}$
Si	312.7	$<1.068x10^{-2}$
Sn	0.320	0.1499
Sr	17.56	7.427
Ti	27.19	$<1.47x10^{-4}$
V	9.652	5.168

The availability of the undesired minerals was found to be as, Arsenic (< 1.339 ppm) in pulp and (< $2.54x10^{-3}$ ppm) in seeds. Cadmium (< $2x10^{-3}$ ppm) in both pulp and seeds. Lead showed relatively high content in seeds (6.198ppm), Vanadium was (9.652ppm) in pulp and (5.168ppm) in seeds.

Aluminum, Silicon and Titanium showed relatively high concentrations in baobab pulps and very low concentrations in the seeds. The three minerals (Si, Al, and Ti) availability may be due to their natural occurrence as, the second, third and ninth in the earth crust composition. According to Farog Abdalaziz, (2015), the high concentrations of Al and Si in baobab fruit may be due to the presence of wedges fungus that, increase the absorption of these two elements by baobab tree. Ba and Sr showed considerable availability in pulp and seeds. Be, Cr, Sn and Li have very low concentrations in pulp and seeds. Isaac Kwasi Baidoo (2016) [11], reported average minerals compositions for the dried Baobab pulp as Al (27.74ppm), Ba (13.10ppm), Co (0.08ppm), Cu (14.9ppm), Fe (26.05ppm), Mn (7.05ppm), V (0.08ppm), Zn (0.79ppm), As (<0.06ppm) and Cd(< 0.08ppm), whereas, the seeds minerals contents were; Al (11.50ppm), Ba(17.3ppm), Co (0.07 ppm), Cu (28.6ppm), Fe(<42ppm), Mn(17.7ppm), V(0.035ppm), Zn (12.06ppm) As(< 0.04ppm) and Cd(< 0.04).

Vitamin C Content

Vitamin C content of baobab fruit pulp in this study was found to be (290 mg/100g). Ibrahima *et al*; (2013) [10] reported vitamin C content ranging, between (60 to 138mg/100g) for six baobab species. They stated that, this value is higher than that of oranges (37 to 92mg/100g). Gebauer *et al*; (2002) [9] showed vitamin C content of Adansonia digitita pulp as (300mg/100g). Jitin Rahul *et al*; (2015) [13] reported vitamin C content of baobab pulp ranging between (280 to 300mg/100g) compared with orange (51mg/100g).

Table 5: Physicochemical properties of baobab seeds oil

Property	Value
Oil yield	10.3%
pH	5.6
Density	0.760 g/cm3
Viscosity	63.032
Refractive Index	1.466.01
Acid value	5.61mg/g
Sap.value	235.62mg/g
Peroxide value	1.23mg/g
Ester value	230.01mg/g

The physicochemical properties of baobab seeds oil as shown by table (5) were pH value (5.6), density (0.760g/cm3), viscosity (63.032), refractive index (1.466) peroxide value (1.23mg/g), acid value (5.610mg/g), saponification value (235.62mg/g) and ester value (230.01mg/g). Alia Mutasim (2016) reported baobab oil properties as: density (0.748g/cm3), viscosity (64.597), refractive index (1.373), peroxide value (1.72mg/g), acid value (5.797mg/g), saponification value (406.725mg/g) and ester value (400.928mg/g). Parkouda C. *et al*; (2015) [23] reported pH value for baobab seeds oil as (4.3) which is fairly low when compared with the results of this study (5.6). Baobab seeds oil may be good for soap production depending on it is high saponification value. The oil yield of baobab seeds was found to be relatively low (10.3%).

GC-MS Characterization of baobab seeds oil

The GC-MS results indicate high percentages of the essential fatty acids, as, linoleic acid (25.10%), palmatic acid (21.14%), oleic acid (17.34%), stearic acid (7.92%), methyl dihydrosterculate (4.81%), methyl arachisate (1.47%), and behenic acid (1.23%). These fatty acids play an important role in modulating human metabolism and reduce cholesterol levels. This may suggest that, baobab seeds oil could be useful as cooking oil. Parcouda C. *et al*; (2015) [23] reported availability of the essential fatty acids in baobab oil as linoleic acid (18.2%), palmatic acid (31.6%), oleic acid (34.3%), stearic acid (3.5%) and behenic acid (0.5%).

Conclusion

The results of this study showed significantly high nutritional value of baobab fruit pulp and seeds, containing considerable concentrations of macronutrients, trace minerals and vitamin C. This may suggest the use of baobab fruit pulp as a good complementary diet for essential minerals supplementation and as a good source of vitamin C. Therefore it may be described as a safe popular food for children and pregnant women, especially for those suffering iron deficiency. Baobab seeds oil was found to be of good quality, so it can be used as edible oil. It may also be used for cosmetic purposes, since it contains suitable amount of behenic acid.

Recommendations

The yield percentage of Baobab seeds oil was relatively low (10.3%), therefore extraction with different types of solvents may be needed, to see if there is any effect of solvent type on the oil extraction. In Sudan no young Baobab trees are observed. So real agricultural efforts may be required for keeping the growth of new generations of this multipurpose tree.

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