

The Potential of Baobab (*Adansonia Digitata* L) Leaves From North- And West Kordofan In Sudan As Mineral Complement Of Common Diets

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Abstract

Baobab is widely growing in the Baobab-Belt of Kordofan, Sudan, where the leaves are consumed restrictively even though food insecurity is a wide spread phenomenon. In order to encourage consumption by all households and promote their values, information on the true nutrient density is sought. In a research conducted for that purpose it was found that the average calcium, magnesium, iron and zinc content of the baobab leaves collected from ten villages are 2852 ± 697 , 555 ± 156 , and 42.39 ± 11.65 and 1.94 ± 0.5 mg/100 g dry matter respectively. The mean values within and between villages are highly variable and the ratio between various minerals is beyond standard e.g. Ca: Mg >5. However, an average of 32g macerated leaves can enrich the calcium content of a daily staple diet per person to adequacy. Similar level of leaves can also optimize the magnesium and iron content of the daily diet per person, but caution is necessary not to overlook the balance of the minerals so that the bioavailability of the minor ones is not hindered.

Keyword: baobab leaves; n-kordofan; w-kordofan; iron; magnesium; zinc; copper

Introduction

Micronutrient deficiency including that of minerals like iron, zinc, calcium and magnesium affects about 2 billion people in the world (1). It contributes to the global burden of diseases by inflicting metabolic problems, physiological disorders, delayed or impaired physical and psychomotor development, and reduced resistance to infection (2). Mineral deficiency additionally imposes tangible economic costs by hampering both individual productivity and overall economic growth (3). It is therefore imperative to engage coherent effort in finding sustainable means of curving these challenges.

One of the best ways of alleviating micronutrient deficiency is through the consumption of balanced diet that is adequate in every nutrient. Unfortunately, this has not been easy to realize everywhere because of inconvenient food habits, lack of awareness and poor availability and accessibility of diverse foodstuffs. However, food fortification, supplementation and public health measures have been recommended as part of the strategies of rectifying micronutrient malnutrition (2). Since recent years, the awareness about micronutrient rich wild and semi-wild food resources including Baobab and the interest of exploiting their potential in terms of food production and ecological maintenance is growing steadily (4, 5).

Baobab represents a massive tree about 10m in diameter and 25m in height; it grows throughout the hot and water stressed tropical areas for hundreds of years (4). An average baobab tree can produce among others; about 130kg leaves per year (6). In the savanna regions of sub-Saharan Africa, the tender leaves are picked during rainy season to make fresh salad dish or to cook like spinach, at the end of the rain season, the leaves are harvested in mass, sun dried and stored or ground before storage for eventual use in the diets.

In a situation where dietary mineral-inadequacy, particularly that of

calcium, iron, zinc and magnesium, is rampant and their social, economic and political impacts are obvious, searching for alternative natural sources is a matter of common sense. An initial strategy of the search focused on reviewing accumulated data, which gave the light that baobab pulp is not only exceptionally rich in some of the minerals but also in vitamin C the promoter of their bioavailability (7, 8). However, the documented results are patchy, very variable and generally inconclusive. For this reason, it was planned to specifically investigate the nutritional quality of baobab leaves from different sites, villages and districts in the Baobab Belt of North- and West-Kordofan (N&W- Kordofan), Sudan. The focus is primarily on the exploration of the potential of baobab leaves from different sites in complementing common diets with essential minerals.

Materials and methods

Sample collection, chemical and statistical analysis are the three major topics that are considered under this sub-title.

Sample Collection

Some collaborating members of the University of Kordofan, Sudan, demarcated the area of sample collection in the Baobab-Belt in N- & W-Kordofan. The area covers approximately 1200 sq. km where villages are sparsely settled. Five villages from each of the two districts and six trees from each village are arbitrarily selected as the origin of representative samples.

Four imaginary lines that crisscross at the center of the crown and extend to opposite edges divide the vegetative part of each tree. Equal batch of subsamples are collected from the two halves of each transect giving a total of 8 sub-samples, which add up to 2 kg representative sample per tree. The representative samples, are shed dried (about 92% DRY MATTER), thoroughly mixed and 60 samples, 200g each, are transported to Giessen, Germany for mineral analysis.

Chemical Analysis

Each sample is absolutely dried in a forced draught oven at 105°C for two hours; they are separately ground and saved in clean dry brown bottles for ten days. A subsample of 1g from each is weighed out in a crucible and ashed in the muffle furnace at 550°C for six hours. The minerals are extracted from the ash using 1N HNO₃ and aliquots are exposed to ICP-OES (inductive coupled plasma-optic emission spectrometer) to measure the concentration of Ca, Mg, Fe, Zn, Cu and Mn. Each sample is analyzed in duplicate, and in cases of variability of more than 3%, the analysis were repeated. Blank tests are conducted to control unwanted adulterants.

Statistical Analysis

In order to test the hypothesis that there is no influence of districts, villages and tree varieties on the mineral concentration of baobab leaves the data obtained were entered to two way ANOVA, and the means of significant differences were distinguished using the T-Test.

Results and Discussion

The data of the mineral composition of baobab-leaf-samples that are collected from sixty randomly selected trees growing in ten villages of the

two districts, N & W Kordofan, are subjected to statistical analysis in order to determine the mean values and the influence of the parent tree and locations of growth. The results for Ca, Mg, Fe, Zn, Cu and Mn content are presented as follows.

Calcium

The average calcium content of dry baobab leaves from the Baobab Belt is 2852 ± 697 mg/100g. There are, however significant (p<0.05) differences between the samples collected from the two districts, N&W-Kordofan, and between the villages within them (Table 1). All of the villages in W-Kordofan contain markedly (p<0.05) more calcium than the villages in N-Kordofan.

Baobab leaves are extraordinarily rich in calcium and the average concentration of the ones from N-Kordofan lie within the range of reported results (9), similarly those from W-Kordofan have identical values to that recorded by (42). However, three out of the sixty randomly selected trees produce the leaves with exceptionally high concentration of calcium (≥ 4g <5 g/100g DRY MATTER) (Figure 1). In reference to the studies conducted thus far, the variabilities are expected but the mean concentration of calcium of the highest magnitude (≥ 4g/100g DRY MATTER) hits a record.

Table 1. The average calcium concentration (mg/100g DRY MATTER) of baobab leaves from two districts and ten villages in Sudan

District	(n)	Mean ± SD	T-test*	Villages (n)	Mean ± SD	T-test*
N-Kordofan (60)		2460 ± 514	a	Eldajo (12)	2408 ± 240	a
				Elarit (12)	2388 ± 329	a
				Fawri (12)	2242 ± 744	a
				Eldigail (12)	2668 ± 568	b
				Elgama (12)	2596 ± 498	b
W-Kordofan (60)		3243 ± 637	b	Nshrbu (12)	3046 ± 510	cd
				Sbihat (12)	3342 ± 715	ce
				Jkhisat (12)	3272 ± 627	ce
				Umejija (12)	2913 ± 433	d
				Khiri (12)	3642 ± 690	e
All	(120)	2852 ± 697				

*Means corresponded by different letters in the same column are significantly (p<0.05) different

In N-Kordofan, the leaves from Eldigail and Elgama have significantly (p<0.05) higher calcium. However, the leaves from Khiri, W-Kordofan, are outstanding. The differences are of practical importance because in most of the cases they go to a level of more than 500mg/100g, which is more than half of the daily requirement by adults. In consideration of all trees selected for sample collection the range stretches from 1132 to 4519 mg/100g DRY MATTER (Figure 1).

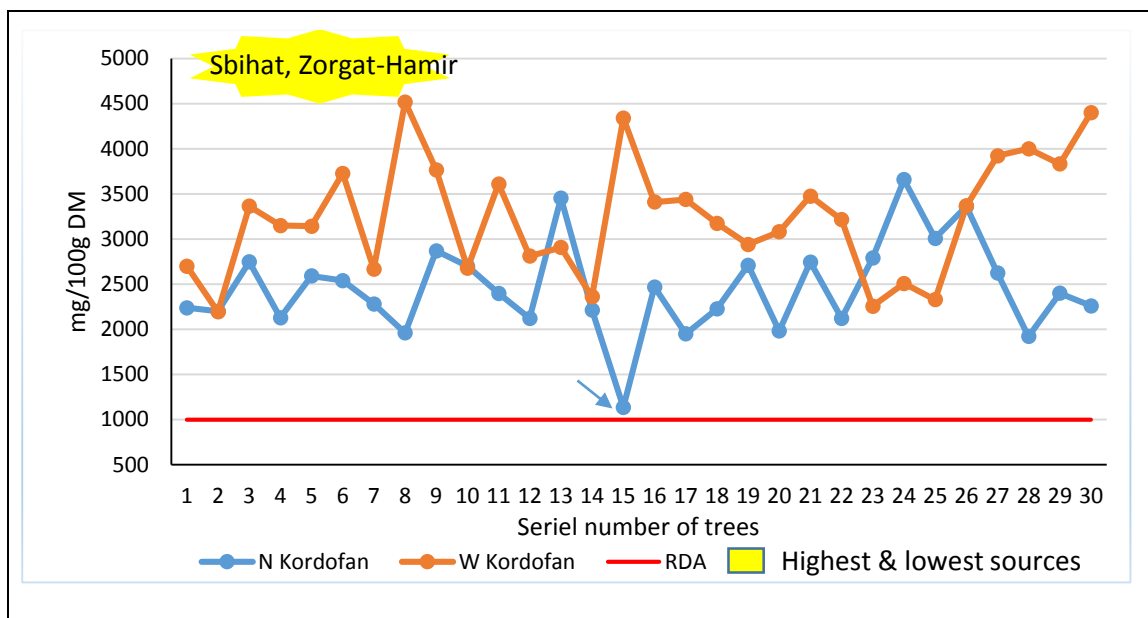


Figure 1. Calcium content (mg/100g DRY MATTER) of baobab leaves from trees in N & W Kordofan

The tree that produces the leaves with the least calcium content (1132mg/100g DRY MATTER) is located in N-Kordofan, in the village Fawri, site Garad, coordinates N 13 12.387 and E 30 21.947. The one with the highest calcium concentration (4519mg/100g DRY MATTER) is found in W-Kordofan, in the village Sbihat, site Zorgat-Hamir, coordinates N 13 00.377 and E 29 13.899.

Calcium is a major mineral that is required for structural, physiological and biochemical functions in the human body, and its inadequate consumption results in reduced bone density, increased risks of bone fracture, osteoporosis, and hypertension (10).

At least one third of the global population is affected by calcium deficiency, the proportion grows to >50% in Africa, and further increase to >75% when the daily diet is dominated by staple foodstuffs that are naturally poor in Ca but high in phytate (11, 12). The average dietary calcium intake in East Africa is lower than the recommended daily allowance (13, 14) and the dietary phytate-to-calcium ratio in the diet predominated by cereals (70%) retards absorption and intensify deficiency (15).

The extraordinary richness in calcium, its availability in water-stress areas

and low cost of production make baobab leaves attractive for human nutrition. An inclusion of an average of 35g macerated dry baobab leaves to the daily diet balances the recommended daily allowance, which is 1g/day for adults (16). However, it is essential to adjust the inclusion according to the concentration of calcium in the leaves of each location, meaning, supplementation in North Kordofan increases to 40g whereas that in West Kordofan goes down to 30g dry leaves. In contrast, 880g either of spinach, broccoli, or mangold or 440g kale, 600g chickpeas, 1100g green peas, 1300g lentils or 1litre milk is required to satisfy the daily allowance (17).

Magnesium

The average magnesium content of dry baobab leaves from N&W Kordofan is 555 ± 156mg/100g DRY MATTER and the range extends from 286.3 – 959.3mg/100g DRY MATTER (Table2, Figure 2). Unlike that of calcium, the baobab leaves from N-Kordofan contain significantly (p<0.05) more magnesium than those from W-Kordofan. There are also significant (p<0.05) differences between different villages.

District (n)	Mean ± SD	T-test*	Villages (n)	Mean ± SD	T-test*
N-Kordofan (60)	651 ± 151	a	Eldajo (12)	637 ± 132	a
			Elarit (12)	686 ± 108	a
			Fawri (12)	587 ± 124	b
			Eldigail (12)	599 ± 138	b
			Elgama (12)	747 ± 200	c
W-Kordofan (60)	460 ± 86	b	Nshrbu (12)	477 ± 54	d
			Sbihat (12)	407 ± 81	e
			Jkhisat (12)	436 ± 97	de
			Umejija (12)	448 ± 95	de
			Khiri (12)	528 ± 36	f
All (120)	555 ± 156				

*Means corresponded by different letters in the same column are significantly (p<0.05) different

Table 2. The average magnesium content (mg/100g DRY MATTER) of baobab leaves from two districts and ten villages in Sudan. The average magnesium content of baobab leaves in this study is comparable to those documented in earlier reports (6, 42). However, the influence of location and individual trees that gave results with very high range deserve attention in balancing a daily diet for correct supply of magnesium.

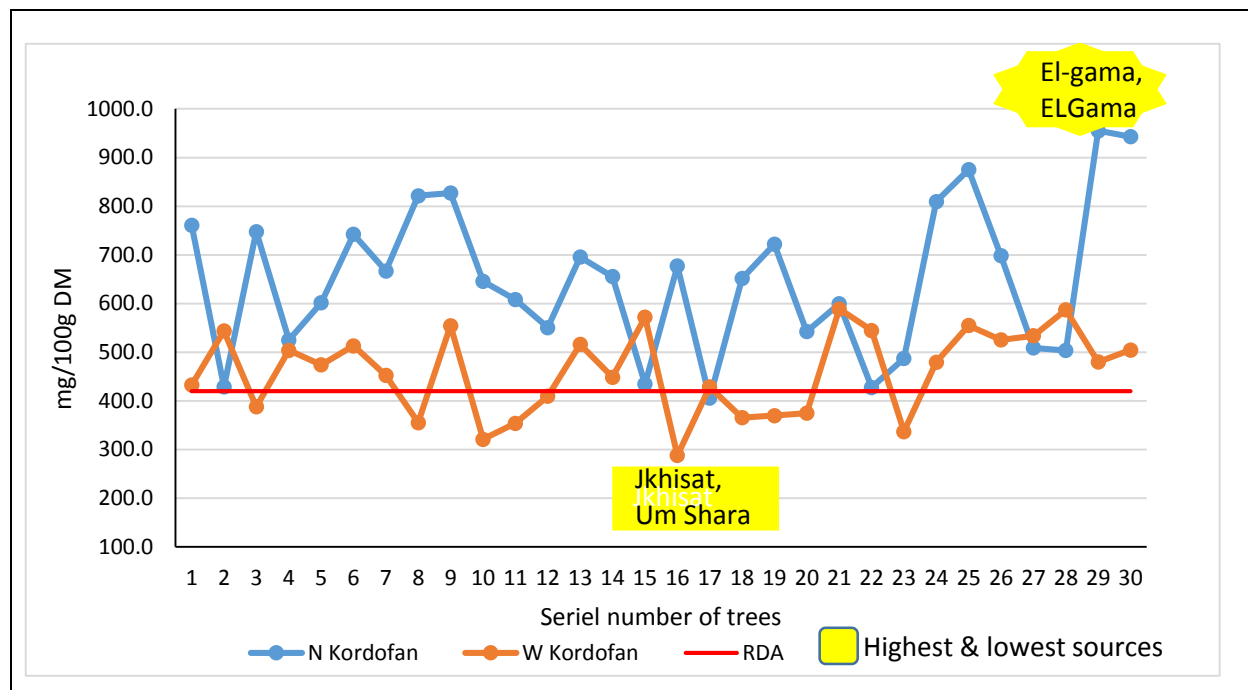


Figure 2. Magnesium content (100mg/100g intervals dry matter) of baobab leaves from trees in N & W Kordofan

The tree that produced the leaves with the outstanding ($p < 0.05$) magnesium concentration (957mg/100g dry matter) grows in N-Kordofan, village Elgama, site Elgama, coordinates N 13 12.080 and E30 18.378; whereas the one with the lowest magnesium concentration (286mg/100g DRY MATTER) grows in W-Kordofan, village Jkhisat, site Um Shara, coordinates N12 58.193 and E29 13.571.

Magnesium is involved in the synthesis and development of bones, other connective tissues and nuclear material; it also acts as a cofactor of more than 300 enzymes in metabolic processes, regulate muscle contraction, neuromuscular conduction, glycemic level, myocardial contraction and active trans-membrane transport of other ions (20, 21). Its deficiency can be catastrophic because it can lead to metabolic syndrome, type 2 diabetes, atherosclerosis, hypertension, oxidative stress, and cardiac dysfunction or even death (22). In addition, it can cause incalculable amount of health care cost to a nation (12). It is therefore essential to take good care of the real magnesium value of foodstuffs or complements like baobab leaves in fulfilling the daily requirement.

Some people call magnesium an “orphan mineral” because it has attained less attention than calcium and it has been less investigated (23). Recent reports claim that the prevalence of magnesium deficiency in Africa is negligible whereas that in the US and Europe is estimated at 48% (12, 22). In reference to the review of several studies, Naithani (2014) (24) claims that in about 60% of adults from these regions, dietary magnesium does not satisfy the daily requirement. The majority of the population consume less than the recommended level of Mg because their daily diet is based on processed food, demineralized water and foodstuffs from agricultural practices in Mg deficient soils (21, 25).

In view of relatively poor availability and accessibility of diverse foodstuffs in sub-Sahara Africa and the underrating of the daily allowance of Mg at 218mg/day (12), which is well below the recommended level of 420mg/day, the prevalence of Mg deficiency is unduly underestimated. However, baobab leaves, which excel Mg-rich food sources (whole

cereals, green vegetables, pulses and nuts), could complement the daily diet wherever and whenever necessary.

It is possible to cover the recommended daily allowance of magnesium (420mg/day) with 72g baobab leaves, or by 3x or 7x of this mass of dry beans/nuts or that of spinach respectively. As most of the staple foods cover half of the recommended allowance of magnesium, the level of baobab leaves (<50g) that complement the daily allowance of calcium could also enrich the diet to satisfy the desired level of magnesium.

The adequacy of magnesium to satisfy the recommended daily allowance is not the only character that proves normal biological development and good health but also the balance between magnesium and calcium consumption. A high deviation of calcium to magnesium ratio can result in the depression of the absorption, circulation and utilization of magnesium (39). Balancing the supply of calcium and magnesium can support long lasting good health of bones and the heart, and a calcium to magnesium ratio of <1.7 or >2.8 can be detrimental while a ratio of about 2 is optimal (40). In conditions of high calcium ratio as is the case with baobab leaves, even the consumption of RDA of magnesium may not be satisfactory inflicting physiological disorders that can cause health problems (41). It is essential to keep the balance. Magnesium is important as a structural component of bones, a facilitator of the absorption and utilization of calcium for bone formation and as a part of the factors that prevent osteoporosis and cardiovascular diseases (42, 43). It is therefore important to watch both the level of its adequacy and the balance of intake with calcium.

Iron

The average iron content (mg/100g DRY MATTER ± SD) of baobab leaves from N&W-Kordofan is 42.39 ± 11.65. However, there are significant ($p < 0.05$) differences between the two districts, some villages and individual trees (Table 3, Figure 3).

Table 3. The average iron concentration (mg/100g DRY MATTER) of dry baobab leaves from two districts and ten villages in Sudan

District (n)	Mean ± SD	Ttest*	Villages (n)	Mean ± SD	Ttest*
N-Kordofan (60)	49.30 ± 8.84	a	Eldajo (12)	57.95 ± 10.11	a
			Elarit (12)	53.05 ± 6.81	a
			Fawri (12)	45.65 ± 5.51	b
			Eldigail (12)	43.58 ± 4.28	b
			Elgama (12)	46.30 ± 8.09	b
W-Kordofan (60)	35.49 ± 9.93	b	Nshrbu (12)	34.65 ± 9.60	c
			Sbihat (12)	33.95 ± 5.39	c
			Jkhisat (12)	30.71 ± 5.07	c
			Umejija (12)	30.35 ± 10.59	c
			Khiri (12)	47.78 ± 6.94	b
All (120)	42.39 ± 11.65				

*Means corresponded by different letters in the same column are significantly (p<0.05) different

N-Kordofan produced the leaves with significantly (p<0.05) higher mean Fe content than W-Kordofan. Except for the baobab leaves from Khiri, all of the samples from the other villages of W-Kordofan have significantly (p<0.05) lower concentration of Fe than those from N-Kordofan, but, the means of the four villages did not prove any statistically meaningful differences.

is 20.35 – 71.47mg/100 DRY MATTER. The tree with the lowest iron content (20.35mg/100g DRY MATTER) is located in W-Kordofan, in a village known as Umejija, site Tomtaddod, coordinates N 12 59.801 and E 29 16.384. Those with the highest iron content are found in N-Kordofan, in the village Eldajo, site UM-Bokhas, coordinates N13 09.190 and E 30 19.346, and site Kattala, coordinates N 13 10.490 and E 30 18.971 (Figure 3).

The range of the mean Fe values of the samples collected from each tree

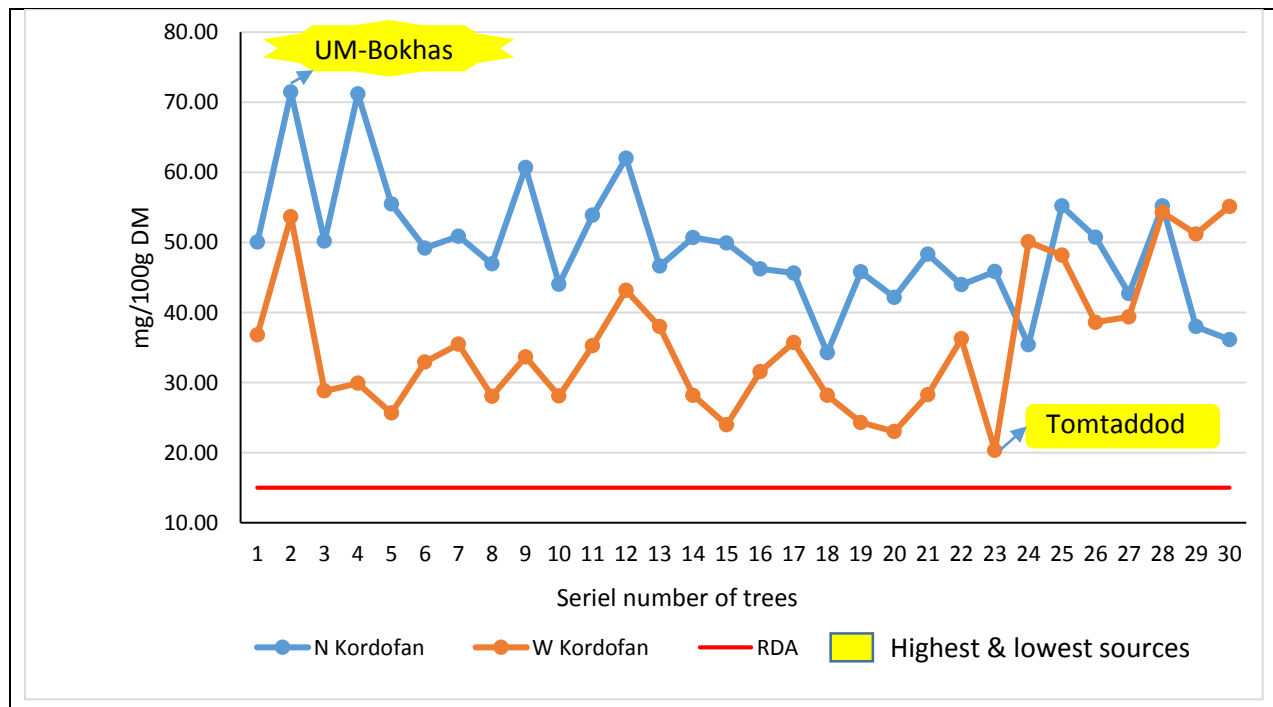


Figure 3. Fe concentration (mg/100g DRY MATTER) of baobab leaves from representative trees in N & W Kordofan

Iron deficiency anemia is a global health problem that affects all age groups with more prevalence in adolescence girls. Globally 50% of the anemia is estimated to result from iron deficiency (26). A cross-sectional study in India revealed that 50% of adolescent girls were anemic (27). In sub-Saharan Africa, the prevalence of anemia in preschool children range from 42% in Swaziland to 91% in Burkina Faso (28). The prevalence of anemia is still alarmingly high and is a serious public health concern because of its capacity to retard cognitive and psychomotor development (29).

Baobab leaves have great potential in tackling these challenges of local, regional or global dimension. In comparison to rich sources Fe from common food origin, baobab leaves from Kordofan in Sudan are unexcelled in iron content. They contain about 7x more iron than pulses and 10x more than that of oil seeds, spinach or even meat; the common foodstuffs considered rich in the element.

The recommended daily allowances for adults (15mg/day), pregnant women (30mg/day) or breast feeding mothers (20mg/day) could be

satisfied with 36g, 70g or 50g baobab leaves respectively. In contrast, about 250g, 500g and 350g of pulses or 7x that of baobab leaves are required for the three physiological states in the respective order. In view of the recommended restriction of the allowance of pulse for consumption at 80 – 100g/day (30), and negligible level of iron in the other components of staple diets of the poor community, about 20g of baobab leaves can complement the diet satisfactorily.

Zinc

The average zinc content (mg/100g DRY MATTER \pm SD) of the dry baobab leaves collected from both N & W-Kordofan is 1.94 ± 0.5 ; and that from N-Kordofan is significantly ($p < 0.05$) higher than that of W-Kordofan (Table 4). Unlike that of Ca, Mg and Fe, the impact of villages on Zn concentration, except that for Eldajo (2.11mg/100g DRY MATTER) and Khiri (1.47mg/100g DRY MATTER) is hardly distinctive. This could be attributed to the relatively low concentration of Zn and the high variability of values within each village (ref SD).

District (n)	Mean \pm SD	Ttest*	Villages (n)	Mean \pm SD	Ttest*
N-Kordofan (60)	2.08 ± 0.53	a	Eldajo (12)	2.11 ± 0.42	a
			Elarit (12)	1.86 ± 0.20	ab
			Fawri (12)	1.70 ± 0.27	cb
			Eldigail (12)	2.31 ± 0.74	dba
			Elgama (12)	2.45 ± 0.53	da
W-Kordofan (60)	1.79 ± 0.43	b	Nshrbu (12)	2.21 ± 0.54	dab
			Sbihat (12)	1.76 ± 0.42	cab
			Jkhisat (12)	1.72 ± 0.18	cb
			Umejija (12)	1.79 ± 0.33	cab
			Khiri (12)	1.47 ± 0.23	e
All (120)	1.94 ± 0.50				

*Means corresponded by different letters in the same column are significantly ($p < 0.05$) different

As shown in Figure 4, the mean Zn concentration ranges from a minimum of 1.11 mg/100g DRY MATTER for baobab leaves collected from W-Kordofan, village Khiri, site UM-Kitar, coordinates N 12 43.750 and E 29 30.858 to 3.52 mg/100g DRY MATTER for leaves collected from N-Kordofan, village El-Digail, site UmGull, coordinates N 13 14.063 and E 30 17.978.

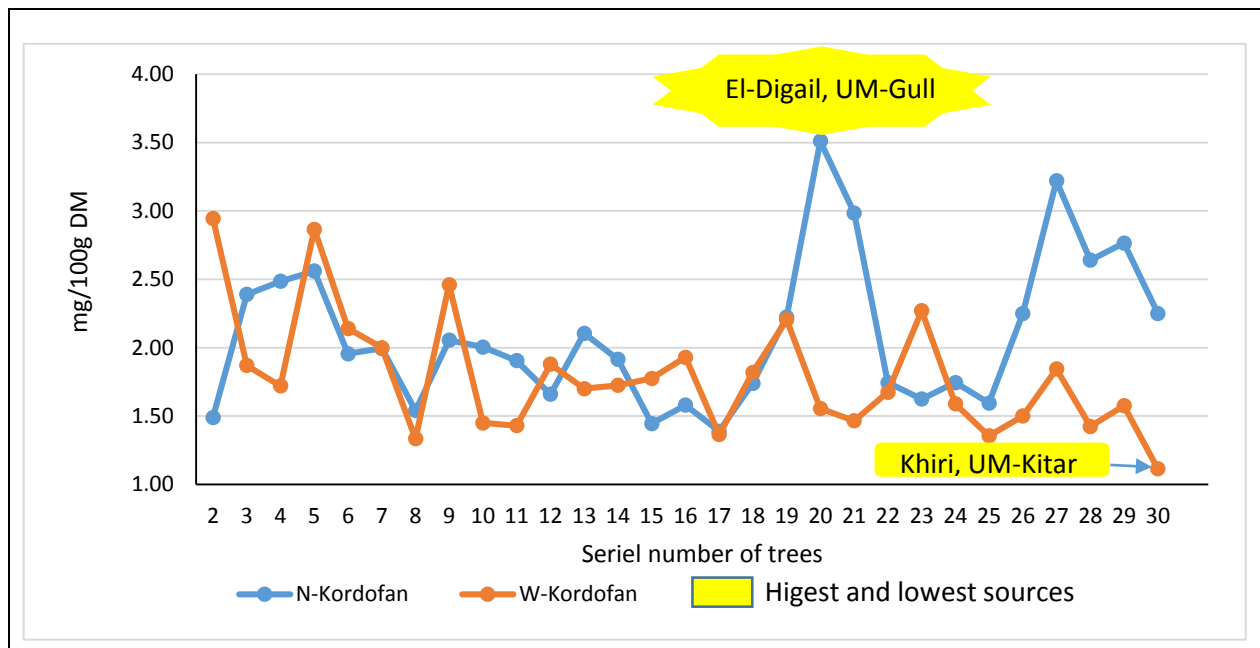


Figure 4. Zn concentration (0.5mg/100g interval dry matter) of baobab leaves from representative trees in N & W Kordofan

Baobab leaves are not exceptionally rich in zinc and they are not better sources than the common foodstuffs (pulses, nuts, whole corn, hard cheese and meat). A provision of 50g baobab leaves can only cover an average of about 10% of the daily-recommended allowance.

It is estimated that about 30% of the world population, mainly women, young children and adolescents living in disadvantaged setting are at risk of zinc deficiency (31, 32). The consequences include poor growth, slow cognitive and immune system development, and skin abnormalities. Poverty, food insecurity and staple diets high in cereals that are rich in phytate, the molecule that inhibits the absorption of zinc, count to the major causes of deficiency.

Baobab leaves that avail themselves even in water stress situation could quantitatively add to the diet and contribute to the prevention of the

unwanted incidences of zinc deficiency. This is particularly practicable in regions where plant-food production and food security are unsustainable. However, care needs to be taken on the large disproportionality of iron to zinc (22:1) in baobab leaves that could adversely affect the utilization of zinc. Iron can inhibit zinc absorption at such high ratio of Fe: Zn (38).

Copper

The average copper content of baobab leaves from sixty trees, distributed in N & W-Kordofan lies at 1.41 ± 0.293 mg/100g DRY MATTER. Those in N-Kordofan have highly significant ($p < 0.001$) concentration of Cu than those from W-Kordofan (Table 5). There are also significant ($p < 0.05$) differences between the mean Cu content of the leaves from the different villages in each district

District	(n)	Mean ± D	T-test*	Villages (n)	Mean ± SD	T-test*
N-Kordofan (60)		1.61±0.186	a	Eldajo (12)	1.53 ± 0.106	ac
				Elarit (12)	1.54 ± 0.288	ac
				Fawri (12)	1.62 ± 0.152	ac
				Eldigail (12)	1.75 ± 0.137	b
				Elgama (12)	1.62 ± 0.148	ac
W-Kordofan (60)		1.20±0.77	b	Nshrbu (12)	1.35 ± 0.287	c
				Sbihat (12)	1.33 ± 0.137	dc
				Jkhisat (12)	1.31 ± 0.124	dc
				Umejija (12)	1.06 ± 0.88	e
				Khiri (12)	0.95 ± 0.142	f
	All (120)			1.41±0.293		

*Means corresponded by different letters in the same column are significantly ($p < 0.05$) different

The leaves with the highest Cu concentration, 1.97 mg/100 g DRY MATTER, come from N-Kordofan, Elarit, Abbalye, coordinates N 13 12.074 and E 30 21.739 (Figure 5). The ones with least Cu content, 0.77 mg/100 g DRY MATTER, are from W-Kordofan, Khiry, Um Kiter, coordinates N 12 43.750 and E 29 30.858. Sixty per cent of the samples from N-Kordofan contain more than 1.5 mg Cu/100 g DRY MATTER, whereas only 10% of the samples from W-Kordofan reflect the same trend.

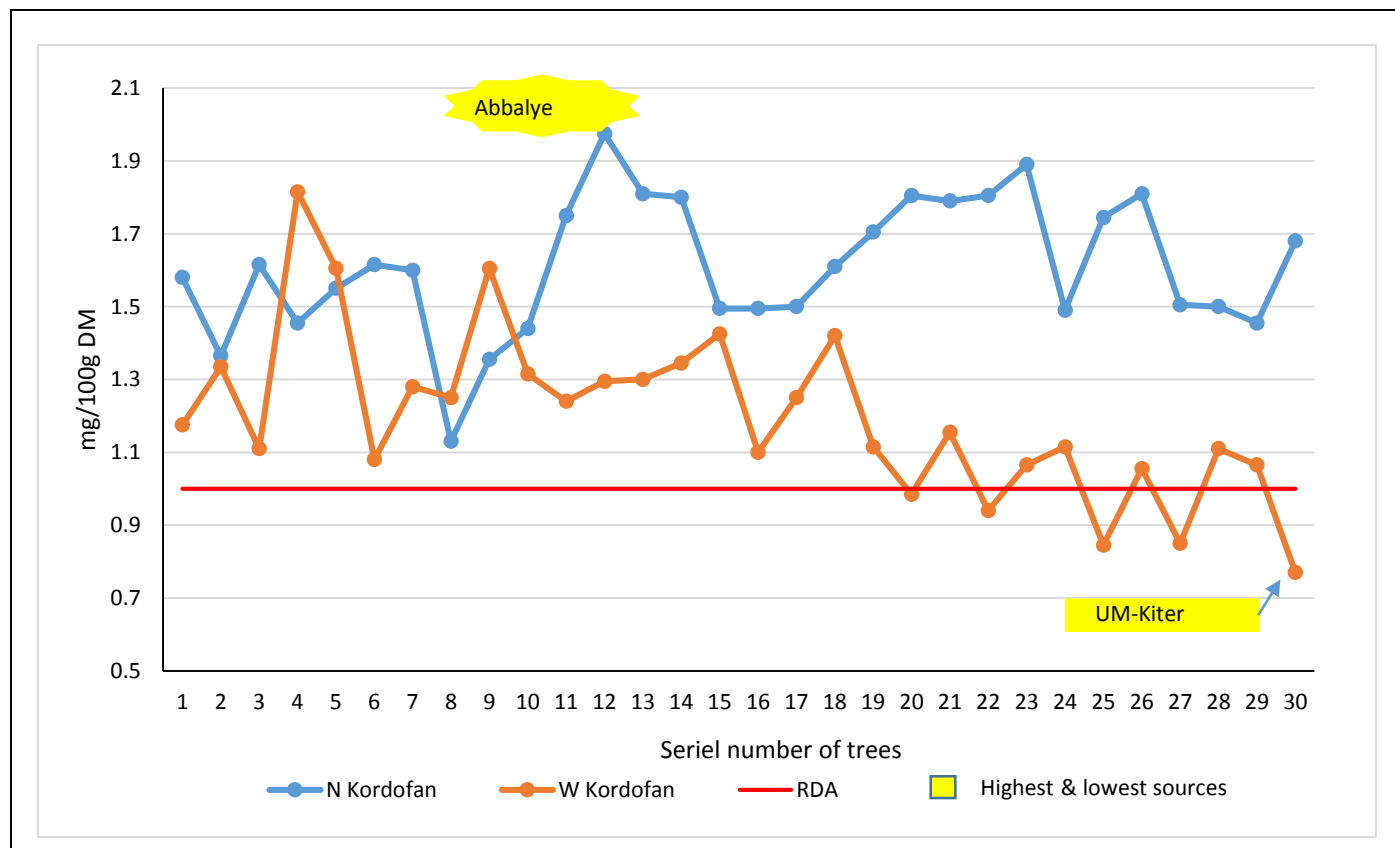


Figure 5. Copper content (mg/100g DRY MATTER) of baobab leaf samples from trees in N & W-Kordofan

Together with iron and zinc, copper is essential for the development of the body and the maintenance of health. It is a cofactor of the proteins involved in transcriptional regulation, oxidoreductases, mitochondrial electron transport, free radical scavenging and body defence mechanisms (43). Copper is crucial in the formation of the brain, the nervous system and haemoglobin, it also helps in sustaining the elasticity of blood vessels and healthy muscle tone, which are vital for healthy heart; its deficiency can cause ischaemic heart disease (43)

There are controversial views about the prevalence of Cu deficiency. One group assumes that copper is adequately supplied with the food and clinical deficiency is a result of poor bioavailability because of

interactions with other nutrients. Some others are of the opinion that Cu intake has been declining with the consumption of common food and this does not even balance the minimum recommended daily allowance (0.9mg/day) let alone the optimal intake of 2mg/day (33).

Baobab leaves are not exceptionally rich in copper; they have lower value than nuts but better than that of commonly known rich sources such as pulses and whole kern grains. An average of 100g pulses, 25g nuts or 72g baobab leaves could satisfy the daily requirement (1mg/day) of an adult. In conditions where the rich sources of copper are lacking or the general food supply is marginal, a level of 50g baobab leaves can contribute to the half of the daily requirement.

Manganese

The average manganese content of the baobab leaves from N-&W-Kordofan is (4.46±.1.81 mg/100g DRY MATTER). However, those from N-Kordofan have significantly (p<0.05) higher level of Mn than those from W-Kordofan. There are also significant (p<0.05) differences between the means of the villages in each district (Table 6).

Table 6. The average Mn content (mg/100g DRY MATTER) of dry baobab leaves from two districts and ten villages in Sudan

District (n)	Mean ± SD	Ttest*	Villages (n)	Mean ± SD	Ttest*
N-Kordofan (60)	5.67 ± 0.75	a	Eldajo (12)	6.18 ± 0.75	a
			Elarit (12)	6.16 ± 0.93	a
			Fawri (12)	5.49 ± 2.12	ab
			Eldigail (12)	4.27 ± 1.86	b
			Elgama (12)	6.24 ± 1.20	a
W-Kordofan (60)	3.41 ± 1.21	b	Nshrbu (12)	3.89 ± 1.07	bc
			Sbihat (12)	4.22 ± 1.44	b
			Jkhisat (12)	2.80 ± 0.55	d
			Umejija (12)	2.16 ± 0.79	e
			Khiri (12)	3.98 ± 0.61	b
All (120)	4.46 ± 1.81				

*Means corresponded by different letters in the same column are significantly (p<0.05) different

Eighty per cent of the baobab leaves in N-Kordofan contain more than 5mg/100g DRY MATTER manganese, whereas the same proportion of baobab leaves from W-Kordofan contain less than 4mg/100g DRY MATTER . The range of the mean values for samples collected from different trees that are distributed in the two districts extends from 1.39mg/100g DRY MATTER to 9.33mg/100g DRY MATTER (Figure 6).

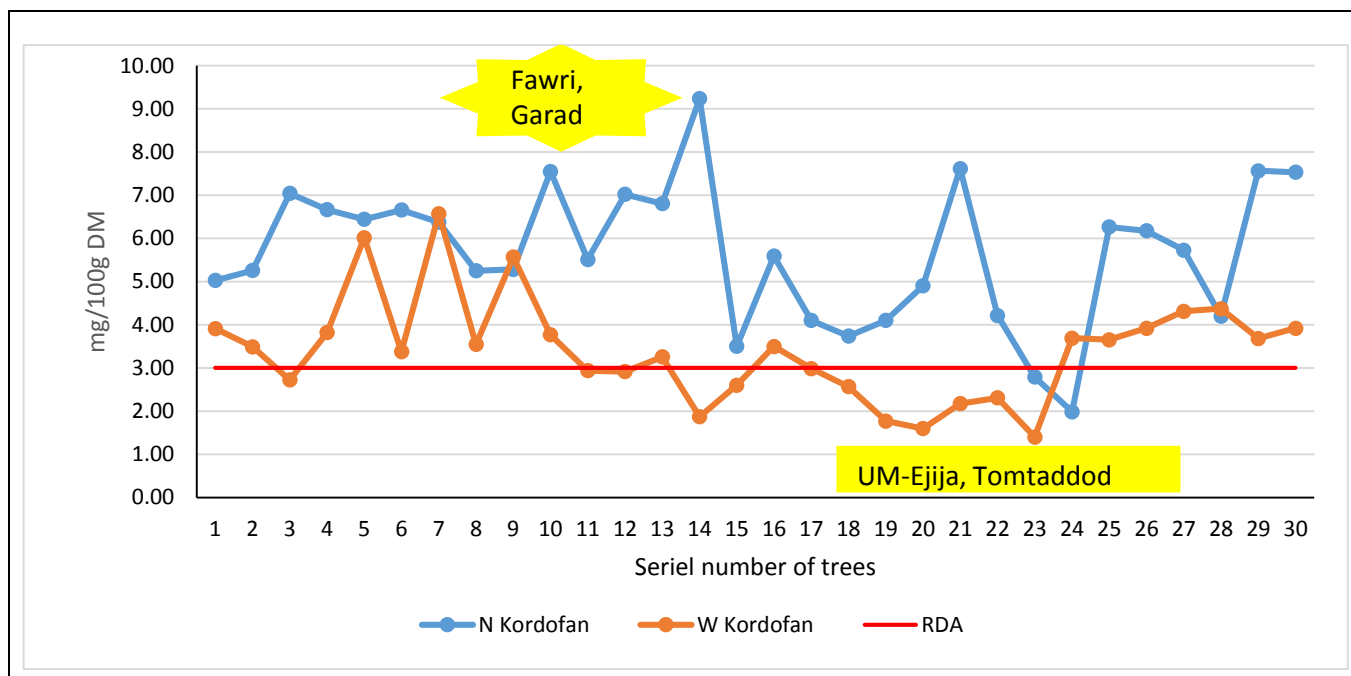


Figure 6. (1mg/100g interval) Manganese content of baobab leaves collected from 60 trees in N-&W-Kordofan

The baobab leaves with the mean least manganese content (1.39mg/100g DRY MATTER) are collected from a tree growing in W-Kordofan, village UMejija, site Tomtaddod, coordinates N12 59.801 and E 29 16.384. The ones with the highest manganese content (9.33mg/100g DRY MATTER) are collected from N-Kordofan, Fawri, Garad, N 13 12.387 E

30 21.947.

In human nutrition, manganese plays important roles as an activator and a cofactor of a number of enzymes in the metabolic processes. It is especially active in protein digestion and amino acids utilization. As a component of Mn-SOD (manganese superoxide dismutase), manganese

belongs to an antioxidant enzyme that neutralizes oxidative radicals and protects the body from inflammatory damages.

Manganese deficiency is a rare case not only because of its adequate supply in common foodstuffs but also because of its availability in drinking water and the air people inhale (34). Whole cereal grains, nuts and legumes are rich sources while meat, fish and other animal products are poor in manganese content. The Mn content of drinking water varies between 1µg and 2mg /L depending on location and the extent of adulteration with soil-, agrochemicals-, and industrial residues (35).

The estimated safe RDA of manganese for adults ranges between 2 and 5mg (36). Excess intake of manganese interacts with iron in the digestive tract and lowers its availability. In conditions where more than required amount of manganese enters the blood system, the homeostatic mechanism facilitates its storage, among others, in the liver and brain; which eventually become part of the exposing factors to liver cirrhosis and Parkinson's disease (34, 37). Therefore, the regulation of supply and intake is more challenging than satisfying the requirement. However, the suggestion of adding 50g dry baobab leaves to complement a diet with calcium and iron still holds because the level of manganese, in such practices, will not go over the limit.

The nutritional adequacy of many of the minerals is not only a subject of supply but also that of absorption and utilization. Some minerals interact with each other in the digestive tract particularly during the competition to occupy a position in the active transport carriers thereby hindering the absorption of the other. Interactions of nutritional significance include Ca-Mg, Mn-Fe, Fe-Cu, and Zn-Cu; when the first mineral in each couple excels, then it suppresses the availability of the partner (37).

Conclusion

Baobab leaves are exceptionally rich in calcium and iron; they contain about 10x more calcium than milk and over 7x more iron than either pulses, nuts, spinach or meat, the common foodstuffs that are considered as the major sources of the minerals. Their mean magnesium, copper and manganese concentration is moderate but they are low in zinc.

There are high variabilities in mineral composition of baobab leaves from different locations and trees, signifying the need for restrictive and specific use of data. It is suggested that some research work focusing on biological characters of baobab (phenotypic/genetic, age) and environmental factors (soil, climate, care, season of harvest...) on which the trees grow are prerequisites for the preparation of classified standard table of nutrient composition of baobab products usable in formulating balanced diets.

The richness of baobab leaves in calcium and iron is a blessing because they could curtail deficiency problems in many parts of the world. However, the imbalance of several of the minerals beyond the biologically accepted limits (ratio) can lead to interactions and the suppression of the bioavailability and utilization of one another, e.g. Ca: Mg ratio of about 2 is optimal but <1.7 and >2.8 are detrimental. Similarly, interactions are possible between Fe and either Zn, Mn or Cu. This implicates the need for broader scope of observation in complementing diets with baobab leaves for optimizing the level of one or the other mineral in diet formulation.

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