COMPARATIVE STUDIES ON THE NUTRIENT COMPOSITION OF SHADE- DRIED AND SUN-DRIED LEAVES OF ROSSELLE (*HIBISCUS SABDARIFFA* L.)

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Abstract

***Hibiscus sabdariffa,* a leafy vegetable consumed extensively in Ghana, provides important source of micronutrients and essential amino acids in diets. Although sun-dried vegetables have been used as alternatives to green vegetables, no study has been done to ascertain the nutritional content against that of shade-dried leaves. This study determined nutritional composition of shade-dried and sun-dried leaves of *Hibiscus sabdariffa* ('Bera') to evaluate the various nutrients supplied, and their abilities to meet the recommended dietary allowance (RDA) for various age and physiological groups of people. Sun- and shade-dried leaves of *Hibiscus sabdariffa* were analyzed for their nutritional content using standard analytical methods. Mean values of protein, carbohydrates, ash, moisture and fibre for sun-dried leaves were 22.7, 42.2, 10.3, 8.1, 8.54 g/100g respectively, for shade-dried leaves, values were 1.6, 7.0, 1.4, 87.1, 1.6 g/100g respectively. Mean values of calcium, Iron, potassium, magnesium, phosphorus, and zinc were: sun-dried leaves; 411.0, 20.1, 39.3, 36.5, 54, 1.8 mg/100g; shade dried leaves values were: 65.6, 6.2, 5.6, 4.8, 14.1, 1.4 mg/100g. For RDA of nutrients per 100g sample, sun-dried leaves provided protein in the range of 32.0 – 206.4 %, carbohydrates 21.5 – 47.7 % and fibre, 29.4 – 47.6 %. For shade-dried leaves, protein was 2.3 – 14.2 %, carbohydrates 3.3 – 7.3 % and fibre 5.5 – 8.4 %. Percentage RDA of minerals supplied per 100g sample for various age and physiological groups were; sun-dried leaves, Fe (74.6 – 287.6), Mg (8.7 – 48.7), Ca (31.6 – 152.2), P (4.3 – 19.6), K (770.6 – 5614.3), Zn (13.5 – 58.3); shade-dried leaves, Fe (23.9 – 89.0), Mg (1.1 – 6.4), Ca (5.0 – 24.3), P (1.1 – 5.1), K (110 – 801.4), Zn (11.0 - 47.7). The study indicates, sun-drying is a better method of preserving *Hibiscus sabdariffa* leaves. It could be included in diet to improve micronutrient intake which is a major problem in Ghana.**

Key words: Recommended Dietary Allowance, Shade-dried leaves, Sun-dried leaves, *Hibiscus sabdariffa*

Introduction

Attaining food and nutrition security continues to be the concern for most health, nutrition and agricultural agencies especially in the developing countries such as Ghana. Diets rich in African leafy vegetables are important sources of vitamins, minerals, essential amino acids and health promoting phytochemicals necessary to address challenges of undernutrition and obesity (Yang and Keding, 2009, Yang et al., 2006). In Sub-Saharan Africa, consumption of vegetables falls far below WHO recommended minimum intake of 400g per person per day, an obvious indication of micronutrient deficiency (WHO, 2003).

Roselle is a leafy vegetable and belongs to the family, *Malvaceae*. It is consumed extensively in various forms in the Northern Regions of Ghana and is locally called "bera." The leaves of the plant are used mainly for soup. The flowers are used for making local drink called "Sobrodo" and the fruits are used for preparing soup referred to as "Berinimdi." The fresh leaves of the plant contain per 100 g nutrients including protein 3.30 g, fat 0.3 g, fibre 10.0 %, ash 1.0 g, carbohydrates 9.20 g, calcium 213 mg, phosphorus 93.0 mg and iron 4.8 mg (Islam et al., 2016).

It is said to have diuretic effects and anti-hypertensive properties (Onyenekwe et al., 1999). In the traditional setting, *Hibiscus sabdariffa* is used as medicine since it is believed to cure malaria(Ojezele et al., 2013) and other diseases including cancer (Lo et al., 2007), scurvy (Morton, 1987), dyspepsia(Owulade et al., 2004) and dysuria (Duke, 1983, Fullerton et al., 2011). As a 'coping crop'',(crops used during periods of food insecurity or famine) roselle leaves harvested during the rainy season can be stored for use in the dry season when production stops and there is limited availability and reduced dietary diversity. The obvious challenge faced by farmers is therefore preservation of the vegetable. Various forms of dehydration are widely practiced by farmers for preservation of leafy vegetables. Although sun-dried vegetables have been used over the years as alternatives to green vegetables, few studies considered the effects of this method on nutrient composition against other forms of preservation. A study by Onoja (2014) showed very little variation in nutrients concentration in sun and shade dried leaves of fluted pumpkin (*Telfairia occidentalis* leaves) whilst Emelike and Ebere (2016) showed higher protein and carbohydrate concentrations in sun dried Moringa leaves compared to shade dried ones. In a similar study, air dried leaves retained more carbohydrates and proteins than sun dried leaves (Oni et al., 2015) These studies suggest inconsistencies in the effects of different dehydration methods on vegetable preservation. In Ghana, there is limited scientific data on the effects of dehydration on nutrient composition of Roselle in spite of its wide usage. There is therefore limited scientific data on effects of these methods on nutritional quality of the vegetable. The objective of this study therefore was to determine and compare the nutrient composition of shade-dried and sun-dried leaves of *Hibiscus sabdariffa* grown in Ghana, for enhanced utilization.

Materials and methods

Fresh leaves of *Hibiscus sabdariffa* were collected from Nyankpala and its surrounding villages in the Tolon-Kumbugu District in the Northern Region of Ghana for a comparative study on the nutrient content after shade-drying and after sun-drying. The samples collected were washed with distilled water until all dust was removed, and the water drained off. The sample was divided into two parts: one part was dried in the sun and referred to as sun-dried and the other in shade (shade-dried) for 72 hours each after which they were placed in separate containers and labeled accordingly.

In each case the samples were finely ground in a sample mill (Cyclotec 1093, Tecator, Sweden) and representative samples were analyzed as duplicates for moisture, protein, fat, fibre and ash with methods described by Association of Official Analytical Chemists (AOAC, 2000). Moisture was determined by drying 10 g of milled sample in hot-air oven at 105^{o}C for 24 hours until constant weight. Crude protein was determined by Kjeldahl method [Total nitrogen, (N) (N x 6.25)]. Neutral detergent fibre (NDF) was determined according to the method of (Van Soest et al., 1991). Ash content of the samples was determined by incineration in a muffle furnace at 550°C for 12 hours until the sample turned white. Carbohydrate (CHO) was determined by difference as 100 – (% moisture + % crude fat + % crude protein + % fibre + % ash) and dietary energy of the milled leaves was estimated by multiplying percentage crude carbohydrates and crude protein by 16.7 and crude fat by 37.7 (Aberoumand, 2011).

Mineral composition was determined according to procedure described by Asaolu and Asaolu (2010) using Atomic Absorption Spectrophotometer (Buck Scientific Model, 200A). Two grams (2g) of sample was digested in concentrated perchloric acid and concentrated nitric acid in the ratio of 5:3. The resulting solution was heated in water bath at 80°C for three hours. The solution was cooled and filtered with Whatman filter paper into a 100ml volumetric flask and made to the mark with deionized water.

The percentage contribution of 100g of shade- and sun-dried leaves of *Hibiscus sabdariffa* of the RDA of measured nutrients was determined by expressing the amount of such nutrients supplied by the leaves as a percentage of RDA for the various age and physiological groups.

Statistical Analysis

Data analysis was by two-sample t test with equal variance using Stata version 9.

Results

The results of the proximate and mineral compositions of the two samples (sun- dried and shade- dried leaves) of roselle are presented in Tables 1 and 2 respectively. The results showed that the nutrient composition of roselle was affected by the treatments. For the same drying period the moisture content of sun-dried sample was 82. 9 % ($P < 0.001$) lower than the moisture content of shade-dried leaves (Table 1). The sun-dried (leaves had higher concentration of all nutrients than the air-dried (AD) leaves. Crude ash, crude fibre and crude protein, carbohydrates and energy were significantly ($P< 0.001$) higher in the sun-dried leaves than the shade-dried leaves. Fat was also significantly ($P < 0.05$) higher in the sun-dried leaves than in the shade- dried leaves. All parameters measured were higher in the sun-dried leaves in the range of 68 % (crude fat) to 86.7 % crude (protein). The combined concentration of Carbohydrates, Protein and Fat was about 78 % higher in the sun-dried leaves than in shade-dried leaves, with carbohydrates predominating.

Table 2 presents mineral composition of sun-dried and shade- dried leaves of roselle. Similar to the proximate composition, the mineral composition were affected by the applied treatments. All the minerals determined were higher in the sun-dried samples than in the shade-dried samples. Calcium, Potassium and Magnesium were more than 70 % ($P < 0.001$) higher in sun-dried leaves than shade-dried ones whilst Iron and Phosphorous were more than 50 % ($P < 0.001$) higher in sun-dried leaves. Zinc was 10 % ($P < 0.037$) higher in sun-dried leaves.

The percentage computed RDA of protein, carbohydrates and fibre supplied by sun- and shade- dried leaves of *Hibiscus sabdariffa* for individuals of various age and physiological groups are shown in Table 3.

The shade-dried leaves generally supplied much lower concentration of the nutrients than the sun-dried leaves. For all physiological groups % computed daily allowance of fibre, carbohydrates and protein supplied by shade-dried leaves ranged between 4.2 to 8.4 %, 3.3 to 7.3 % and 2.3 % to 14.2 % respectively. The highest value of 14.2 % (protein) was observed for infants 7 – 12 months whilst the lowest, 2.3 % also of protein was recorded for pregnant and lactating mothers (Table 3). Sun-dried leaves provided for fibre, carbohydrates and protein values in the ranges of 22.7 % (males, 14 – 15 years) to 47.6 % (infants 7 – 12 months), 21.5 % (lactating mothers) to 47.7 % (infants 7 – 12 months) and 32.0 % (pregnant and lactating mothers) to 206.4 % (infants 7 – 12 months) respectively of the RDA. Sun-dried leaves supplied more than enough protein per 100 g leaves to meet the RDA of individuals 8 years and below.

Table 1: Proximate and energy composition of sun-dried and shade-dried leaves of *Hibiscus sabdariffa* grown in Northern Ghana

Macronutrients	Treatment means (g/100 g)		P value
	Shade-dried leaves	Sun-dried leaves	
	Mean ± SD	Mean ± SD	
Ash (g)	1.4 ± 0.05	10.3 ± 0.08	< 0.001
CHO (g)	7.6 ± 0.06	46.9 ± 0.14	< 0.001
Energy (Kj)	179.5 ±0.15	1292.3 ± 0.06	< 0.001
Fat (g)	0.7 ± 0.04	3.5 ± 0.06	0.003
Fiber (g)	1.6 ± 0.06	8.5 ± 0.1	< 0.001
Protein (g)	1.6 ± 0.03	22.7 ± 0.04	< 0.001
Moisture (g)	87.1 ± 0.01	8.1 ± 0.11	< 0.001

Table 2: Mineral composition of sun-dried and shade-dried leaves of *Hibiscus sabdariffa* grown in Northern Ghana

Micronutrients	Treatment means (g/100 g)		P value
	Shade-dried leaves	Sun- dried leaves	
	Mean ± SD	Mean ± SD	
Calcium	65.6 ± 0.01	411 ± 0.045	< 0.001
Iron	6.2 ± 0.05	20.1 ± 0.03	<0.001
Potassium	5.6 ± 0.03	39.3 ±0.05	<0.001
Magnesium	4.8 ± 0.01	36.5 ± 0.02	<0.001
Phosphorus	14.1 ± 0.025	54.0 ±0.3	<0.001
Zinc	1.4 ± 0.03	1.8 ±0.06	0.037

Table 3: Percentage recommended dietary allowances (% RDA) of some macronutrients supplied by air and solar dried leaves of *H. sabdariffa* L. grown in Northern Ghana. Supply in terms of 100 g of edible portion

Life stage (Years)**	RDA (g/Day)**			Percentage computed dietary allowance per 100g *Hibiscus sabdariffa* leaves					
				Shade-dried			Sun-dried		
	Fibre	CHO	Prot.	Fibre	CHO	Prot.	Fibre	CHO	Prot.
7 - 12 *	-	95	11	-	7.3	14.2	47.6	47.7	206.4
1 - 3	19	130	13	8.4	5.4	12.5	44.9	34.8	174.6
4 - 8	25	130	19	6.4	5.4	8.5	34.2	34.8	119.5
Males									
9 - 13	31	130	34	5.2	5.4	4.8	27.9	34.8	66.8
14 - 18	38	130	52	4.2	5.4	3.1	22.7	34.8	43.7
19 - 30	38	130	56	4.2	5.4	2.9	22.7	34.8	40.5
31 - 50	38	130	56	4.2	5.4	2.9	22.7	34.8	40.5
50 - 70	30	130	56	5.3	5.4	2.9	28.8	34.8	40.5
70+	30	130	56	5.3	5.4	2.9	28.8	34.8	40.5

Females									
9 - 13	26	130	34	6.2	5.4	4.8	32.8	34.8	66.8
14 - 18	26	130	46	6.2	5.4	3.5	32.8	34.8	49.3
19 - 30	25	130	46	6.4	5.4	3.5	34.1	34.8	49.3
31 - 50	25	130	46	6.4	5.4	3.5	34.1	34.8	49.3
50 - 70	21	130	46	7.6	5.4	3.5	40.7	34.8	49.3
70+	21	130	46	7.6	5.4	3.5	40.7	34.8	49.3
Pregnancy									
≤ 18 - 50	28	175	71	5.7	4.0	2.3	30.5	25.8	32.0
Lactation									
≤ 18 - 50	29	210	71	5.5	3.3	2.3	29.4	21.5	32.0

*months, **Calculation of percentage recommended dietary allowances supplied by sun-and shade-dried leaves of *Hibiscus sabdariffa* L. was based on references figures obtained from Summary Table: Dietary Reference Intakes (Gelaw et al.) (Gelaw et al. 2013): Recommended Dietary Allowances and Adequate Intakes, Total Water and Micronutrients. Food and Nutrition Board, Institute of Medicine, National Academies Available @ https://www.ncbi.nlm.nih.gov/books/NBK56068/

Percentage Recommended Dietary Allowance (%RDA) of selected Minerals supplied by 100 g of Sun- and Shade-dried leaves of Hibiscus sabdariffa L.

Table 4 provides a guide to the average nutrient intake required by various physiological groups in relation to "safe and adequate" amount and the extent to which the shade and sun-dried leaves of the plant satisfy these amounts. . In this context, "safe" means "not too much" and "adequate" means "not too low".

Shade-dried leaves supplied potassium in excess of RDA by 10 -700 % for the various physiological groups whilst the maximum amount of iron supplied ranged between 69 and 89 %. Percentage RDA of phosphorus and magnesium supplied were very low ranging from 1.1 to 5.1 % and 1.1 to 6.4 % respectively. Percentage of RDA of potassium supplied by sun-dried leaves exceeded the RDA for all age and physiological groups by 670 % (lactating mothers) to 5514 % (infants, 7 -12 months). The lowest percentage iron supplied (74.6 %) of RDA was recorded for pregnant women in the age group of 18 to 50 years. For all other physiological groups the supply exceeded the maximum RDA by 11.8 – 187.6 %. Besides children between 7 months and 8 years, the supply of potassium and magnesium were generally low not exceeding 15 % of the RDA.

Discussion

The concentrations of nutrients were generally higher in sun-dried leaves than in the shade-dried leaves. This observation is consistent with the findings of Chege et al. (2014) which suggested that solar drying results in concentration of nutrients such as iron, zinc and beta-carotene. This may be due to the loss of water which increases nutrients density..Thus the concentration of nutrients in a leave is influenced by drying time and temperature. A dehydration process that rapidly removes moisture from a plant tissue inactivatse the plant enzymes and reduce the loss of nutrients. Drying time is relatively shorter in sun drying than shade drying therefore sun drying will reduce the loss of non-structural carbohydrates, loss of volatile organic compounds and protein due to relatively short time available for metabolic activities (Ramsumair et al., 2014).

Protein concentration in sun-dried leaves compared favourably with the observation of Taiga et al. (2008), that protein content of some leafy vegetables ranged between 3.3 to 29.3 %.. The protein content was however 51.6 % and 60.5 % higher than levels reported by Kwenin et al. (2011) for *Moringa oleifera* and *Talinum triangulare* respectively. It was also consistent with the protein content of *Vigna unguiculata* (21.96 %) (Patricia et al., 2014) and Ogyefo, a variety of *Ipomea batatas* (Owusu et al., 2008). The protein content of shade dried leaves was very low compared to sun-dried in the current study and other studies reported above.

As shown in Table 3, 100 g of the sun-dried leaves provided more than 60 % of the RDA of proteins for individuals 9-13 years and over 100 % of the RDA of children 8 years and below. It also supplied adequately the protein requirements of adults, pregnant and lactating mothers. Children need protein and energy for growth thus in areas where protein energy malnutrition among children is high and intake of animal source food is low, the use of sun-dried leaves of *Hibiscus sabdariffa* could be very important for their survival. Sun-dried leaves as a plant food derived more than 12 % of its caloric value from protein and therefore constitute a good source of protein (Jimoh et al., 2010, Ali, 2009).

The crude fat content of sun-dried leaves in the curent study related positively with content of *Xanthosoma sagittifolia* (Kotombire),(3.2 %) but higher than reported value for *Amaranth cruenth* (3 %), *Talinum triangulare* (1.3 %) and *Moringa oleifera* (1.5 %) (Kwenin et al., 2011) and *S. nigrum* leaves (1.8 %) (Gqaza et al., 2013). Shade-dried leaves had low content of crude fat compared to sun-dried leaves in the current study but higher than the crude fat content of Ogyefo (*Ipomoea batatas*) (Owusu et al., 2008). The low levels of crude fat observed supports the suggestion that leafy vegetables are not good sources of fats (Ejoh et al., 1996). A diet that provides 1-2 % of its caloric energy as fat is sufficient for human beings as excess fat consumption yields to obesity and it associated implications of cardiovascular disorders including atherosclerosis, cancer and aging (Antial et al., 2006, Kris-Etherton et al., 2002). Foods containing sun-dried leaves of *H. sabdariffa* would be more palatable than foods containing shade-dried leaves and foods containing some varieties of sweet potato because as functionality, dietary fat increases palatability by absorbing and retaining flavours (Aiyesanmi and Oguntokun, 1996).

Table 4: Percentage RDA of some minerals supplied by Shade- and Sun-dried Leaves of *Hibiscus sabdariffa* L. grown in Northern Ghana. Supply in terms of 100 g of edible portion

Life stage (years)**	RDA(mg/day)**						Computed percentage of recommended dietary allowance of minerals per 100g *Hibiscus sabdariffa* leaves											
							Shade-dried						Sun-dried					
	Fe	Mg	Ca	P	K(1000)	Zn	Fe	Mg	Ca	P	K	Zn	Fe	Mg	Ca	P	K	Zn
7 - 12 *	11	75	260	275	0.7	3	56.6	6.4	25.2	5.1	801.4	47.7	183.0	48.7	158.1	19.6	5614.3	58.3
1 - 3	7	80	700	460	3.0	3	89.0	6.0	9.4	3.1	187.0	47.7	287.6	45.7	58.7	11.7	1310.0	58.3
4 - 8	10	130	1000	500	3.8	5	62.3	3.7	6.6	2.8	147.6	28.6	201.3	28.1	41.1	10.8	1034.2	35.0
Males																		
9 - 13	8	240	1300	1250	4.5	8	77.9	2.0	5.0	11	124.7	17.9	251.6	15.2	31.6	4.3	873.3	21.9
14 - 18	11	410	1300	1250	4.7	11	56.6	1.2	5.0	11	119.4	13.0	183.0	8.9	31.6	4.3	836.2	15.9
19 - 30	8	400	1000	700	4.7	11	77.9	1.2	6.6	2.0	119.4	13.0	251.6	9.1	41.1	7.7	836.2	15.9
31 - 50	8	420	1000	700	4.7	11	77.9	1.1	6.6	2.0	119.4	13.0	251.6	8.7	41.1	7.7	836.2	15.9
51 - 70	8	420	1200	700	4.7	11	77.9	1.1	5.5	2.0	119.4	13.0	251.6	8.7	34.2	7.7	836.2	15.9
70+	8	420	1200	700	4.7	11	77.9	1.1	5.5	2.0	119.4	13.0	251.3	8.7	34.2	7.7	836.2	15.9
Females																		
9 - 13	8	240	1300	1250	4.5	8	77.9	2.0	5.0	1.1	124.7	17.9	251.6	15.2	31.6	4.3	873.3	21.6
14 - 18	15	360	1300	1250	4.7	9	41.5	1.3	5.0	1.1	119.4	15.9	134.2	10.2	31.6	4.3	836.2	19.4
19 - 30	18	310	1000	700	4.7	8	34.6	1.5	6.6	2.0	119.4	17.9	111.8	11.8	41.1	7.7	836.2	21.9
31 - 50	8	320	1000	700	4.7	8	77.8	1.5	6.6	2.0	119.4	17.9	251.6	11.4	41.1	7.7	836.2	21.9
51 - 70	8	320	1200	700	4.7	8	77.9	1.5	5.5	2.0	119.4	17.9	251.6	11.4	34.2	7.7	836.2	21.9
70+	8	320	1200	700	4.7	8	77.9	1.5	5.5	2.0	119.4	17.9	251.6	11.4	34.2	7.7	836.2	21.9
Pregnancy																		
≤ 18	27	400	1300	1250	4.7	12	23.9	1.2	5.0	1.1	119.4	11.9	74.6	9.1	31.6	4.3	836.2	14.5
19 - 30	27	350	1000	700	4.7	11	23.9	1.4	6.6	2.0	119.4	13.0	74.6	10.4	41.1	7.7	836.2	15.9
31 - 50	27	360	1000	700	4.7	11	23.9	1.3	6.6	2.0	119.4	13.0	74.6	10.2	41.1	7.7	836.2	15.9
Lactation																		
≤ 18	10	360	1300	1250	5.1	13	62.3	1.3	5.0	1.1	110.0	11.0	201.3	10.2	31.6	4.3	770.6	13.5
19 - 30	9	310	1000	700	5.1	12	69.2	1.5	6.6	2.0	110.0	11.9	223.7	11.8	41.1	7.7	770.6	14.5
31 - 50	9	320	1000	700	5.1	12	69.2	1.5	6.6	2.0	110.0	11.9	223.7	11.4	41.1	7.7	770.6	14.5

*months, Calculation of percentage recommended dietary allowances supplied by sun-and shade-dried leaves of *Hibiscus sabdariffa* L. was based on references figures obtained from: Summary Table: **Dietary Reference Intakes (Gelaw et al.) (Gelaw et al., 2013): Recommended Dietary Allowances and Adequate Intakes, Elements , Food and Nutrition Board, Institute of Medicine, National Academies, Available @ https://www.ncbi.nlm.nih.gov/books/NBK56068/

The fibre contents of shade- and sun-dried leaves vary significantly. Sun-drying increased the concentration of fibre by 68.3 % compared to shade trying. The fibre content of sun-dried leaves in the current study was consistent with the concentration reported for cocoyam leaves (10 %) but higher by 11.1 % and 81.8 % than that of *Talinum triangulare* and *Moringa oleifera* Kwenin et al. (2011) respectively. It was however lower than Sauti, Otoo and Okumkom, varieties of *Ipomoea batatas* (Owusu et al., 2008). In relation to shade-dried leaves, sun-dried leaves of *H sabdariffa* provided adequate amount of fibre for individuals of all age and physiological groups. Inclusion of sun-dried leaves in foods therefore provides the opportunity of enhanced intake of dietary fibre. This is of significance because adequate dietary fibre intake was shown to reduce risk of colon cancer by decreasing stool colonic transit time, absorption of moisture, and increase in stool bulk, dilutes potential carcinogens, and induce anaerobic fermentation of fibre by colonic microbacteria (Vulcan et al., 2015). It is also known to reduce serum cholesterol level and risk of cardiovascular disease (Hanif et al., 2006).

Carbohydrate content of sun-dried leaves was 68.3 % higher than the amount determined in the shade-dried leaves in this study but lower than the concentration reported for sweet potato leaves by 7 % (Antial et al., 2006). It was higher by 38.7 %, 31.2 % and 7.2 % than values recorded for *Senna obtusfolia, Amaranthus incurvatus* and *Momordica balsamina* repectively *by Hassan and Umar (2006)* but lower than the values (53.3 % - 59 %) observed for a number of *Ipomoea batatas* varieties by Owusu et al. (2008). . A 100g sun-dried leaves of *Hibiscus sabdariffa* could provide adequate amounts of carbohydrate in the diet of individuals and may be good for people desirous of reducing body weight.

The ash content of the sun-dried leaves of the plant was 76.1 % ($P < 0.001$) higher than the ash content of shade-dried leaves. This was a reflection of the mineral composition of the leaves and suggests the mode of drying significantly influenced mineral concentration of the leaves of *Hibiscus sabdariffa*. This supported the findings of Chege et al. (2014) that solar-drying increases minerals and carotenoid concentration of vegetables. The concentration of iron noted in the shade-dried leaves was lower ($P < 0.001$) than recorded values for sun-dried leaves in this study. The sun-dried leaves however, had higher concentration of iron compared to *Xanthosoma sagittifolia* (14.6 mg/100g) but lower than values reported for *Amaranth cruentus* (40.5mg/100g) (Kwenin et al., 2011). The shade-dried leaves had more iron than amounts determined in *Colocassia esculenta* (3.0 mg/100g) and *Ocimum gratissimum* (0.3 mg/100g) (Thomas and Oyediran, 2008). Except for pregnant women where iron supplied by sun-dried leaves was 74.6% of RDA, sun-dried leaves provided in excess of 11 % -187 % of RDA of for all other groups. Apart from pregnant women where % RDA supplied by shade-dried leaves was low (23.1%), iron supplied by shade dried leaves was high for all other age and physiological groups reaching highest % RDA of 89 for children 1 – 3 years. Sun- and shade-dried leaves are good sources of iron. These results suggest pregnant women who might be depending on *Hibiscus sabdariffa* leaves need to supplement their iron supply with other sources. This is in line with recommendation by WHO, that pregnant women need to take iron supplements daily to meet their iron needs (Stoltzfus and Dreyfuss, 1998).

Hibiscus sabdariffa is a poor source of phosphorus. The amount of phosphorus supplied by both sun- and shade-dried leaves was very low compared to the recommended RDA which ranged from 275 to 1250 mg/day for all ages and physiological groups. Whilst the phosphorus contents were higher in *Colocassia esculenta, (*51mg/100g) and

Ocimum gratissimum, (39.3 mg/100g) (Thomas and Oyediran (2008), compared to the shade-dried leaves they were lower than the amount determined in the sun-dried leaves in the present study. Calcium concentration of both sun- and shade dried leaves in the current study were generally low compared to the values reported for *Moringa oleifera* (2009.79 mg/100g) and six varieties of *Ipomoea batatas* (1310.52-1402.27 mg/100g) (Owusu et al., 2008). It was however higher in both leaves than the amount reported for *Ocimum gratissimum* (15.7 mg/100g), lower in shade-dried leaves compared to the recorded values for *Colocasssia esculenta* (240 mg/100g) (Thomas and Oyediran, 2008) but higher in sun-dried. With regards to % RDA of calcium for individuals of various age and physiological groups, a 100g of shade-dried leaves gives a minimum of 5% and a maximum of 25.2 % whiles 100g of sun-dried leaves supplied a minimum of 31.6% and a maximum of 158.1 %.

Although sun-dried leaves of *Hibiscus sabdariffa* contain a good amount of iron and calcium especially for individuals between 7 months and 8 years, it must be noted that their bioavailability may be affected by the presence of anti-nutritive factors. Phytic and oxalic acids are anti-nutritive factors that chelate multivalent ions and are known to decrease the bioavailability of calcium, iron and zinc (Champ, 2002, Schlemmer et al., 2009) The effects of these anti-nutritive factors are influenced by threshold anti-nutrient to nutrient ratio (Hassan et al., 2007). Calcium and phosphorus are major minerals involved in growth and maintenance of teeth, bones and muscles (Turan et al., 2003). About 99% and 85 % of total body calcium and phosphorus respectively are present in the bone/skeleton (Ilich and Kerstetter, 2000, Downey and Siegel, 2006). A diet containing shade- and sun-dried leaves may be considered good in terms of calcium and phosphorus because of the calcium/phosphorus ratio which is greater than one for both shade- and sun-dried leaves of *Hibiscus sabdariffa*. A diet is described as good if the calcium/ phosphorus ration is greater than 1 and poor if it is less than 0.5 (Adeyeye and Aye, 2005).. It is worth noting that solar drying has the benefit of reducing significantly, the concentrations of phytates, oxalates acid and polyphenols (Elisha et al., 2016).

Potassium composition was lower in shade-dried leaves by 75 % ($P < 0.001$) compared to sun-dried leaves in the current study. The concentration in the sun-dried leaves was 91.2 % lower than in *Colocassia esculenta* (850 mg/100g) but 12 % higher compared to the concentration in *Ocimum gratisssium* (30.7 mg/100g) (Thomas and Oyediran, 2008). The highest and lowest % RDA of potassium supplied by shade- and sun-dried leaves for individuals in the various age and physiological groups was 801 and 110 and 5614.3 and 770.6 respectively. This suggests that when the leaves are taken in either shade- or sun-dried form, they supply more than enough potassium for all individuals of various age and physiological groups. Studies suggested that potassium in conjunction with sodium regulate blood plasma volume, acid-base balance, impulse transmission along the nerve fibre and muscle contraction (Akpanyung, 2005). Clinical, experimental and epidemiological evidence suggested a positive association of high dietary intake of potassium, magnesium and calcium with improved blood pressure (Houston and Harper, 2008). The implication of this for human is that *Hibiscus sabdariffa* has the potential for management of hypertension. Care must however be taken in consuming the leaves in order to prevent potassium toxicity.

The concentration of magnesium was 76.8 % ($P < 0.001$) higher in sun-dried leaves compared to shade-dried leaves but very low in relation to values (348 – 2110 mg/100g) recorded by Patricia et al. (2014) for a number of leafy vegetables consumed in in Cote d'Ivoire. Both shade- and sun-dried leaves provided a maximum of 6.4 % and 48.7 % and a minimum of 1.1 % and 8.7 % RDA respectively making the leaves very poor sources of magnesium. Zinc content of the shade-dried leaves was 12.5 % ($P < 0.001$) lower compared to that of sun-dried leaves. The concentration in the shade-dried leaves however, compared favourably with the amount reported for *Amamranth albus* (1.4 mg/100g) but higher than that of *Amaranth. dubius* (0.6 mg/100g) (Muriuki et al., 2014). The zinc content of sun-dried leaves was consistent with the highest recorded value (1.67 mg/100g) for Amaranth species (Muriuki et al., 2014). Considering the highest and minimum amounts of % RDA supplied by both shade- and sun-dried leaves it could be suggested *Hibiscus. sabdariffa* is a good source of zinc for infants 7 – 12 months. The intake of the leaves of the plant, coupled with regular breast-feeding could help boost the immunological status of infants and help prevent childhood infections, resulting in good health and normal grow.

A limitation to this study was that nutritional composition of fresh leaves of roselle was not determined however the study provided the opportunity to compare the effects of shade and sun drying methods on nutritional quality of the plant.

Conclusion

The leaves of *Hibiscus sabdariffa* ('Bera') are valuable sources of nutrients for people in all physiological groups. The sun-dried leaves had higher concentrations of both macro and micro nutrients and higher caloric value than the shade-dried leaves. Dehydration by drying in the sun is a better form of preservation of *Hibiscus sabdariffa* leaves. Sun drying of the leaves also reduces the drying time therefore preventing possible growth of mould. With respect to meeting the RDA of various age and physiological groups, (iron, potassium,and calcium) the leaves must be taken with moderation to prevent toxicity from these minerals especially for individuals between 7 months and 8 years. Though sun drying of *Hibiscus sabdariffa* leaves is a good source of most nutrients, dietary supplementation is necessary to meet the RDA in many individuals.

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