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Robert Agbemafle
University of Cape Coast

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EFFECTS OF SHADE AND SUN DRYING ON NUTRIENT COMPOSITION OF *HIBISCUS CANNABINUS*

***Garti, H., **Agbemafle, R., and ***Ibrahim, A.**

**School of Allied Health Sciences, University for Development studies, Tamale, Ghana*
***School of Physical Sciences, University of Cape Coast, Cape Coast, Ghana*
****Yendi Senior High School, P. O. Box 74, Yendi, Ghana*
Corresponding Author's email: alhassanibrihim29@gmail.com.

Abstract

Leafy vegetables are very rich sources of nutrients in diet. However, they are perishable and have short shelf lives after harvest. This study assessed effects of shade and sun drying as methods of preservation or retention of nutrients of Hibiscus cannabinus, a leafy vegetable commonly cultivated in Northern region of Ghana. Freshly harvested leaves of H. cannabinus were either shade or sun dried for 72 hours. Proximate (moisture ash, fat, protein, fibre and carbohydrate) and minerals (calcium, copper, iron, potassium, magnesium, phosphorus and zinc) analysis were done using Association of Analytical Chemists (AOAC) methods. Results showed that sun drying retained more nutrients than shade drying of leaves, which were significant ($P < 0.05$). Ash, protein, fat, fibre and carbohydrate contents of shade and sun dried leaves were respectively 1.75±0.35 g/100g and 6.91±0.06 g/100g, 2.56±0.03 g/100g and 19.14±0.09 g/100g, 0.78±0.06 g/100g and 4.12±0.04 g/100g, 1.68±0.07 g/100g and 12.19±0.07 g/100g, 7.38±0.12 g/100g and 49.16±0.17 g/100g. Calcium, copper, iron, potassium, magnesium, phosphorus and zinc contents of shade and sun dried leaves were 60.98±0.03 mg/100g and 454.03±0.03mg/100g, 0.03±0.01 mg/100g and 0.28±0.01 mg/100g, 4.36±0.03 mg/100g and 21.58±0.23 mg/100g, 5.60±0.02 mg/100g and 41.33±0.02 mg/100g, 5.33±0.02 mg/100g and 37.87±0.04 mg/100g, 21.31±0.03 mg/100g and 154.16±0.06 mg/100g, 0.26±0.01 mg/100g and 1.81±0.03 mg/100g respectively. Sun dried leaves thus provided more of Recommended Dietary Allowance (RDA) of fibre, carbohydrate, proteins and fat than shade dried leaves. Apart from calcium and phosphorus, sun dried leaves provided more of Recommended Dietary Allowance (RDA) of the mineral than shade dried leaves. Sun drying is therefore recommended for preservation of Hibiscus cannabinus. Continued intake of sun-dried H. cannabinus could significantly increase micronutrient consumption thus reducing micronutrient deficiency among Ghanaian population.

Keywords: ***Hibiscus cannabinus, Macronutrients, Minerals, Preservation, Shade-dried, Sun-dried***

Introduction

The problem of micronutrient deficiency is a serious challenge to the world, especially in areas where dietary diversity is lacking (Kennedy, Nantel, & Shetty, 2003). This is particularly true of tropical Africa where daily diets consist mainly of starchy and cereal-based staples which may be exacerbated by globalized agricultural modernization (Welch & Graham, 2004).

Leafy vegetables are the most widely grown crops in Ghana (Kwenin, Wolli, & Dzomeku, 2011). Indigenous leafy vegetables provide good sources of vitamins, minerals and amino acids in addition to bioactive compounds, many of which have reported health-promoting properties (Kamga, Kouamé, Atangana, Chagomoka, & Ndango, 2013). Their inclusion in diets could promote dietary diversity and reduce micronutrient deficiency and its attendant growth and development complications. Vegetable farming provides a major opportunity for employment and income for people living in rural and peri-urban communities (Schippers, 2000).
Consumption of leafy vegetables differs significantly within populations in different countries. This phenomenon is attributed to factors such as poverty status, degree of urbanization, location within a country, season of the year, cultural background, gender and age of consumers (Uusiku, Oelofse, Duodu, Bester, & Faber, 2010). It was also observed that consumption of these vegetables is higher among rural poor (Elisha, Arnold, Christian, & Huyskens-Keil, 2016). The

association of consumption of leafy vegetables with poor and rural communities has led to its neglect by researchers to the extent that many farmers still apply traditional postharvest management practices such as sprinkling cold water on vegetables to maintain freshness, open sun drying and poor packaging methods including use of non-perforated polythene bags and gunny bags (Elisha et al., 2016).

Hibiscus cannabinus commonly known as 'Kenaf' belongs to the Malvaceae family. In Ghana, it is consumed extensively in the Northern Region where it is locally referred to as "beremehe." As a "coping crop" the leaves are harvested in large quantities during the rainy season and stored for use in the dry season when there is reduced availability. However, the challenge of preservation in an attempt to meet market demands particularly during the dry season remains a major concern. Despite this long tradition of use, there is hardly any evidence from scientific studies to ascertain the effects of shade and sun drying on nutritional composition of many vegetables in northern Ghana. Considering the traditional method of preservation and the high dependency on the dried vegetable as a 'coping crop', source of micronutrients and to some extent macronutrients, this study was designed to investigate the effects of shade and sun drying on the nutrient content of the harvested leaves of *Hibiscus cannabinus* and to make commendations to improve its nutritional benefits.

Materials and Methods

Fresh edible healthy leaves of *Hibiscus cannabinus* were harvested from a cultivated field in Zanerigu, a suburb of Tamale metropolis in the Northern Region of Ghana. The leaves were washed with tap water then with distilled water and the water allowed to drain off. The sample was divided into two parts one of which was dried in the sun (labeled sun-dried) and the other in shade (shade-dried) for 72 hours. The samples were then homogenized into fine particles in a household food blender, transferred into separate glass screw cap containers and labeled appropriately.

Proximate Analysis

Representative samples were analyzed for macromolecules as duplicates by methods described in AOAC, 2000. Crude protein was determined by measuring nitrogen with Macro Kjeldahl method and converting nitrogen protein by a factor of 6.25. Moisture was determined by drying 5g of milled sample in hot-air oven at 105^{o}C for 24 hours until constant weight. Total ash content determination was by incineration in a muffle furnace for 12 hours at 550^{o}C until sample turned white. Neutral detergent fibre (NDF) was determined according to the method of Van Soest, Robertson, & Lewis, 1991. Carbohydrate (CHO) was measured by difference as 100 – (% moisture + % crude fat + % crude protein + % fibre + % ash). Energy in Kilojoules (Kj) of sample was estimated by multiplying percentage component of oil by 37.7, and protein and CHO by 16.7 (Aberoumand, 2011).

Mineral composition was determined according to the procedure described by Asaolu and Asaolu (2010) using Atomic Absorption Spectrophotometer (Buck Scientific Model, 200A). Two grams (2 g) 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^{o}C for three hours. The solution was cooled and filtered with Whatman filter paper into a 100 ml volumetric flask and made to the mark with deionized water.

The percentage contribution of 100g of shade- and sun-dried leaves of *Hibiscus cannabinus* of the recommended daily allowance (RDA) of measured nutrients was determined by expressing the amount of such nutrients determined in the leaves as a percentage of RDA for various age and physiological groups of humans.

Statistical Analysis

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

Results and Discussion

Shade- and sun-drying of *H. cannabinus* leaves had significant effect on their proximate composition (Table 1). Sun-drying reduced moisture content of the leaves by 82 % (P = 0.001) compared to shade-drying. The moisture content of leaves dried under shade was consistent with the moisture content of fresh leaves of Ocimum gratissimum (86.9 %) (Thomas & Oyediran, 2008) and Amaranthus sp (83-91 g/100g) (Uusiku et al., 2010) and Amaranthus hybridus (84.0 g/100g %) (Oyelola, Banjoko, & Ajioshin, 2014). This suggests that a longer drying period is required if shade drying is to have any significant reduction effect on the moisture content of the leaves. The long period of drying in shade could allow for growth of moulds on the leaves and the subsequent possible intake of aflatoxins by people who eat them. High moisture content of vegetables would promote growth of microorganisms and activities of enzymes and interactions between constituents of the foods leading to rapid deterioration (Kolawole, Ajiboye, Aturu, & Anibijuwon, 2011). The moisture content of sun dried leaves in this study was 8.5 ± 0.085% which was higher than moisture content of sun dried leaves of spinach (6.23 ± 0.01%) and Telferia occidentalis (6.23 ± 0.01%) but lower than recorded moisture content of solar dried samples of Hibiscus esculentus (11.34 ± 0.01%) (Ukegbu & Okereke, 2013). The low moisture content of the sun dried leaves will not only enhance the keeping quality or shelf-life of the vegetable but also the concentration of nutrients. Nutrient concentration was higher in dry leafy vegetable samples compared to fresh samples (Makobo, Shoko, & Mtaita, 2010; Mepba, Eboh, & Banigo, 2007). Carbohydrates concentration was 73.9 % (P = 0.003) higher in sun dried than shade dried samples in this study making sun dried sample a better source of energy.

Table 1: Proximate and Energy Composition of Sun-dried and Shade-dried Leaves of *Hibiscus cannabinus* Grown in Northern Ghana.

Macronutrients	*Hibiscus cannabinus* (g/100g)		P value	% Difference
	Shade-dried leaves	Sun-dried leaves		
	Mean ± SEM	Mean ± SEM		
Ash (g)	1.75 ± 0.04	6.91 ± 0.03	0.005	59.6
Carbohydrates (g)	7.38 ± 0.12	49.16 ± 0.17	0.003	73.9
Energy (Kj)	195.32 ± 0.16	1234.8 ± 64	0.039	72.7
Fat (g)	0.78 ± 0.06	4.12 ± 0.04	0.014	68.2
Fibre (g)	1.68 ± 0.07	12.19 ± 0.07	0.001	75.8
Protein (g)	2.56 ± 0.03	19.14 ± 0.09	0.003	76.4
Moisture	85.87±0.06	8.5 ± 0.09	0.001	82.0

Carbohydrates content of sun-dried leaves of *H. cannabinus* was higher than those of sun-dried leaves of *Momordica balsamina* (39.05 ± 2.01%) (Hassan, Umar, & Tijjani, 2006) and *S. nigrum* (20 ± 0.00%) (Gqaza, Njume, Goduka, & Grace, 2013) but lower than values obtained in seven varieties of sun-dried *Ipomoea batatas* leaves (54.4 ± 0.03% to 59.01 ± 0.05%) (Oduro, Ellis, & Owusu, 2008). Sun dried leaves of *H. cannabinus* in this study supplied per 100g edible portion, 37.8 % RDA of carbohydrates for individuals between the ages of 1 to 70 years and above whereas the shade dried leaves provided approximately 6 % of RDA needs of individuals within the same age group (Table 2). Fat was higher in sun dried samples by 68.2% (p = 0.014) compared to shade dried leaves (Table 1). The concentration in shade dried leaves was higher compared to reported values (0.2 – 0.6 g/100g) for eight leafy African vegetables (Van Jaarsveld et al., 2014) but compared favourably with the concentration in fresh leaves of Cucurbita pepo (0.7 g/100g) (Uusiku et al., 2010). Fat in sun dried sample was relatively higher compared to many African leafy vegetables (Uusiku et al., 2010; Van Jaarsveld et al., 2014). The value of fat obtained in sun dried leaves in this study was consistent with those reported for a number of leafy vegetables (1.17 – 4.9 g/100g) (Patricia, Zoue, Megnanou, Doue, & Niamke, 2014). The low level of fat recorded in the two forms of leaves in the current study suggests that the plant may be recommended for individuals with challenges of overweight and obesity (Patricia et al. 2014).

Table 2: Percentage Recommended Dietary Allowances (% RDA) of Some Macronutrients Supplied by Shade- and Sun-dried Leaves of *Hibiscus cannabinus* Grown in Northern Ghana Supply in Terms of 100 g of Edible Portion

Life stages (years)**	RDA (g/Day)**			Percentage computed dietary allowance per 100g *Hibiscus cannabinus* leaves					
				Shade-dried leaves			Sun-dried leaves		
	Fibre	CHO	Protein	Fibre	CHO	Protein	Fibre	CHO	Protein
7 – 12*	-	95	11	-	7.8	23.6	-	51.8	173.6
1 – 3	19	130	13	8.9	5.7	20.0	64.2	37.8	146.9
4 – 8	25	130	19	6.8	5.7	13.7	48.8	37.8	100.5
Males									
9 – 13	31	130	34	5.5	5.7	7.6	39.4	37.8	56.2
14 – 18	38	130	52	4.5	5.7	5.0	32.1	37.8	36.7

19 – 30	38	130	56	4.5	5.7	4.6	32.1	37.8	34.1
31 – 50	38	130	56	4.5	5.7	4.6	32.1	37.8	34.1
50 – 70	30	130	56	5.7	5.7	4.6	40.7	37.8	34.1
70+	30	130	56	5.7	5.7	4.6	40.7	37.8	34.1
Females									
9 – 13	26	130	34	6.5	5.7	7.6	46.9	37.8	56.2
14 – 18	26	130	46	6.5	5.7	5.7	46.9	37.8	41.5
19 – 30	25	130	46	6.8	5.7	5.7	48.8	37.8	41.5
31 – 50	25	130	46	6.8	5.7	5.7	48.8	37.8	41.5
51 – 70	21	130	46	8.1	5.7	5.7	58.1	37.8	41.5
70+	21	130	46	8.1	5.7	5.7	58.1	37.8	41.5
Pregnancy									
≤ 18 – 50	28	175	71	6.1	4.2	3.7	43.6	28.1	26.9
Lactation									
≤ 18 – 50	29	210	71	5.9	3.5	3.7	42.1	23.4	26.9

*Months **Dietary Reference Intakes (Gelaw et al.): 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 (accessed on 1st May, 2018)** .Calculation of percentage recommended dietary allowances supplied by sun-and shade-dried leaves of *Hibiscus cannabinus* was based on reference figures obtained from Summary the Table: **RDA (g/day)

Fibre was 75.8 % (P < 0.001) lower in shade dried leaves than sun dried leaves. The concentration in sun dried leaves was lower than reported for four wild leafy vegetables (16.1 – 23.08%) in South Africa by Afolayan and Jimoh (2009) but higher than crude fibre content of seven varieties of *Ipomoea batatas* reported by Oduro *et al.,* (2008). Fibre forms a very important component of human diet and is significant in the prevention of a number of non-communicable diseases. Consumption of adequate amounts of fibre has the potential of reducing serum cholesterol, hypertension, coronary heart disease, colon cancer, diabetes and constipation (Hanif, Iqbal, Iqbal, Hanif, & Rasheed, 2006). Sun dried leaves of *Hibiscus cannabinus* provided approximately 32 to 58 % RDA of fibre per 100 g of edible portion for individual of different physiological groups 9 to 70 years and above whereas for the same group of individuals shade dried leaves supplied 5.7 to 8.1% RDA per 100 g edible portion. Sun dried leaves of the plant may be recommended for inclusion in diet as a good source of fibre. A food may be described as good and excellent source of fibre if it contains 2.5 g and 5 g per serving respectively (Slavin & Lloyd, 2012). The study revealed that protein concentration was 76.4% (P = 0.003) higher in sun dried leaves compared to shade dried samples (2.56 ± 0.03g) (Table 1). The concentration in sun dried leaves was lower than the recorded value for *S. nigrum* (32.3g/100g) (Gqaza et al., 2013), but higher than concentrations in *Xanthosoma sagittifolia* (4.65 ± 0.02g/100g), *Amaranthus cruentus* (4.46 ± 0.03 g/100g) and *Moringa oleifera* (6.6 ± 0.02) (Kwenin et al., 2011). Sun dried leaves of *H. cannabinus* provide more than 100% RDA of protein for children 7- 96 months. For individuals 9 – 70 years and above, the leaves supplied RDA of protein in the range of 34.1 % to 56.2% whilst for pregnant and lactating mothers it provided 26.9% (Table 2). Sun dried leaves of the plant may be recommended for children in areas where animal source food consumption is low. However, for pregnant women it may be necessary to supplement a diet containing sun dried leaves of *H. cannabinus* with animal source protein. Ash was 59.6 % (p = 0.005) higher in sun dried than shade dried leaves suggesting higher concentration of minerals in sun dried leaves than shade dried leaves. The concentration in sun dried samples compares favourably with those of *Hibiscus sabdariffa* (7.5g/100g) and *Basella alba* (5.05g/100g) but lower than reported for *Ocimum gratissimum* (13.01g/100g) (Asaolu, Adefemi, Oyakilome, Ajibulu, & Asaolu, 2012). The estimated energy was higher in sun dried leaves by 72.7 % compared to shade dried leaves. The energy content of shade dried leaves was higher than values observed in *Ocimum gratissimum* and *Colocassia esculenta* (Thomas & Oyediran, 2008) whilst the estimated value in sun dried leaves was higher than in *S nigrum.*

The mean concentrations of minerals determined are presented in Table 3. All minerals were significantly higher (p < 0.05) in sun-dried leaves compared to shade-dried leaves. The concentrations were higher by 80.6 % for copper to 71.6% for zinc. The concentration of calcium in the sun dried samples was higher than values determined in four weeks old (386.13 mg/100g) but lower than concentrations in five to eight (620.8 – 694.8 mg/100g) and three (681.4mg/100g) weeks old sun dried samples of *Amaranthus cruentus* (Makobo et al., 2010). It was also higher than concentrations measured in samples of *Colocassia esculenta* (240 ± 14.14 mg/100g) (Thomas & Oyediran, 2008). A 100g of shade dried leaves provided a minimum of 4.7% and a maximum of 23.5% RDA whilst sun dried leaves supplied between 34.9% and 174.6% RDA of calcium for people in various age and physiological groups (Table 4). These suggest, apart from the solar dried leaves of the plant which contain more than enough calcium for infants, people consuming the leaves of the plant must supplement their diets with other calcium containing foods such as soft bones. The sun dried leaves of the plants may be recommended for infants in order to prevent osteoporosis and other calcium deficiency disorders in later years. Phosphorus concentration in this study was 75.7 % (p = 0.001) higher in sun dried leaves compared to shade dried leaves (21.31 ± 0.03 mg/100g) (Table 3).

Table 3: Mineral Compositions of Sun-dried and Shade-dried Leaves of *H. cannabinus* Grown in Northern Ghana

Mineral (mg/100g)	*Hibiscus cannabinus*		P value	% Difference
	Shade-dried leaves	Sun-dried leaves		
	Mean ± SEM	Mean ± SEM		
Calcium	60.98 ± 0.025	454.03 ±0.03	0.001	76.3
Copper	0.03 ± 0.01	0.28 ± 0.01	0.003	80.6
Iron	4.36 ± 0.03	21.58 ± 0.23	0.008	66.4
Potassium	5.6 ± 0.015	41.33 ± 0.015	0.001	76.1
Magnesium	5.33 ± 0.015	37.87 ± 0.035	0.001	75.3
Phosphorus	21.31 ± 0.03	154.16 ± 0.055	0.001	75.7
Zinc	0.26 ± 0.01	1.81 ± 0.025	0.011	71.6

The phosphorus content of shade dried leaves in this study compared favourably with the concentration obtained in three weeks old sun dried leaves of *Amaranthus cruentus* (22 mg/100g) but lower than concentrations in four to eight weeks (38-50 mg/100g) old of the plant (Makobo et al., 2010). The sun dried leaves of *H. cannabinus* in this study recorded higher values of phosphorus than sun dried leaves of *Amaranthus cruetus* (22 – 50 mg/100g) (Makobo *et al.* 2010) and values reported for selected fresh leafy vegetables (Kwenin et al., 2011; Thomas & Oyediran, 2008) but lower than concentrations recorded for five leafy vegetables (362 – 1320 mg/100g) (Patricia *et al.* (2014). The inconsistency of phosphorus concentration in the vegetables may be associated with the concentration of the mineral in the soil which is influenced by the application of phosphorus containing fertilizer (NPK) (Kwenin et al., 2011). With regards to RDA, shade and sun dried leaves of the plant supplied per 100 g, 1.7 – 7.7 % and 12.3 – 56.1% respectively for all age and physiological groups of humans (Table 4). Calcium to phosphorus ratios for both shade and sun dried leaves were 2.86 and 2.95 respectively which suggest that nutritionally it is good to incorporate either form of the leaves in diet. According to Adeyeye and Aye (2005), a diet with Ca/P ration greater than 1 is considered good and poor if the ratio is less than 0.5. Iron was 66.4% lower in shade dried leaves compared to sun dried leaves (p = 0.008) (Table 3). The iron levels determined in both forms of leaves in this study were lower than observed (30-90 mg/100g) by Patricia *et al.,* (2014) but higher than values reported for *Ocimum gratissimum* (0.3 ± 0.00 mg/100g) and *Colocassia esculenta* (3 ± 0.43 mg/100g) (Thomas & Oyediran, 2008). The iron content of sun dried leaves of *H. cannabinus*, compared favourably to 22.5 mg/100g reported for *Falcaria vulgaris* (Turan, Kordali, Zengin, Dursun, & Sezen, 2003) but higher than reported content for *Xanthosoma sagittifolia* (14. 64 ± 0.05mg/100g) and lower compared to *Talinium triangulare* (28.21± 0.05 mg/100g) and *Amaranthus cruetus* (40.5 ± 0.02 mg/100g) (Kwenin et al., 2011). Both shade and sun dried leaves of *H. cannabinus* provided good amounts of iron in the diet of people. Shade dried leaves supplied 16.3 % RDA of iron for pregnant mothers but supplied between 40 and 62.9 % RDA per100 g edible portion for all other groups of people (Table 4). Beside pregnant mothers where the supply was 80% RDA, sun dried leaves provided far in excess of 100% RDA for all individuals. This indicates that whereas consumption of shade dried leaves of *H. cannabinus* requires supplementation to meet RDA, extreme care is necessary in the consumption of solar dried leaves to prevent any toxicological effect that might be associated with excess intake of iron assuming 100% absorption. Amount of zinc in shade dried leaves was 71.6% (P = 0.011) lower compared to sun-dried leaves in the current study. Zinc concentration in shade dried leaves was consistent with concentrations in *Lathyrus tuberosus* (0.25 ± 0.04 mg/100g) and *Ocimum basilicum* (0.28 ± 0.04 mg/100g) (Turan et. Al 2003). Sun dried leaves had lower concentration of zinc than reported for 3-8 weeks old sun dried *Amaranthus cruetus* (7.8 – 28.6 mg/100g) (Makobo et al., 2010) but higher than concentration in *Colocassia esculenta* (0.9 ± 0.07 mg/100g) (Thomas & Oyediran, 2008) and compared favourably with concentration in *Capparis spinosa* (1.95 ± 0.06 mg/100g) (Turan et al., 2003). For shade dried leaves 100g supplied between 2.2 and 8.7% RDA zinc whilst sun dried leaves provided 13.9 – 60.3% RDA for individuals of all physiological and age groups. The intake of sun dried leaves of the plants, coupled with regular breast-feeding will help boost the immunological status of infants therefore reducing childhood infections and support good health and normal growth. Zinc deficiency in children results in reduced growth, increase incidence of infectious diseases and impaired cognitive ability (Salgueiro et al., 2002). Absorption of iron and zinc from plant sources is affected by presence of oxalates, phytates and polyphenols (Gupta, Lakshmi, Manjunath, & Prakash, 2005; Zimmermann, Chaouki, & Hurrell, 2005) however, the concentration of these anti-nutritional factors in plants is reduced by solar drying (Elisha et al., 2016). This is an advantage associated with sun drying and may enhance bioavailability of these minerals.

Table 4: Percentage RDA of Some Minerals Supplied by Shade- and Sun-dried Leaves of *Hibiscus cannabinus* Grown in Northern Ghana Supply in Terms of 100 g of Edible Portion

Life stage (years)**	RDA(mg/day)**						Computed percentage dietary allowance of minerals per 100g *Hibiscus cannabinus* leaves											
							Shade-dried						Sun-dried					
	Fe	Mg	Ca	P	K(g)	Zn	Fe	Mg	Ca	P	K(g)	Zn	Fe	Mg	Ca	P	K(g)	Zn
7 – 12 *	11	75	260	275	0.7	3	40.0	7.1	23.5	7.7	0.9	8.7	196.4	50.5	174.6	56.1	5.9	60.3
1 – 3	7	80	700	460	3.0	3	62.9	6.6	8.7	4.6	0.2	8.7	308.6	47.4	64.9	33.5	1.4	60.3
4 – 8	10	130	1000	500	3.8	5	44.0	4.1	6.1	4.3	0.2	5.2	216.0	29.2	54.4	30.8	1.1	36.2
Males																		
9 – 13	8	240	1300	1250	4.5	8	55.0	2.2	4.7	1.7	0.1	3.3	270.0	15.8	34.9	12.3	0.9	22.6
14 – 18	11	410	1300	1250	4.7	11	40.0	1.3	4.7	1.7	0.1	2.4	196.4	9.2	34.9	12.3	0.9	16.5
19 – 30	8	400	1000	700	4.7	11	55.0	1.3	6.1	3.0	0.1	2.4	270.0	9.5	45.4	22.0	0.9	16.5
31 – 50	8	420	1000	700	4.7	11	55.0	1.3	6.1	3.0	0.1	2.4	270.0	9.0	45.4	22.0	0.9	16.5
51 – 70	8	420	1200	700	4.7	11	55.0	1.3	5.1	3.0	0.1	2.4	270.0	9.0	37.8	22.0	0.9	16.5
70+	8	420	1200	700	4.7	11	55.0	1.3	5.1	3.0	0.1	2.4	270.0	9.0	37.8	22.0	0.9	16.5
Female																		
9 – 13	8	240	1300	1250	4.5	8	55.0	2.2	4.7	1.7	0.1	3.3	270.0	15.8	34.9	12.3	0.9	22.6
14 – 18	15	360	1300	1250	4.7	9	29.3	1.5	4.7	1.7	0.1	2.9	144.0	10.5	34.9	12.3	0.9	20.1
19 – 30	18	310	1000	700	4.7	8	24.4	1.7	6.1	3.0	0.1	3.3	120.0	12.2	45.4	22.0	0.9	22.6
31 – 50	8	320	1000	700	4.7	8	55.0	1.7	6.1	3.0	0.1	3.3	270.0	11.8	45.4	22.0	0.9	22.6
51 – 70	8	320	1200	700	4.7	8	55.0	1.7	5.1	3.0	0.1	3.3	270.0	11.8	37.8	22.0	0.9	22.6
70+	8	320	1200	700	4.7	8	55.0	1.7	5.1	3.0	0.1	3.3	270.0	11.8	37.8	22.0	0.9	22.6
Pregnancy																		
≤ 18	27	400	1300	1250	4.7	12	16.3	1.3	4.7	1.7	0.1	2.2	80.0	9.5	34.9	12.3	0.9	15.1
19 – 30	27	350	1000	700	4.7	11	16.3	1.5	6.1	3.0	0.1	2.4	80.0	10.8	45.4	22.0	0.9	16.5
31 – 50	27	360	1000	700	4.7	11	16.3	1.5	6.1	3.0	0.1	2.4	80.0	10.5	45.4	22.0	0.9	16.5
Lactation																		
≤ 18	10	360	1300	1250	5.1	13	44.0	1.5	4.7	1.7	0.1	2.0	216.0	10.5	34.9	12.3	0.8	13.9
19 – 30	9	310	1000	700	5.1	12	48.9	1.7	6.1	3.0	0.1	2.2	240.0	12.2	45.4	22.0	0.8	15.1
31 – 50	9	320	1000	700	5.1	12	48.9	1.7	6.1	3.0	0.1	2.2	240.0	11.8	45.4	22.0	0.8	15.1

*Months, ** **Dietary Reference Intakes (Gelaw et al.): 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**/ (accessed on 1st may, 2018) Calculation of percentage recommended dietary allowances supplied by sun-and shade-dried leaves of *Hibiscus cannabinus* was based on references figures obtained from: Summary Table **RDA (mg/day)

Potassium concentration was 76.1 % (P < 0.001) lower in shade dried leaves compared to sun dried leaves. Concentration of potassium in sun dried leaves in this study was higher than in three weeks (22mg/100g) and six weeks (38mg/100g) old sun dried leaves of *Amaranthus cruentus* but lower than measured concentrations in seven to eight weeks (45 -50mg/100g) old sun dried leaves of the plant (Makobo *et. al.* 2010). It was also lower than in *Amaranthus hybridus* (168.96mg/100g) and *Hibiscus sabdariffa* (84.11mg/100g) (Asaolu et al., 2012). For all individual 9 – 70 years and above sun dried leaves supplied less than 1.0 % RDA of Potassium and just between 1 and 6% for infants and young children 7 to 96 months. Magnesium content was 75.3% (P < 0.001) higher in sun dried leaves than shade dried leaves. The concentration in sun dried leaves was higher than 14.3 ± 1.15 mg/100g reported for fresh leaves of *Ocimum gratissimum* (Thomas and Oyediran, 2008) and sun dried leaves of *Basella alba* L (27.51mg/100g) but lower than concentration in sun dried leaves of *H. sabdariffa* (120.09mg/100g)(Asaolu et al., 2012). Magnesium in the body serves as coenzymes to enzymes involved in energy metabolism, synthesis of protein, RNA and DNA and maintenance of electrical potential of nerve tissues and cell membranes (Joint & Organization, 2005). *H. cannabinus* is a poor source of magnesium. Nutritionally, 100g of sun dried leaves of the plant supplied for males nine years and above and pregnant and lactating mothers 9 to 15.8 % and 9.5 to 12.2 % of RDA respectively.

Conclusion

The study revealed that sun drying of *H. cannabinus* retained more macronutrients and minerals than shade drying. Similarly, the sun dried *H. cannabinus* leaves provided values of dietary allowance of fibre, carbohydrate, protein and minerals closer to the recommended dietary allowance (RDA) compared to the shade dried *H. cannabinus*. Hence sun drying is recommended for preservation and shelf-life extension of *Hibiscus cannabinus*.

Limitation

Data were not available for fresh leaves of the plant for comparison.

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Corrections effected

Comments	Corrections
A1	Micronutrients and minerals changed to nutrients
A2	Micronutrients and minerals changed to nutrients
A3	Analysis of macronutrients changed to Proximate analysis
A4	There were significant differences ($p < 0.05$) in proximate and mineral compositions between shade and sun dried leaves.
A5	Units provided
A6	Unit provided
A7	Results show that sun dried leaves provided more fibre, carbohydrate, protein and fat than shade dried leaves. Refer to Table 2. Apart from calcium and phosphorus sun dried leaves provided more of Recommended Dietary Allowance (RDA) of the mineral than shade dried leaves. Refer to Table 4
A8	Shelf life extension removed because shelf life studies was not conducted
A9	72 hours was used for the two drying methods for better comparison because prolong drying under the shade will result in mould growth that will lead to spoilage of the samples which may not make it available for analysis
A10	As in A9
A11	Consistent decimal places effected
A12	*Mormodica* balsamina is also a type leaves dried and consumed. The leaves and young fruits of *Momordica balsamina* are cooked and eaten as a vegetable in Cameroon, Sudan and southern Africa
A13	All minerals were significantly higher ($p < 0.05$)