Effect of Different Drying Methods on the Mineral content of three accessions of Roselle (*Hibiscus sabdariffa*) calyces

Amoasah B.[1*], Appiah F. [1], Tandoh P and Amoateng E.

[1]*Department of Horticulture, Kwame Nkrumah University of Science and Technology Kumasi, Ghana*

ABSTRACT

Fresh Roselle (*Hibiscus sabdariffa l*) calyces have shorter shelf life due to their high moisture content. In order to extend their shelf life, Roselle calyces are dried. However, the effect of different drying methods on mineral composition are not sufficiently reported. A study was therefore conducted to determine the influence of oven, solar and sun drying methods on the mineral content of three accessions (HS11, HS41 and HS89) of roselle calyces grown in Ghana. A 3×3 factorial experiment laid in Completely Randomized Design (CRD) with three replications was used. The roselle accessions were harvested 12 weeks after planting. Sodium, magnesium, calcium, zinc, potassium, phosphorus and iron were the mineral elements analyzed for using recommended procedures. The study showed that accession HS41 had the highest calcium, iron, potassium, phosphorus and zinc content being (0.98%), (8.36mg/kg), (0.60%), (0.36%), and (2.34mg/kg) respectively. Accession HS89 had the highest magnesium (0.55%) and sodium content (0.030%). With respect to methods of drying, sun recorded significantly highest calcium (0.81%), iron (6.77mg/kg), magnesium (0. 42%), sodium (0.03%), and zinc content (1.93mg/kg). On the other hand, Oven drying resulted in the highest potassium (0.58%) and phosphorus content (0.34).

Keywords: Roselle, Accessions, Drying methods, Minerals, Calyx.

1.0 INTRODUCTION

Roselle calyx (*Hibiscus sabdariffa* l.) is an annual herbaceous crop of West African origin. Roselle has many uses both on the local and international market. Their high pectin content makes roselle calyces useful in the production of jellies, beverages, jams and confectionaries. According to [1], roselle calyx has high nutritional and mineral composition due to the presence of β-carotene (1.88mg/100g), vitamin C (141 mg/100g), anthocyanin (2.52 mg/100g), lycopene (164μg/100g) and other bioactive compounds such as phytosterols, polyphenols, flavonoids, organic acids and other water-soluble antioxidants. Dried calyces are used as food colorants, flavoring for liquors and herbal tea [2]. In Ghana a refreshing beverage (Sobolo) produced from the infusion of the calyx is widely consumed [2]. Roselle has high content of protocatechuic acid which helps in reducing hypertension, leukemia, pyrexia and blood pressure [3]. It also has high mineral content which function both as an electrolyte and as a catalyst for maintaining growth and development [4]. Open air and solar drying are common methods used for drying agricultural produce though each of them has its own effects on food [5]. [6] reported that Vitamin C is heat sensitive and significant quantities are lost when subjected to high temperatures while [7] reported of a decrease in the protein content of dried food product. In addition, the method of drying and processing conditions influence the texture of dried products [8]. Dried foods have low moisture content which minimizes deteriorative activities of micro-organisms [9] and extend shelf life. Again, drying reduces weight of food making them lighter and convenient for transportation. Although open sun drying is the most common drying method used in developing countries, there is insufficient information on effect of different drying methods on the mineral composition of roselle calyces. This research therefore sought to determine the effect of three different drying methods (oven, sun and solar) on the mineral composition of calyces of three accessions of roselle.

Email: amoasahbeatrice@gmail.com

2.0 MATERIALS AND METHODS

2.1 Source of Roselle calyces

Seeds of the HS41, HS11 and HS89 roselle accessions were obtained from the Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana. The seeds were then planted on the field at the Department of Horticulture, KNUST.

2.2 Land preparation, planting and harvesting of calyces of the accessions

Land preparation involved ploughing and harrowing, followed by application of weedicide for pre-emergence weed control. The field was laid out in a randomized complete block design (RCBD) with three replications. Experimental plots consisted of 6 m × 0.6 m row. Plots were separated by 1.0 m alley and blocks were separated by 2 m. Planting density was 20,000 plants/ha. Recommended crop management techniques were applied. Irrigation was applied regularly as needed. Fertilizer equivalent to 120:60:40 kg ha-1 of N-P_2O_5-K_2O was applied at 14 days after planting. Post-emergence weeds were controlled with Atrazine (4.5 L ha-1) and hand weeding with a hoe. The pests, cabbage fly (Delia radium) and cotton strainer (*Dysdercus superstitious* and *Dysdercus parasiticum*) were controlled using Conpyrifos 48 % (1-1.5 L ha-1) and Cymethoate Super (1-1.5 L ha-1) and 100 g/L alpha-cypermethrin (1 L ha -1). Irrigation was applied regularly as needed.

Harvesting of fresh calyces were done at the 8th week after sowing when the plants were physiologically matured. At this maturity stage the calyces were harvested and subjected to the various drying methods

2.3 EXPERIMENTAL DESIGN FOR LABORATORY STUDIES

A 3 × 3 factorial arrangement in Completely Randomized Design was used and replicated three times. The factors were the drying methods (oven, sun and solar) and the various accessions of roselle (HS41, HSII and HS89)

2.4 Morphological description of the accessions used

HS41 has smooth dark red stems and veins. Leaves are leathery, partially tri-lobed, broad and green-pigmented with succulent dark red calyces and ovoid capsule. HS11 has green leaves which are slender and deeply penta-lobed. Its calyces are also succulent and dark red with bright red stems and rough ovoid capsules while HS89 is partially tri-lobed and has broad leaves, succulent calyces, ovoid capsules and smooth dry stems.

2.5 DRYING TREATMENTS

Roselle calyces were dried using sun, oven and solar drying.

2.5.1 Sun Drying

One hundred grams (100g) of fresh roselle calyces of each accession were put on a pre-weighed aluminium foil and placed on a table directly under the sunlight at (34.9°C) for 72 hours. The calyces were constantly turned to ensure uniformity in drying. The temperature (averaged 34.9^{o}C) was monitored using RH/Temp data logger (EL-USB-2-LCD+USA).

2.5.2 Solar Drying

One hundred grams (100g) of fresh roselle calyces from each accession were put on a pre-weighed aluminium foil and placed in the solar dryer (Plate 1) for 48hours. The calyces were frequently turned to ensure uniformity and even drying under an average temperature of 56.5°C using RH/Temp data logger (EL-USB-2-LCD+, USA).

Email: amoasahbeatrice@gmail.com

Plate 1. Solar drier

2.5.3 Oven Drying

One hundred grams (100g) of fresh roselle calyces from each accession were put on a pre-weighed aluminium foil and placed in the oven (Plate 2) to dry at 60°C within 24 hours.

Plate 2. Oven

2.6 PARAMETERS STUDIED

Parameters monitored during the study were drying dynamics (temp, weight, moisture) and mineral composition (calcium, sodium, iron, magnesium, potassium, phosphorus and zinc)

2.6.1 Sample preparation for Mineral determination

Calcium (Ca), Sodium (Na), Iron (Fe), Magnesium (Mg), Potassium (K), Phosphorus (P) and Zinc (Zn) were determined using methods based on Association of Official Analytical Chemists [10].
A 1.0g of powdered roselle calyce was weighed into a porcelain crucible and ashed for 4 hours at 500^{o}C. Ten milliliters (10ml) of 1:5 HCl to water was added to the ashed sample, digested on a hot plate and boiled for 2mins. The digest was then filtered into a 100ml flask. The filtrate was made to the 100 ml meniscus mark of the volumetric flask using distilled water. The solution was further diluted with distilled water at a ratio of 1:50 using a combined solution of 2.5ml lanthanum solution and 2.5ml cesium oxide to remove the interference of other cations. Potassium, Magnesium, Manganese, Zinc, Sodium, Iron, Calcium and Copper levels were read using AAS by preparing standards for each element at their specific elemental wavelength after calibration.

2.7 DATA ANALYSIS

Email: amoasahbeatrice@gmail.com

Data obtained from the laboratory analysis was subjected to Analysis of Variance (ANOVA) using STATISTIX Statistical Software Version 9. The differences in means were separated using Tukeys Honesty Significant Difference (HSD) at 1%. The results were then presented in tables and graphs.

3.0 RESULTS

3.1 Moisture content

Generally, the different drying methods resulted in significant ($P \leq 0.01$) variation in moisture content within each accession. With respect to HS89, oven drying resulted in the least moisture content (6.50%) (Table 1) compared to the sun (8.67%) and solar (10.13%). A similar trend was observed in HS11. On the other hand, sun drying of HS41 resulted in the least moisture content (7.60%) as compared to the oven (7.75%) and solar (12.88%) drying methods.

Table 1: Effect of oven, solar and sun drying on the moisture content of three accessions (HS41, HS11 and HS89) of roselle calyces

	Moisture content (%)			
	Drying methods			
Accessions	Oven	Sun	Solar	Means
HS89	6.50f	8.67d	10.13c	8.43b
HS41	7.75e	7.60e	12.88a	9.41a
HS11	6.67f	9.98c	11.75b	9.46a
Means	6.97c	8.75b	11.58a	

HSD (1%): Drying=0.309; Accessions=0.309; Drying*Accession=0.700

Means with the same letter(s) are not significantly different using the method of Tukeys Honesty significant difference (HSD) at 1% probability

3.2 Ash content

Oven drying of HS89 calyces resulted in higher ash content (5.50%) than solar (4.75%) and sun (4.50%) as indicated in Table 2. Similarly, HS11 dried using oven had the highest ash content (6.20%) followed by sun (5.25% and solar (4.53%. With respect to HS41, solar drying had the highest ash content (7.25%) than sun (6.25%) and oven (5.71%). As regards the various interactions, solar-dried HS41 calyces had the highest ash content with sun-dried HS89 being the least (4.50%). As far as the drying methods were concerned, there were no statistical differences among the means of oven (5.8%), sun (5.33%) and solar (5.51%) at P=0.01.

Table 2: Effect of oven, solar and sun drying on the ash content of three accessions (HS41, HS11 and HS89) of roselle calyces.

	Drying methods (%)			
Accessions	Oven	Sun	Solar	Means
HS89	5.50bcd	4.50d	4.75cd	4.92b
HS41	5.71bc	6.25ab	7.25a	6.40a
HS11	6.20ab	5.25bcd	4.53d	5.33b
Means	5.80a	5.33a	5.51a	

HSD (1%); Drying=0.508; Accessions=0.508; Drying*Accession= 1.150

Means with the same letter(s) are not significantly different using the method of Tukeys Honesty significant difference (HSD) at 1% probability

Email: amoasahbeatrice@gmail.com

3.3 Calcium content

The calcium content of the roselle calyces under the different drying methods differed significantly (p ≤ 0. 01). HS41 had the highest calcium content (0.98%) followed by HS11 (0.86%) and HS89 (0.53%) as indicated in Table 3. Roselle calyces dried by sun had the highest calcium content (0.81%) followed by roselle calyces dried by solar (0.79%) and oven (0.78%). Interactively, the calcium content also differed significantly (p ≤ 0.01) from 0.49% to 1.07%. The least (0.49%) recorded calcium content was HS89 subjected to oven drying and the highest (1.07%) was HS41 subjected to sun drying.

Table 3. Effect of different drying methods on calcium content of three accessions of roselle calyces

	Calcium (%)			
Accessions	Oven	Sun	Solar	Means
HS89	0.49c	0.51c	0.60c	0.53c
HS41	0.99ab	1.07a	0.89ab	0.98a
HS11	0.87ab	0.84b	0.88ab	0.86b
Means	0.78a	0.81a	0.79a	
HSD (1%): Drying=0.094; Accessions=0.094; Drying*Accession=0.212				

Means with the same letter(s) are not significantly different using the method of Tukeys Honesty significant difference (HSD) at 1% probability

3.4 Iron content

Drying of calyces of the different accessions of roselle using the different drying methods resulted in significantly different (p ≤ 0.01) iron content ranging from 4.77mg/kg to 9.42mg/kg. The least (4.77mg/kg) was recorded by HS89 subjected to solar drying while the highest (9.42mg/kg) was recorded by HS41 subjected to oven drying. For the individual effects, solar dried calyces had the least iron content (6.07mg/kg) while the highest was the sun-dried having iron content of 6.77mg/kg. Among the accessions, HS89 had the least iron content of 5.41mg/kg similar to HS11 (5.42mg/kg). The highest (8.36mg/kg) was recorded by HS41 (Table 4).

Table 4 Effect of oven, solar and sun drying on the iron content of three accessions (HS41, HS11 and HS89) of roselle calyces.

	Iron (mg/kg)			
	Drying methods			
Accessions	Oven	Sun	Solar	Means
HS89	4.80ef	6.65d	4.77f	5.41b
HS41	9.42a	7.37c	8.30b	8.36a
HS11	4.80ef	6.30d	5.15e	5.42b
Means	6.34b	6.77a	6.07c	
HSD (1%): Drying=0.159; Accessions=0.159; Drying*Accession=0.360				

Means with the same letter(s) are not significantly different using the method of Tukeys Honesty significant difference (HSD) at 1% probability

3.5 Potassium content

Table 5 shows results for potassium content of the calyces of the accession of roselle dried using different methods. Significant differences (p ≤ 0.01) existed in potassium content of the calyces of the different accessions of roselle. HS41 had the highest potassium content (0.60%), followed by HS11 (0.58%) while the least ().52%) was recorded by HS89. With respect to the drying methods, roselle calyces dried by oven had the highest potassium content (0.58%) followed by roselle calyces dried by solar (0.57%) with sun drying recording the least (0.54%). As regards the interaction between accessions and drying methods, HS41 subjected to oven drying had the highest potassium content of 0.62%.

Email: amoasahbeatrice@gmail.com

Table 5 Effect of oven, solar and sun drying on the potassium content of three accessions (HS41, HS11 and HS89) of roselle calyces.

	Potassium (%)			
	Drying methods			
Accessions	Oven	Sun	Solar	Means
HS89	0.57c	0.43d	0.57c	0.52c
HS41	0.62a	0.61a	0.57c	0.60a
HS11	0.57c	0.59b	0.57c	0.58b
Means	0.58a	0.54c	0.57b	

HSD (1%): Drying=0.006; Accessions=0.006; Drying*Accession=0.013

Means with the same letter(s) are not significantly different using the method of Tukeys Honesty significant difference (HSD) at 1% probability

3.6 Magnesium content

The magnesium content of the calyces of the roselle showed significant difference ($p \leq 0.01$) as far as the accessions and the drying methods were concerned. Sun drying of roselle calyces was resulted in the highest magnesium content (0.42%) whereas the least (0.32%) was by solar drying. Sun drying had magnesium content of 0.42%, being higher than Oven (0.37%) and Solar (0.32%). There was significant accession and drying method interaction ($p \leq 0.01$) with respect to magnesium content. HS89 subjected to sun drying was the highest (0.63%) and the least (0.20%) was recorded by HS11 subjected to solar drying as shown in Table 6.

Table 6 Effect of oven, solar and sun drying on the magnesium content of three accessions (HS41, HS11 and HS89) of roselle calyces.

	Magnesium (%)			
	Drying methods			
Accessions	Oven	Sun	Solar	Means
HS89	0.54b	0.63a	0.49c	0.55a
HS41	0.21h	0.38d	0.27f	0.29b
HS11	0.36e	0.25g	0.20h	0.27c
Means	0.37b	0.42a	0.32c	

HSD (1%): Drying=0.006; Accessions= 0.006; Drying*Accession=0.013

Means with the same letter(s) are not significantly different using the method of Tukeys Honesty significant difference (HSD) at 1% probability

3.7 Sodium content

Differences in sodium content of the roselle calyces under the different drying methods were not significant ($p \leq 0.01$). However, significant differences in sodium content was recorded in the accessions. Whereas the least sodium content (0.016%) was recorded by oven dried HS11, the highest (0.030%) was by HS89. With regards to the interactive effects, Sun and Oven-dried calyces of HS89 had the highest sodium content ().04%) with the least being sun-dried HS41 (0.01%) and solar-dried HS11 (0.01%) as shown in Table 7.

Email: amoasahbeatrice@gmail.com

Table 7 Effect of oven, solar and sun drying on the sodium content of three accessions (HS41, HS11 and HS89) of roselle calyces.

	Sodium (%)			
	Drying methods			
Accessions	Oven	Sun	Solar	Means
HS89	0.04a	0.04a	0.02abc	0.030a
HS41	0.02ab	0.01bc	0.02abc	0.019b
HS11	0.006c	0.03a	0.01bc	0.016b
Means	0.02a	0.03a	0.02a	

HSD (1%); Drying=0.007; Accessions=0.007; Drying*Accession=0.017;

Means with the same letter(s) are not significantly different using the method of Tukeys Honesty significant difference (HSD) at 1% probability.

3.8 Phosphorus content

From Table 8, significant differences ($p \leq 0.01$) were observed in the phosphorus content for the roselle calyces subjected to the different drying methods. Sun dried calyces had the least (0.32%) phosphorus content which was similar to that of solar dried calyces (0.33%). The phosphorus content of oven dried calyces was the highest (0.34%). For the accession, HS41 had the highest (0.36%) phosphorus content as compared to HS11 which was the least (0.31%). Interactions between accessions and drying methods resulted in significant variation ($p \leq 0.01$) in the phosphorus content Oven dried HS41 which was highest (0.36%) phosphorus content was similar to solar and sun dried HS41 as well as oven dried calyces of HS89. The least (0.31%) was HS11 subjected to both oven, solar and sun as well as HS89 subjected to sun drying (0.31%).

Table 8 Effect of oven, solar and sun drying on the phosphorus content of three accessions (HS41, HS11 and HS89) of roselle calyces.

	Phosphorous (%)			
	Drying methods			
Accessions	Oven	Sun	Solar	Means
HS89	0.36a	0.31b	0.33b	0.33b
HS41	0.36a	0.36a	0.36a	0.36a
HS11	0.31b	0.31b	0.31b	0.31c
Means	0.34a	0.32b	0.33b	

HSD (1%): Drying=0.010; Accessions=0.010; Drying*Accession= 0.024

Means with the same letter(s) are not significantly different using the method of Tukeys Honesty significant difference (HSD) at 1% probability

3.9 Zinc content

From Table 4.2.7, the zinc content recorded a significant difference ($p \leq 0.01$) in the accessions and the drying methods respectively. Roselle calyces dried by sun had the highest zinc content (1.93mg/kg) followed by roselle calyces dried by solar (1.82mg/kg) and the least (1.55mg/kg) was roselle calyce dried by oven. HS41 had the highest (2.34mg/kg) zinc content of the accession and the least (0.91mg/kg) was

Email: amoasahbeatrice@gmail.com

HS11. The interaction between drying methods and accessions were significant ($p \leq 0.01$) HS41 subjected to solar drying had the highest (3.06mg/kg) zinc content and HS11 subjected to solar drying had the least (0.85mg/kg) as shown in Table 9.

Table 9: Effect of oven, solar and sun drying on the zinc content of three accessions (HS41, HS11 and HS89) of roselle calyces.

	Zinc (mg/kg)			
	Drying methods			
Accessions	Oven	Sun	Solar	Means
HS89	2.30bc	2.26c	1.58d	2.05b
HS41	1.49d	2.48b	3.06a	2.34a
HS11	0.85ef	1.05e	0.82f	0.91c
Means	1.55c	1.93a	1.82b	

HSD (1%) Drying=0.093; Accessions=0.093; Drying*Accession=0.211

Means with the same letter(s) are not significantly different using the method of Tukeys Honesty significant difference (HSD) at 1% probability

4.0 DISCUSSION

4.1 Moisture and ash content

Fresh roselle calyces have moisture content of 86% [11,12]. The study however showed a reduction in the moisture content of all dried calyces. Oven drying resulted in lower moisture content as compared to sun and solar. Generally, oven drying is known to provide a constant heating effect which promotes drying. The higher temperature and presence of an extractive fan of the oven were major factors in enhancing removal of humid air on the surface of the calyces consequently facilitating drying. The moisture content of the dried calyces was within acceptable levels for dried foods and consequently would have a longer shelf life.

Ash content of food gives an indication of the total mineral content present in a food sample according to [13,14 and 12]. The higher ash content of oven-dried samples may be attributable to higher rate of drying which minimizes moisture content and consequently growth of micro-organisms that use minerals in food substrates for their metabolism. The higher ash content of the solar-dried calyces suggest they would have higher mineral content and therefore could be more useful as source of minerals when the calyces are used in food preparation.

4.2 Calcium

Calcium as an essential mineral helps in bone and teeth formation, as well as the proper growth of the body. [13] reported a calcium content of 1.27% for roselle but from the study, the calcium content was comparatively lower (0.49% to 1.07%).
The various drying methods had similar effect on Calcium content. However, variation existed in Calcium content of the accessions which could be attributable to variation in genetic makeup of the accessions. HS41 could be a better source of Calcium than HS89 and HS11.

4.2 Iron

The Recommended Daily Allowance (RDA) of iron for infants, children and adults according to Carolyn (1998) is between 6 mg/kg and 15mg/kg. The present study showed that the Roselle calyces had iron content ranging from 4.77mg/kg to 9.42mg/kg, this suggests that the calyces of the accessions could

Email: amoasahbeatrice@gmail.com

provide significant amount of iron when consumed. Iron is known to be important for hemoglobin formation, oxygenation of red blood cells and consequently combating of anemia. The variation in the data might however be due to variable uptake of minerals by the accessions.

4.3 Potassium

[14] [13] as well as [15] reported 4.94% and 4% as the potassium content of fresh roselle calyces. From the study, calyces dried by oven had the highest potassium content (0.58%) followed by calyces dried by solar (0.570%) and sun respectively (0.54%). Variation in the results might be due to the different genetic makeup of the calyces. From the study more Potassium needs to be consumed in order to meet the daily recommended allowance. Potassium maintains the body's fluid volume and promote proper functioning of the nervous system [16].

4.4 Magnesium

The magnesium content found in roselle was reported by [13] as 3.87%. Comparatively, the magnesium content (0.20% - 0.63%) obtained from the studies was lower probably due to differences in the genetic make-up of the calyce. Magnesium (Mg) is an activator of many enzyme systems which maintains electrical potential during nerve metabolism and Protein synthesis. It also helps in the assimilation of potassium [17;18]. The magnesium content of HS89 was highest among the accession making it a better source of magnesium than HS41 and HS11.

4.5 Sodium

Sodium is a micronutrient that maintains osmotic pressure and helps in the relaxation of muscles [14]. Sodium helps in cell functioning as well as regulation of the body's fluid volume. The Sodium content according to [15] was reported to be 0.0006 %. Comparatively, high sodium content (0.006% - 0.04%) obtained from the present study may be due to differences in the genetic make-up of the accessions. Considering the lower level in HS11, it would be recommended for conditions where lower sodium are desirable.

4.6 Phosphorus

Phosphorus plays a vital role in metabolic processes and helps in the production of ATP. roselle is reported to contain phosphorus of 0.004% [19; 13]. From the study, a higher phosphorus content (0.31% - 0.36%) obtained might be due the removal of moisture which tends to increase the concentration of nutrients (Morris *et al*., 2004). Consumption of phosphorus helps maintain balance with calcium for strong bones and teeth. HS41 would be a better source of Phosphorus compared to HS89 and HS11.

4.7 Zinc

Zinc helps in the breakdown of carbohydrates as well as maintaining the structural integrity of proteins. The RDA for zinc is 15mg/kg [20]. From the study, the zinc content obtained ranged from 0.82mg/kg - 3.06mg/kg which was comparatively lower than that reported by [13] being 12220mg/kg. This might be due to differences in the genetic make-up of the calyces. Infants, children, adolescents and pregnant women would be at risk if the RDA for zinc is not met. The study suggests that the accessions are poor sources of zinc and consequently meals based on HS89, HS41 and HS11 needs to be enhanced with alternative sources of zinc.

5.0 CONCLUSION

Accession HS41 had highest calcium, iron, potassium, phosphorus and zinc content while HS89 recorded highest magnesium and sodium content.
Of the drying methods sun recorded highest calcium, iron, magnesium, sodium and zinc content with oven recording highest potassium and phosphorus content.

Email: amoasahbeatrice@gmail.com

COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration with all authors. Author AB designed the study and wrote the protocol as well as the first draft of the manuscript. Author AF supervised the work, read and approved the final manuscript. Author TP and AE managed the analyses of the study.

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Email: amoasahbeatrice@gmail.com

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Email: amoasahbeatrice@gmail.com