Original Research Article

Effect of different drying methods (oven, sun and solar) on the mineral content of three accessions of roselle (*Hibiscus sabdariffa*) calyces

ABSTRACT

Fresh roselle 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).

Comment [DMAK1]: The plant name should be italic and first word capital

Keywords: roselle accessions, drying methods, minerals.

1.0 INTRODUCTION

Roselle calyces (*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 Wong *et al.* (2002), roselle calyx has highest nutritional and mineral composition due to the presence of b-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 (Bolade *et al*, 2009). In Ghana a refreshing beverage (soobolo) produced from the infusion of the calyx is widely consumed (Bolade *et al*, 2009)

The high content of protocatechuic acid in roselle makes it a useful product in reducing hypertension, leukemia, pyrexia and blood pressure (Tseng *et al.*, 2000).

Roselle extract has high mineral content which function both as an electrolyte and as a catalyst for maintaining growth and development (Untoro *et al.*, 2005).

Roselle calyces are harvested when moisture contents are slightly high leading to quick loss of quality and rapid deterioration during handling at ambient conditions (Liberty *et al.,* 2013). Consequently, roselle calyces are dried for extended shelf life.

Dried foods have low moisture content which minimizes deteriorative activities of micro-organisms (Mujumdar and Law, 2010) and extend shelf life. Again, drying reduces weight of food making them lighter and convenient for transportation.

Open sun, solar and oven drying are common methods used for drying agricultural produce though each of them has its own effects on food (Wankhade *et al*., 2013). Zanoni *et al*. (1999) found out that Vitamin C is heat sensitive and is greatly lost when subjected to high temperatures while Torres *et al.* (1985), 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 (Krokida *et al*., 2001). Although various effects of different methods on food characteristics are known, 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.

Comment [DMAK2]: Does the author mean open air and solar drying. It is not clear

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.

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

Land preparation involved ploughing and harrowing, followed by application of Round Up Ready (glyphosate, 360 g/L) applied at 5.0 L/ha and Gramoxone (Paraquat) applied at 3.5 L/ha for pre-emergence weed control. All entries were planted in a randomized complete block design with three replications. Experimental plots consisted of 6 m × 0.6 m row containing 8 to 12 plants per plot. 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 stainer (*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

2.2 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)

2.3 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

2.4 DRYING TREATMENTS

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

2.4.1 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 even drying.

2.4.2 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 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).

2.4.3 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 to dry at 60°C within 24 hours.

2.5 PARAMETERS STUDIED

Different parameters studied under this research were drying dynamics (temp, weight, moisture) and mineral composition (calcium, sodium, iron, magnesium, potassium, phosphorus and zinc) as described by (24)

2.6 DATA ANALYSIS

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

2.0 RESULTS

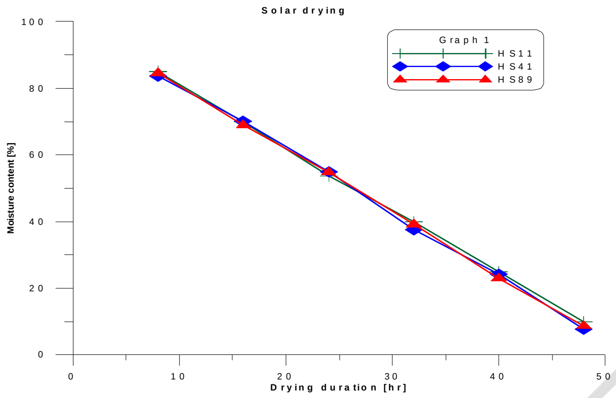

Fig 1. Rate of drying (solar) of roselle calyx

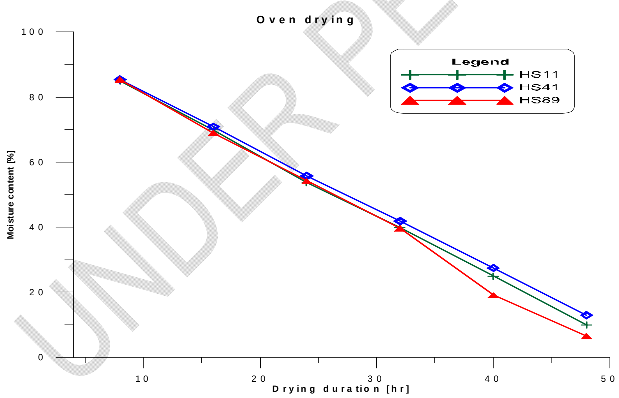

Fig 2. Rate of drying (oven) of roselle calyx

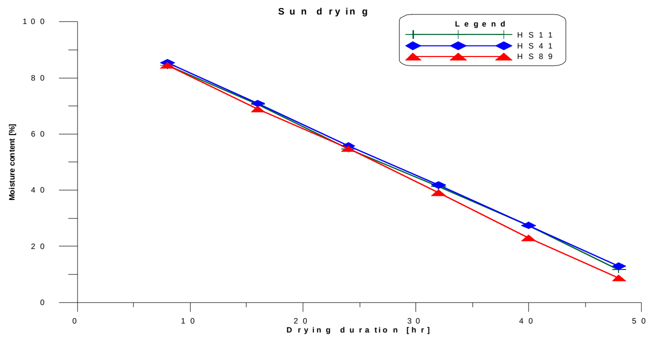

Fig 3. Rate of drying (sun) of roselle calyx

Generally, moisture content declined in all the drying methods. The decrease in moisture content was higher in the oven followed by sun and solar. Whereas the drying temperature in the oven was 60^{o}C, the solar drier and the ambient temperatures were 56.5^{o}C and 34.9^{o}C respectively. With respect to the ambient, the Relative Humidity was 15 – 30%.

3.1 MINERAL CONTENT OF THREE ACCESSIONS OF ROSELLE CALYCES.

3.1.1Calcium content

The calcium content of the roselle calyces under the different drying methods differed significantly ($p \leq 0.01$). HS41 had the highest calcium content (0.98%) followed by HS11 (0.86%) and HS89 (0.53%). 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 ($p \leq 0.01$) 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 3.1.1 Effect of different drying methods on calcium content of three accessions of roselle calyces

	Calcium (%)			
	Drying methods			
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				

3.1.2 Iron content

Drying of calyces of the different accessions of roselle using the different drying methods resulted in significantly different ($p \leq 0.01$) 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 3.1.2).

Table 3.1.2 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				

3.1.3 Potassium content

Table 3.1.3 shows results for potassium content of the calyces of the accession of roselle dried using different methods. Significant differences ($p \leq 0.01$) 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%.

Table 3.1.3 Effect of oven, solar and sun drying on the potassium content of three accessions (HS41, HS11 and HS89) of roselle calyces.

	Potassium (%)	
Accessions		Drying methods

	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

3.1 4 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 3.1.4.

Table 3.1.4 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

3.1.5 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 3.1.5.

Table 3.1.5 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;				

3.1.6 Phosphorus content

From Table 3.1.6, 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 3.1.6 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

3.1.7 Zinc content

From Table 3.1.7, 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 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 3.1.7.

Table 3.1.7: 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

4.1 MINERAL COMPOSITION OF THE CALYCES OF ROSELLE ACCESSIONS

4.1.1 Iron

The Recommended Daily Allowance (RDA) of iron for infants, children and adults according to Carolyn, (1998) ranged from 6 - 15mg/kg while that obtained from the study, was from 4.77mg/kg - 9.42mg/kg, slightly lower than that of the RDA. Iron helps in the growth and development of connective tissues and hormones. Its consumption is also vital for the production of hemoglobin and the oxygenation of red blood cells.

4.1.2 Calcium

Calcium as an essential mineral helps in bone and teeth formation, as well as the proper growth of the body. Adanlawo and Ajibade, (2006) reported a calcium content of 1.27% for roselle but from the study, the calcium content was comparatively lower (0.49% to 1.07%). This might be due to the genetic makeup of the accessions.

4.1.3 Potassium

Increasing potassium in the diet protects against hypertension for people who are sensitive to high levels of sodium (Okoli, 2009). Adanlawo and Ajibade, (2006) as well as USDA, (2016) reported 4.94% and 4% as the potassium content of roselle. From the study, a lower potassium content within the range of 0.43% - 0.62% was obtained. Variation in the results might be due to the differences in the soil type used for cultivation as well as the different genetic makeup of the calyces. Potassium maintain the body's fluid volume and also promote proper functioning of the nervous system (Shahnaz *et al.,* 2003).

4.1.4 Magnesium

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 (Underwood, 1994; Shills and Young, 1992). The magnesium content found in roselle was reported by Adanlawo and Ajibade (2006) 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.

4.1.5 Sodium

Sodium is a micronutrient that maintains osmotic pressure and helps in the relaxation of muscles (Okoli, 2009). The Sodium content according to USDA, (2016) was reported to be 0.0006 %. Comparatively, high sodium content (0.006% - 0.04%) obtained from the studies, might be due to differences in the genetic make of the calyces. Sodium helps in cell functioning as well as regulation of the body's fluid volume.

4.1.6 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% (Nnam and Onyeke, 2004; Adanlawo and Ajibade, 2006). From the study, a higher phosphorus content (0.31% - 0.36%) obtained might be due to differences in the genetic make-up of the accessions. Consumption of phosphorus helps maintain balance with calcium for strong bones and teeth.

4.1.7 Zinc

Zinc helps in the breakdown of carbohydrates as well as maintaining the structural integrity of proteins (Kawashima and Valente-Soares, 2003). The RDA for zinc is 15mg/kg (Myhill, 2010) while the zinc content contained in roselle is 12220mg/kg (Adanlawo and Ajibade, 2006). From the study, the zinc content obtained ranged from 0.82mg/kg - 3.06mg/kg which was comparatively lower than that reported by (Adanlawo and Ajibade, 2006). 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. To meet the RDA for roselle, more of the calyces needs to be consumed.

5.0 CONCLUSION

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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