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# Effects of Different Drying Methods on Proximate Composition of Three Accessions of Roselle (*Hibiscus sabdariffa*) Calyces

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***Authors' contributions***

*This work was carried out in collaboration with all authors. Author BA designed the study, performed the statistical analysis and wrote the protocol as well as the first draft of the manuscript. Authors FA and PK supervised the work, read and approved the final manuscript. All authors read and approved the final manuscript.*

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## ABSTRACT

Seeds of three roselle accessions (HS11, HS89 and HS41) were obtained from the Department of Horticulture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana and grown to obtain the calyces. The calyces were dried by sun (34.9°C), solar (56.5°C) and oven (60.0°C) methods. Most people consume the roselle calyces due to their nutritional and medicinal benefits. The study sought to, therefore, determine the effect of the different drying methods (oven, sun and solar) on the proximate composition of roselle accessions. The experiment was set up in a 3×3 factorial arrangement in a Completely Randomized Design (CRD) with three replications. The roselle accessions were harvested 12 weeks after sowing. From the results, HS89 had significantly ($P \leq 0.01$) least moisture content of 8.43% and highest carbohydrate content (65.30%). Ash and protein contents were highest ($P \leq 0.01$) in HS41 being 6.40% and 6.91%, respectively. As regards crude fat and crude fibre contents, HS11 had the highest being 2.49% and 17.92%, respectively. Concerning the methods of drying, oven-drying resulted in calyces with significantly ($P \leq 0.01$) lower moisture content (6.97%), but higher fat (2.88%), ash (5.80%) and carbohydrate (62.46%)

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contents. solar-dried calyces had significantly higher ($P \leq 0.01$) protein content (5.86%) while sun-dried calyces had significantly higher ($P \leq 0.01$) crude fibre content (17.60%). Interactively, oven-dried HS89 had significantly ($p \leq 0.01$) lowest moisture (6.50%) and highest fat (3.23%) while solar-dried HS41 had highest protein (8.17%) and ash (7.25%) contents. The study concluded that oven drying was more efficient than solar and sun in reducing the moisture, maintaining fat, ash and carbohydrate contents of roselle calyces. Solar drying resulted in higher protein content while sun-dried calyces produced higher fibre content in all the three accessions.

*Keywords: Roselle accessions; sun drying; solar drying; oven drying; proximate.*

## 1. INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) is an annual herbaceous vegetable plant of West African origin which belongs to the family Malvaceae [1]. The most exploited part of Roselle plant is its calyces which may be green, red or dark red [2]. The recent increase in knowledge in the health benefits of Roselle has increased consumer demand for processed products that can retain more of their original characteristics. This is because in the last five years a huge chain of trade has been built with these calyces. Many people along the entire value chain derive employment, income and livelihood from it. The Roselle calyx is highly perishable even though it has many essential nutrients such as vitamins, minerals and other quality attributes [3]. However, due to its high perishability, processing it into more stable forms like jellies, jams, juice and powder will go a long way to extend its shelf life [4]. Drying as a processing method ensures safe level moisture content reduction of products thereby minimizing quality deterioration for more economic returns. As one of the oldest methods of preserving food, drying eliminates water from food by directly exposing food to hot air from the sun [5] until it is in equilibrium with the surrounding air [6]. Preservation of food by drying is mostly done to maintain its value as well as increasing the number of days to spoilage [7]. For instance, [8] posited that freeze drying is the best drying method for jute followed by shade, sun and vacuum drying based on the quality parameters analyzed. According to [9], air-dried foods are less susceptible to lipid oxidation than freeze-dried products due to lower porosity. Moreover, the method of drying and processing conditions also influence the texture of dried products. The effect of different drying methods such as convective, vacuum, microwave, freeze and osmotic drying on quality of apple, banana, potato and carrot were reported by [10]. It was found that air, vacuum and microwave dried materials caused extensive browning in fruits and vegetables whereas freeze drying seemed to preserve colour changes, resulting in a product with improved colour characteristics. However, the effect of drying methods on the quality characteristics of roselle calyces has not been sufficiently investigated. This research, therefore, sought to determine the effect of three different drying methods (oven, sun and solar) on the proximate composition of calyces of three accessions of Roselle.

## 2. MATERIALS AND METHODS

### 2.1 Source of Roselle Calyces

Seeds of the roselle accessions were obtained from Kwame Nkrumah University of Science and Technology Kumasi, Ghana (KNUST). The seeds were sown on a field at the Department of Horticulture, KNUST. At maturity (12 weeks after sowing), the calyces were harvested and subjected to the various drying methods. Dried Roselle calyces were ground into powder after which they were sent to the laboratories of the Department of Horticulture and Department of Pharmacy, (KNUST) for analysis.

### 2.2 Experimental Design

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 three drying methods namely; sun, oven and solar.

### 2.4.1 Sun drying

One hundred grams (100 g) of fresh roselle calyces of each accession were put on a metallic tray and placed on a table directly under the sunlight within the hours of 9 am to 4 pm for 7 days. To ensure uniformity and even drying, the calyces were constantly stirred. The drying temperature (averaged 34.9°C) was monitored using RH/Temp data logger (EL-USB-2-LCD+, USA).

### 2.4.2 Solar drying

One hundred grams (100 g) of fresh roselle calyces from each accession were put on a metallic tray and placed in the solar dryer (cabinet type) from 9 am to 4 pm for 7 days. The calyces were constantly stirred to ensure uniformity and even drying under an average temperature of 56.5°C using RH/Temp data logger (EL-USB-2-LCD+, USA).

**Plate 1. Solar dryer**

### 2.4.3 Oven drying

One hundred grams (100 g) of fresh roselle calyces from each accession were put on a clean metallic tray and placed in the oven to dry at 60°C within 24 hours.

## 2.5 Parameters Studied

Different parameters studied under this research included the proximate composition as described by [11].

### 2.5.1 Moisture content

The moisture was determined by weighing two grams each of the sample into an already weighed moisture can. The samples were then dried in the oven at 60°C for 24 hours. After drying, they were put into a desiccator and allowed to cool after which it was reweighed. Drying continued until a constant weight was obtained. The moisture was calculated as the difference in weight of the original sample in percentage.

**Calculations**

$(A + B) – A = B$

$(A + B) – (A + C) = B - C = D$

$\% \text{ Moisture} = D/B \times 100$

Where,

A = crucible wt.,
B = sample wt.,
C = dry sample wt.,
D = moisture wt.

**Plate 2. Oven**

### 2.5.2 Protein

The micro Kjeldahl method described by A.O.A.C (1990) was used for determining the protein content. Two grams of the powdered calyces was weighed into a digestion flask followed by addition of 10 ml concentrated $H_2SO_4$ and a tablespoon of selenium as a catalyst. The mixture was heated inside a fume chamber until there was a clear digest formation. It was transferred to a distilled water. An equal portion of 10 ml 45%

NaOH was added and transferred into a Kjeldahl distillation apparatus. Distillation of the mixture was carried out and the distillate was received into a 4% boric acid solution containing 3 drops of methyl red indicator. A 50 ml sample of the distillate was collected and titrated with HCl. The sample was triplicated and the mean was calculated. A calculation of the nitrogen content was made and multiplied by a factor of 6.25 to obtain the crude protein content. This was given as:

$$\text{Percentage Nitrogen} = \frac{50(S\text{-}B) \times 0.019057 \times 0.0140 \times 100}{10 \times \text{wt. of sample}}$$

$$\%P = \%\,N \times 6.25$$

Where,

S = Titre value
B = Blank (0.20)
% P = Percentage Protein

### 2.5.3 Fibre

Two grams (2 g) of the sample was boiled with a 200 ml $H_2S0_4$ (1.25%) in the presence of 1 g asbestos for 30 minutes. The acid mixture was filtered using a muslin cloth placed over a Buchner funnel. The residue was thoroughly washed with boiling water until it was free from acid. The process was repeated using 200 ml of 1.25% NaOH after which it was washed with 10 ml of 95% ethanol. The residue obtained was scooped into a clean dried porcelain crucible and dried in the oven at 100°C to a constant weight. The dried sample was cooled, reweighed and the difference in weight calculated. The percentage crude fibre content was also calculated using the formula shown below.

**Calculation**

$$\%\ \text{crude fibre} = \frac{A - B}{C} \times 100$$

Where,

A = wt. of dry crucible and sample
B = wt. of incinerated crucible and ash,
C = sample weight.

### 2.5.4 Fat

Two grams of each sample was loosely wrapped with a filter paper into a thimble containing 120 ml petroleum ether after which it was fitted with an already weighed round bottom flask. It was connected to a condenser and a Soxhlet extractor over a heating mantle. Reflux was allowed for 3 hours undisturbed. After the set period, the flask containing the ether and the extracted fat was heated until all ether present evolved. The flask was dried in the oven at 100°C for 10 minutes. The flask was reweighed and the percentage fat content calculated.

**Calculation**

$$\%\ \text{Fat} = \frac{A - B}{C} \times 100$$

Where,

A = wt. of flask and extracted fat,
B =weight of fat
C = sample weight.

### 2.5.5 Ash

Two grams (2 g) each of the samples were weighed into a porcelain crucible of known weight into a muffle furnace for ashing at 550°C for 3 hours. Ashing was carefully done until samples turned white and were free from carbon. The sample was cooled in a desiccator after ashing to room temperature and reweighed. The weight of the residual ash was then calculated as:

**Calculations**

$$(A + B) – A = B$$

$$(A + C) - A = C$$

$$\%\ \text{Ash} = C/B \times 100$$

Where,

A = crucible weight,
B = sample weight,
C = ash weight.

### 2.5.6 Carbohydrate

The carbohydrate was calculated as the nitrogen-free extract described by A.O.A.C (1990) by summing up all the proximate parameters and deducting from 100.

**Calculation**

Nitrogen free Extract (NFE) = 100- (m + p + f1 + A +f2)

Where,

A = ash
f2 = Crude fibre
m = moisture
p = Protein
f1 = Fat

## 2.6 Data Analysis

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

## 3. RESULTS

## 3.1 Proximate Composition of the Calyces of Roselle Accessions

### 3.1.1 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.

### 3.1.2 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.

### 3.1.3 Crude fat content

The crude fat content of HS89 calyces was higher (3.23%) in oven-dried samples than sun (1.25%) and solar (0.75%). Similar trends were observed for HS41 and HS11 calyces dried using oven, sun and solar methods.

Generally, among the drying methods, roselle calyces subjected to oven drying had the highest (2.88%) fat content while the least was obtained by roselle calyces subjected to solar drying (1.25%).

### 3.1.4 Crude fibre content

Significant variation ($P<0.05$) in crude fibre content was recorded in each accession with

**Table 1. Moisture content (%) of Roselle calyces**

| Accessions | Moisture content (%) | | | |
|---|---|---|---|---|
| | Drying methods | | | |
| | Oven | Sun | Solar | Means |
| HS89 | 6.5 ± 0.2f | 8.67±1.15d | 10.13±0.38c | 8.43±1.83b |
| HS41 | 7.75±0.25e | 7.60±0.13e | 12.88±0.13a | 9.41±3.01a |
| HS11 | 6.67±0.21f | 9.98±0.02c | 11.75±0.12b | 9.46±2.58a |
| Means | 6.97±0.68c | 8.75±1.19b | 11.58±1.36a | |

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

**Table 2. Ash content (%) of Roselle calyces**

| Accessions | Ash content (%) | | | |
|---|---|---|---|---|
| | Drying methods | | | |
| | Oven | Sun | Solar | Means |
| HS89 | 5.50±0.5bcd | 4.50 ± 0.50d | 4.75±0.25cd | 4.92±0.52b |
| HS41 | 5.71±0.25bc | 6.25±0.25ab | 7.25±0.25a | 6.40±0.78a |
| HS11 | 6.20±0.21ab | 5.25±0.25bcd | 4.53±0.25d | 5.33±0.84b |
| Means | 5.80±0.36a | 5.33±0.88a | 5.51±1.51a | |

*HSD(1%); Drying=0.508; Accessions=0.508; Drying*Accession= 1.150* respect to the different drying methods. Solar-dried calyces of HS89 had higher crude fibre content (15.36%) compared to oven (14.98%) and sun (14.40%) as indicated in Table 4. HS41 (18.80%) and HS11 (19.54%) on the other hand, recorded higher crude fiber content when sun-dried. Generally, sun-dried calyces had higher crude fibre content (17.60%) followed by solar (17.02%) and oven (16.12%).

### 3.1.5 Crude protein content

Crude protein content was higher in solar-dried calyces (5.86%) than oven (5.76%) and sun (5.65%). The crude protein content of HS89 was highest in sun (5.02%) and oven (4.87%) dried calyces than solar (4.12%). On the other hand, the calyces of HS41 recorded significantly (*P*<0.05) higher protein content when dried using solar (8.17%) than sun (6.50%) and oven (6.07%). As regards HS11, oven drying recorded the highest crude protein content (6.35%) followed by sun (5.42%) and solar (5.29%).

### 3.1.6 Carbohydrate content

Overall, the carbohydrate content varied between the drying methods ranging from 58.77% to 62.46% as indicated in Table 6. No differences were observed in drying method for HS89. However, significant differences (*P*<0.05) in effect of different drying method were observed for HS41 and HS 11. Carbohydrate content was highest in oven-dried HS41 (60.02%) and HS11 (62.45%).

## 4. DISCUSSION

### 4.1 Moisture Content

The study showed that oven drying resulted in lower moisture content for HS89 and HS11. Generally, oven drying is known to provide a constant heating effect which promotes drying. The presence of an extractive fan in the oven ensured removal of humid air on the surface of the calyces consequently facilitating moisture

**Table 3. Crude fat content (%) of Roselle calyces**

| | Crude fat content (%) | | | |
|---|---|---|---|---|
| **Accessions** | **Drying methods** | | | |
| | **Oven** | **Sun** | **Solar** | **Means** |
| HS89 | 3.23±0.21a | 1.25 ± 0.25de | 0.75±0.25e | 1.74±0.60b |
| HS41 | 2.25±0.25bc | 2.17±0.15c | 1.75±0.25cd | 2.06±1.29b |
| HS11 | 3.17±0.21a | 3.06±0.12ab | 1.25±0.25de | 2.49±0.93a |
| Means | 2.88±0.55a | 2.16±0.91b | 1.25±0.50c | |

*HSD(1%): Drying=0.362; Accessions = 0.362: Drying*Accession= 0.820*

**Table 4. Crude fibre content (%) of Roselle calyces**

| | Fibre content (%) | | | |
|---|---|---|---|---|
| **Accessions** | **Drying methods** | | | |
| | **Oven** | **Sun** | **Solar** | **Means** |
| HS89 | 14.98±0.02f | 14.4± 0.03 g | 15.36±0.03e | 14.94±0.28b |
| HS41 | 18.20±0.2c | 18.80±0.02b | 16.64±0.04d | 17.88±0.42a |
| HS11 | 15.17±0.15ef | 19.54±0.04a | 19.07±0.02b | 17.92±0.36a |
| Means | 16.12±1.81c | 17.60±2.73a | 17.02±1.88b | |

*HSD(1%): Drying = 0.127;Accessions= 0.127; Drying*Accession = 0.288*

**Table 5. Crude protein content (%) of Roselle calyces**

| | Protein content (%) | | | |
|---|---|---|---|---|
| **Accessions** | **Drying methods** | | | |
| | **Oven** | **Sun** | **Solar** | **Means** |
| HS89 | 4.87±0.01e | 5.02 ± 0.01 e | 4.12±0.02f | 4.67±0.48c |
| HS41 | 6.07±0.01c | 6.50±0.01b | 8.17±0.15a | 6.91±1.11a |
| HS11 | 6.35±0.02b | 5.42±0.03d | 5.29±0.01d | 5.69±0.58b |
| Means | 5.76±0.79b | 5.65±0.77c | 5.86±2.08a | |

*HSD (1%): Drying=0. 078; Accessions=0. 078; Drying*Accession=0.176*

**Table 6. Carbohydrate content (%) of roselle calyces**

| Accessions | Carbohydrates (%) | | | |
|---|---|---|---|---|
| | Drying methods | | | |
| | Oven | Sun | Solar | Means |
| HS89 | 64.92±0.54a | 66.09 ± 0.40a | 64.89±0.36a | 65.30±0.68a |
| HS41 | 60.02±0.53c | 58.69±0.09cd | 53.32±0.52f | 57.34±3.55c |
| HS11 | 62.45±0.74b | 56.75±0.31e | 58.11±0.24de | 59.10±2.98b |
| Means | 62.46±2.45a | 60.51±4.93b | 58.77±5.81c | |

*HSD (1%): Drying=0.719; Accessions=0.719; Drying*Accession=1.627*

loss. These accounted for the least moisture content in the oven-dried samples. Lower moisture content is indicative of longer shelf life [11] as the enzymatic and microbial activity is reduced. Hence, Oven drying could be a method of choice when drying Roselle calyces.

## 4.2 Ash Content

Ash content is the measure of minerals present in a food sample. Oven drying resulted in higher ash content in HS89 and HS11. According to [11] and [12] high ash content of food is suggestive of high mineral content. The mineral content of HS89 and HS11 could, therefore, be better conserved when roselle calyces are oven-dried.

## 4.3 Crude Fat Content

The low-fat content of roselle calyces dried by solar may be due to the prolonged exposure of the samples to heat (56.5°C) and light within the solar dryer. This is because heat, light and radiation are factors which decrease fat content through lipid oxidation [13].

Fats and oils are known to be carriers of fat-soluble vitamins such including Vitamin A, D, E and K. They are also known to be carriers of flavour-enhancing compounds. Roselle calyces with higher crude fat content could be rich in these vitamins and have desirable flavours [14] and [15]. Generally, drying Roselle calyces in an oven could be more desirable as crude fat content is preserved and consequently flavor and fat-soluble vitamins.

## 4.4 Crude Fibre Content

Roselle calyces dried by sun had higher crude fibre content than those dried by the oven and solar. This may be due to the complexing of carbohydrate with amino acids under ambient temperature [16] for a longer period of time. The crude fibre content in Roselle as reported by [17] was 4.69%. From the current study, higher fibre contents within the range of 14.48% - 19.54% were obtained. Since roselle calyces are used mainly in drink preparation, drying methods such as oven and solar which uses shorter periods for drying of calyces is recommended.

## 4.5 Carbohydrate Content

The high carbohydrate content from the study is similar to the finding of [18] and [19]. The high carbohydrate content of roselle calyces dried by oven as compared to that dried by solar may be due to the minimal break down of carbohydrate in the oven-dried samples than that in the solar. This is because the time samples took to dry in the oven was less (12 hours) as compared to the time samples took to dry in the solar dryer (3 days). Prolonged drying predisposes produce metabolic and microbial breakdown through processes including respiration. Consequently, drying roselle calyces using oven would be preferred.

## 4.6 Crude Protein Content

The lower protein content obtained for roselle calyces which were subjected to sun drying may be due to the prolonged exposure of samples to ambient temperature. According to [20], protein forms a complex with carbohydrate through Maillard reaction and cause protein denaturation when it is exposed to high temperature. The protein content of the Roselle calyces in this study was similar to those reported by [17]. In order to maintain crude protein content of roselle calyces, drying should be done by either solar or oven.

## 5. CONCLUSION

Oven drying was more efficient than solar and sun in reducing the moisture, increasing fat, ash and carbohydrate. However, solar drying resulted in higher protein content while higher fibre content was obtained in sun-dried calyces.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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