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Effect of Different Drying Methods and Storage Time on Quality of Roselle Calyxes (*Hibiscus sabdariffa L.*) Plants

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This research was conducted during the 2018 and 2019 seasons, and the aim of the research was to study the effect of each of the different drying methods (drying in the shade, direct sunlight, electric ovens, and solar dryer) and the different storage periods (0, 2, 4 and 6 months) on the quality of Roselle (*Hibiscus sabdariffa L.*) for both variety cultivars Sabhia 17 Dark and Sabhia 17 Light. The results showed that the method of drying in the shade gave the best results for most of the characterizes studied for both varieties of the both seasons, and the results for the different storage times did not differ significantly between them, especially the calyxes content of the two varieties of TPC, DPPH% and TFC. On the other hand the chemical composition data of roselle observed about the light variety is rich in ascorbic acid, TFC and TPC, while the dark variety is rich in the total anthocyanin content (490 mg / 100g DWS).

Keywords: Hibiscus sabdariffa L.; total anthocyanins content; drying methods; DPHH%; storage time.

1. INTRODUCTION

Roselle (*Hibiscus sabdariffa L.*), Family Malvaceae is a tropical annual herbal shrub and is characterized by red calyxes and flowers with a unique sour taste. Roselle calyxes have been widely used as an edible colorant in food, drink and some cosmetic products and are rich in

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antioxidant components, mainly anthocyanin that counteracts oxidative damage to prevent some diseases [1,2]. Previous studies have shown that the free radical scavenging effect (DPPH %) of *Hibiscus sabdariffa* extract is able to attenuate lipid peroxidation and protein oxidation in renal tissues and hepatic [3].

The fresh calyxes of roselle contained natural bio active of organic acids such as citric and malic and more acids (4) This played a key role in giving the juice samples a bright, concentrated red color. The high acidity of distinctive taste in the roselle calyxes extracts due to organic acids [5].

The human body lacks the ability to synthesize vitamin C. Previous studies have shown that the calyxes of roselle are rich in vitamin C. [6]. This implies that Roselle has a higher content of ascorbic acid than guava, orange and mango [7]. Vitamin C content of roselle calyxes is related to the state of freshness or dryness time. Vitamin C is also an important antioxidant which plays an important role in preventing free radicals [8].

Roselle shows the presence of flavonoids, it can be used to cure many disorders and as an antioxidant agent. In more the studies, polyphenols were detected. Polyphenols have attracted a great attention in relation to their potential for beneficial effects on health. Over the last few years, several experimental studies have revealed biological and pharmacological properties of polyphenols compounds, especially their anti-inflammatory activity, antiviral and cytotoxic activity [9]. The fact that most medicinal plants is a well-documented, are enriched with polyphenol compounds that have excellent antioxidant properties [10,11].

Previous studies indicated that roselle calyxes extracts contain a high percentage of organic acids, in two groups the first group like citric acid (12–20%), hydroxycitric acid, hibiscus acid (13–24%), tartaric (8%) malic (2– 9%) acids as major compounds, and the second group include oxalic and ascorbic (0.02–0.05%) acids as minor compounds [12]. The human health benefits of Ascorbic acid or vitamin C are many. It prevents the scurvy, treatment of common cold, lowering the hypertension, stimulating the immune system, treatment of cancer; Maintains skin vitality by remaining elastic [13]. Ascorbic acid and other different phenolic compounds are good for human health maintenance and prevention of more diseases. Phenolic compounds including hydroxyl benzoic acids, flavones, phenolic acids, caffeoylquinic acids and anthocyanins are known to be responsible for antioxidant activities in most fruits .on other hand fruits with higher phenolic contents, generally show stronger antioxidant activities such as calyxes content of roselle [14].

Anthocyanin can lower cholesterol, lower blood pressure, increase blood circulation, enhance capillary strength and combat oxidative stress [15]. Anthocyanins, flavonoids and polyphenol which are the main phytochemical groups with biological activities. The anthocyanins have been found to be cardio protective, hypercholesterolemia, antioxidative and hepatoprotective [16,17]. They also have an antioxidant activity [9] and inhibit low-density lipoprotein (LDL) oxidation [18]. Flavonoids are commonly known for their anti-inflammatory, antioxidant, antiviral activity, cytotoxic and also used in the treatment of diabetes, hypertension and rheumatic fever [19, 20]. Anthocyanin is the largest group of water-soluble natural pigment from plants provide red, blue and violet colors to flowers, fruits, vegetables, juices, liquor and jams. It is an active compound, which is sensitive to pH, temperature, light, oxygen, enzyme and sulphur dioxide. Anthocyanin was reported to be destroyed by high heat during processing and storage of food [21]. Increasing one's antioxidant intake is essential for optimum health, especially in today's polluted world. Antioxidant intake can protect body against heart problem, eye problems, memory problems, mood disorders, immune systems problems [22]. DPPH radicals are widely used to study the recovery activities of several naturally occurring compounds. The effect of antioxidant on DPPH radical scavenging was thought to be due to their hydrogen donating ability or radical scavenging activity, and it used as a substrate to evaluate the antioxidant activity [23]. Several in vitro and animal studies with anthocyanins strongly suggest their beneficial effects in cardiovascular complications in diabetes, clinical evidence for the use of anthocyanins and anthocyanin-rich extracts in diabetes is not convincing. The vision improving effect of anthocyanins is an interesting and important field of study, because myopia is prevalent in today's society, with decreased contrast sensitivity, a vague eye discomfort (asthenopia) arising from over-use of the eyes [24].

The flavonoids inhibit different varieties of Cancers in animals. High flavonoid intake can reduce human cancer risk [25] Flavonoids are

considered metabolites of plants that impart coloration to most fruits, and seeds [26]. Flavonoids and phenolic have been considered as important antioxidants and turned out to be more efficient than vitamin C, E and carotenoids [27]. A high-consumption diet of fruits and vegetables that are high in antioxidants reduces the risk of many types of cancer [28]. Antioxidants in the diet hold great promise as an inhibitor of cancer due to their low toxicity, safety and general acceptance [29, 30].

In addition, the drying process is considered one of the most important post-harvest transactions and aims to prolong the storage period and reduce the costs of the packaging process, as well as the cost of sea freight or others [31]. The method of drying in direct sunlight is the oldest traditional method, and the product in this way is high crop losses ensue from inadequate drying which results to exposed to weather conditions such as air moisture or rain, as well as to attacking fungi, insects and rodents [32]. On the other hand, solar dryers are the best methods that produce a dry crop that is protected from attacking fungi and is not exposed to climate fluctuations and others, meaning that the product is in sufficient protection as this method depends on two basic processes, namely, heat transfer to the product and then removing moisture from it [33].

This research was designed to assessment the free radical scavenging of anthocyanins and different active content from calyxes of Roselle under different drying methods in different storage times.

2. MATERIALS AND METHODS

Two filed experiments were conducted in the Experimental Farm (Alqanater Alkhiria) of Medicinal and Aromatic Plants Res. Dept., ARC, Egypt, during, the two growing seasons of 2018 and 2019 to study the Effect of different drying methods on quality (chemical composition) of Roselle calyxes (*Hibiscus sabdariffa L.*) Plants.

Roselle seeds (Sabhia 17, two cultivars dark and light) are planted in April in the two growing seasons, respectively. The distance between the rows are being 60 cm and 50 cm between plants.

The recommended dose of NPK (2:1:1) will be divided in two equal parts, the first one will be applied one month after sowing and the second one will be applied after the first dose. The chemical fertilizers will be applied as ammonium sulphate (20.5%N), calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O) at (150 kg/fed, respectively) which are the recommended dose. (Guidance bulletin of the Department of Medicinal and Aromatic Plants Research, HRI, ARC, 2016).

At harvest dates in September in both seasons, plants were taken from the experiment field at random to estimate the following characteristics which were recorded:

2.1 Preparation of Roselle Calyxes

At the field we cut the base of the flower stalk with a knife to release the capsule to remove seeds of capsules for obtained fresh calyxes by shelling hand or tool shelling.

2.2 Drying Methods Treatments

The two cultivars for the two processing were collected and the after that drying is carried out after shelling, by four drying methods, first is sun rays drying. It reduces the moisture content of the calyxes from 86% to 13 -16% for improved preservation. Currently drying is traditionally performed by direct exposure of the calyxes to the sun rays. Calyxes are spread on mats or plastic sheets placed directly on the ground. The duration of drying is between 6 and 10 days. Second method is an OAD (oven air dryer) at 60^0C for 36 hr. to obtain the lowest of moisture content in dried roselle calyxes (10%). The third drying method is using solar energy by a direct solar – heated forced air system (DSA) shown in Fig. 1 according to [34]. The duration of drying is between 6 and 8 days. It reduces the moisture content of the calyxes from 86% to 12 -14%. Fourth method of drying in the shade in perforated shelves. The moisture content of the calyxes were reduced from 86% to 12 -14%. All previously treatment of dark and light red roselle calyxes were divided into two groups randomly assigned to each of the treatment combinations all were packed in polypropylene (pp) package.

2.3 Storage Time Treatments

All samples for all dry methods were stored at room temperature (at 25^0C). Various quality indices along with subjective evaluation were determined during storage period up to eight months at room temperature. The physical and chemical properties of roselle calyxes for the two cultivars were determining on zero day and (2, 4 and 6 months).

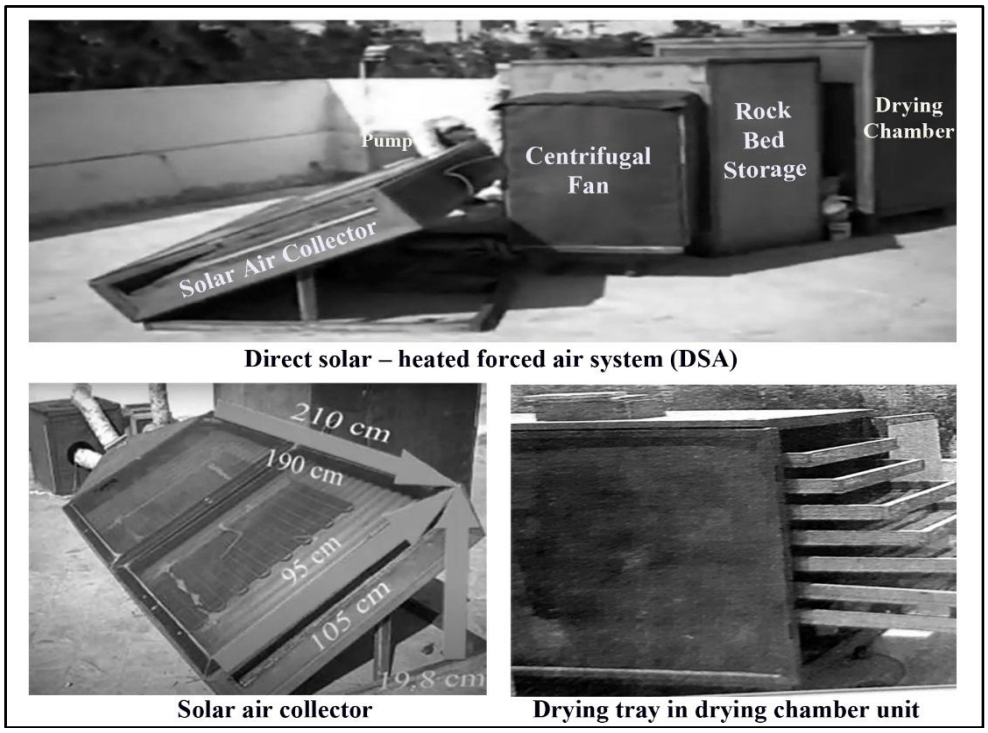

Fig. 1. Direct solar- heated forced air system (DSA)

2.4 Determination of Dried Roselle Calyxes Percentage

The percentage of dried roselle calyxes was calculated as X = (weight of DRC after drying / weight of FRC before drying) x 100.

2.5 Moisture Content

The amount of moisture content (MC) in a product is designated on the basis of the weight of water (i.e. dry or wet basis). On dry basis (%) it can be calculated as follows [35].

2.6 Physical and Chemical Properties

1. (TAC) Total anthocyanin content is determining in fresh calyxes samples using the method by [36].
2. (TPC) Total phenolic content and the free radical-scavenging activity (DPPH) of Roselle calyxes extract were estimated according to [37].
3. Vitamin (C) content was determined in filtered juice samples and expressed as (mg) ascorbic acid/100 ml fresh juice as described by [38].
4. (TFC) Total flavonoids content of freeze-dried extract was determined using the method described by [39].

The factorial experimental design will be a **randomized complete block design** (RCBD) with three replicates. The obtained data are, statistically, analyzed for ANOVA, and $L.S.D._{0.05}$ values were calculated to test the differences between the studied treatments according to [40].

3. RESULTS AND DISCUTION

3.1 Determination of Moisture Content (MC), Ash and Dry Percentage

It is obviously observed from the Tables 1, 2 and 3 for both seasons that the moisture content is decreased at the electric oven and solar methods compared with other drying methods for both variety of roselle (Dark and light). The results indicate that the different drying methods did not have significant differences for both variety during the two seasons. The results indicate that the MC of calyxes of the dark variety was lower than that of the light variety, while the opposite was true for the percentage of ash. The same results (moisture content and ash percentage) obtained for different storage time were consistent with the results of different drying methods. The accelerated drying rate can be due to internal heat generation. As the temperature increased, the drying time became shorter [41]

Table 1. Effect of different drying methods on calyxes content. (Moisture % and Ash %) in the two seasons 2018 and 2019

Roselle variety	Drying method	Moisture %		Ash %	
		2018	2019	2018	2019
Sabhya 17 (Dark)	Shade	11.15 c	11.30 b	10.18 a	10.18 a
	Sun	11.10 c	11.08 c	10.18 a	10.15 a
	E.Oven	10.13 d	10.13 e	10.08 a	10.08 a
	Solar	10.23 d	10.28 d	10.10 a	10.08 a
Sabhya 17 (Light)	Shade	11.55 a	11.53 a	9.35 b	9.25 b
	Sun	11.35 b	11.38 b	9.30 b	9.33 b
	E.Oven	11.10 c	11.08 c	9.30 b	9.33 b
	Solar	11.05 c	11.08 c	9.30 b	9.30 b
L.S.D $_{0.05}$		0.15	0.12	0.19	0.17

Means with similar letters of the alphabet are not significantly different according to the least significant difference test at the 0.05 probability level

Table 2. Effect of different storage time on calyxes content. (Moisture % and Ash %) in the two seasons 2018 and 2019

Roselle variety	Storage time	Moisture %		Ash %	
		2018	2019	2018	2019
Sabhya 17 (Dark)	Zero month	10.55 d	10.63 d	10.25 a	10.23 a
	2 month	10.63 cd	10.60 d	10.20 a	10.18 a
	4 month	10.68 c	10.75 c	10.15 a	10.15 a
	6 month	10.75 c	9.93 e	9.93 b	9.93 b
Sabhya 17 (Light)	Zero month	11.15 b	11.15 b	9.33 c	9.38 c
	2 month	11.23 ab	11.23 ab	9.33 c	9.35 c
	4 month	11.33 a	11.33 a	9.30 c	9.33 c
	6 month	11.35 a	11.35 a	9.30 c	9.30 c
L.S.D $_{0.05}$		0.14	0.11	0.18	0.16

Means with similar letters of the alphabet are not significantly different according to the least significant difference test at the 0.05 probability level

and it is appeared that the roselle calyxes had high ash content which reached 10.3 at zero month to 9.9 at six months in a good agreement with [42, 43]. The higher the drying temperatures used, the higher the rate of moisture loss was achieved. Sun drying method gave the highest percentage of drying for both variety of roselle (Dark and light) compared to other drying methods under study in both seasons. The drying percentage of the light variety was higher compared to the dark variety due to its increased moisture content. The percentage of drying for the majority of storage periods was not significant for each variety of roselle separately (Tables 4, 5 and 6). However, there are significant differences between the dark and light varieties. The drying methods were higher at the beginning of the process probably due to the evaporation of moisture from the surface of samples and later decreased with decreasing the moisture content, then the percentage of drying is decreases.

3.2 Total Acidity Content (As Malic Acid %)

It is clear from Tables 4 - 6 in general that the total acidity content was higher in the light variety compared to the dark variety. The sun drying method gave the highest total acidity content for almost both cultivars and the majority of storage times in general, without significant differences within each cultivar separately. These results agree with [41].

3.3 Determination of pH

The pH values of dried calyxes roselle are presented in Tables (7, 8 and 9). The results showed that the pH values of the dark variety was higher (3.63) compared to the light variety (2.74) under different of drying methods and storage times. While the different drying methods have no significant differences between them for each variety (dark and light), as well as there are

Table 3. Means percentage moisture and ash in calyxes content as influenced by the interaction between different drying methods and storage time in the two seasons 2018 and 2019

Roselle variety	Storage time	Drying method	Moisture %		Ash %	
			2018	2019	2018	2019
Sabhya 17 (Dark)	Zero month	Shade	11.2	11.4	10.3	10.3
		Sun	11.0	11.0	10.3	10.2
		E.Oven	10.0	10.0	10.2	10.2
		Solar	10.0	10.1	10.2	10.2
	2 month	Shade	11.1	11.0	10.2	10.2
		Sun	11.1	11.0	10.2	10.2
		E.Oven	10.1	10.2	10.2	10.2
		Solar	10.2	10.2	10.2	10.1
	4 month	Shade	11.1	11.4	10.2	10.2
		Sun	11.1	11.1	10.2	10.2
		E.Oven	10.2	10.1	10.1	10.1
		Solar	10.3	10.4	10.1	10.1
	6 month	Shade	11.2	11.4	10.0	10.0
		Sun	11.2	11.2	10.0	10.0
		E.Oven	10.2	10.2	9.8	9.8
		Solar	10.4	10.4	9.9	9.9
Sabhya 17 (Light)	Zero month	Shade	11.6	11.5	9.4	9.5
		Sun	11.2	11.2	9.3	9.3
		E.Oven	10.9	10.8	9.3	9.4
		Solar	10.9	11.1	9.3	9.3
	2 month	Shade	11.6	11.6	9.4	9.4
		Sun	11.3	11.3	9.3	9.4
		E.Oven	11.0	11.0	9.3	9.3
		Solar	11.0	11.0	9.3	9.3
	4 month	Shade	11.5	11.5	9.3	9.4
		Sun	11.5	11.5	9.3	9.3
		E.Oven	11.2	11.2	9.3	9.3
		Solar	11.1	11.1	9.3	9.3
	6 month	Shade	11.5	11.5	9.3	9.3
		Sun	11.4	11.5	9.3	9.3
		E.Oven	11.3	11.3	9.3	9.3
		Solar	11.2	11.1	9.3	9.3
L.S.D $_{0.05}$			0.14	0.12	0.19	0.2

no significant differences between the different storage periods for both varieties (dark and light). The pH depends on the concentration of free H ions or mirrored the changes in total organic acids. The free state of H ions is due to dissociation of H ions from the carboxylic group (- COOH) of organic acid. This increase in pH throughout maturation was due to a metabolic process in the fruits that resulted in the decrease of organic acids. This is because organic acids are an important source of respiratory energy in plant cell [42].

3.4 Ascorbic Acid

Data in Tables 7, 8 and 9 indicate that the calyxes content of ascorbic acid was higher with the method of drying in the shade compared to other drying methods in both cultivars in the two seasons (2018 and 2019), while the calyxes content of the ascorbic acid for both variety (dark and light) were slight differences between them for the different storage periods. Also, the results showed that the calyxes content of ascorbic acid for the light variety was higher than the dark variety with significant differences in the two seasons (2018 and 2019). These results were in a good agreement with the findings of [12].

3.5 Total Anthocyanin Content (mg/100 g DWS)

Tables 7, 8 and 9 showed that drying methods in the shade and direct sunlight gave the highest

calyxes content of anthocyanins compared to other drying methods in both variety (Dark and Light) in the two seasons. On the other hand, the results indicated that the roselle calyxes content of the anthocyanins was clearly higher in the dark variety than in the light variety in the two seasons. In agreement with [44] their showed that heat treatment had a significant impact on anthocyanin stability. The results are in a good agreement with the results obtained [45].

3.6 Total Phenolic Compound (TPC)

Based on Tables 10, 11 and 12, the results show that the calyxes content of total phenols for light variety was the highest in the fourth drying methods relative to the dark variety in the two seasons (2018 and 2019), on the other hands the zero time of storage gave the heights TPC for both varieties in the two seasons. The results of TPC for the light variety showed that there are no significant differences between the storage times (zero and two months) for the first season 2018 and the four different storage times (zero,2,4 and 6 months) for the second season 2019. The results in an agreement with [41, 42] and also in an agreement with [43].

3.7 Total Flavonoids Content (TFC)

From Tables 10, 11 and 12 the same trend as the results obtained for the total phenol content (TPC) of calyxes roselle was obtained for the total flavonoids (TFC). Also, the results indicated that the roselle calyxes content of the total flavonoids was clearly higher in the light variety than in the dark variety in the two seasons. Most of the total flavonoids content (TFC) obtained results indicate that there are no significant differences between the different storage periods within each variety (Dark or Light) separately in the two seasons (2018 and 2019). These results were in a good agreement with the findings of [41, 46].

Table 4. Effect of different drying methods on calyxes content (Dry % and Total acidity content) in the two seasons 2018 and 2019

Roselle variety	Drying method	Dry %		Total acidity content (As malic acid %)	
		2018	2019	2018	2019
Sabhya 17 (Dark)	**Shade**	20.75 f	21.00 d	4.19 d	4.15 c
	Sun	21.25 e	21.50 b	4.35 c	4.33 bc
	E.Oven	20.25 h	20.25 f	4.18 d	4.28 c
	Solar	20.50 g	20.75 e	4.20 d	4.23 c
Sabhya 17 (Light)	**Shade**	22.00 b	21.75 a	4.53 a	4.55 a
	Sun	22.25 a	21.25 c	4.58 a	4.53 a
	E.Oven	21.25 e	21.00 d	4.50 ab	4.55 a
	Solar	21.50 d	21.50 b	4.43 bc	4.43 ab
L.S.D $_{0.05}$		0.17	0.15	0.11	0.14

Means with similar letters of the alphabet are not significantly different according to the least significant difference test at the 0.05 probability level

Table 5. Effect of different storage time on calyxes content (Dry % and Total acidity content) in the two seasons 2018 and 2019

Roselle variety	Storage time	Dry %		Total acidity content (As malic acid %)	
		2018	2019	2018	2019
Sabhya 17 (Dark)	**Zero month**	20.75 d	21.25 b	4.28 b	4.20 b
	2 month	20.50 e	20.50 e	4.28 b	4.28 b
	4 month	20.75 d	20.75 d	4.28 b	4.28 b
	6 month	20.75 d	21.00 c	4.23 b	4.23 b
Sabhya 17 (Light)	**Zero month**	21.75 b	21.25 b	4.53 a	4.55 a
	2 month	21.50 c	21.25 b	4.50 a	4.53 a
	4 month	21.75 b	21.75 a	4.48 a	4.48 a
	6 month	22.00 a	21.25 b	4.53 a	4.50 a
L.S.D $_{0.05}$		0.20	0.15	0.19	0.17

Means with similar letters of the alphabet are not significantly different according to the least significant difference test at the 0.05 probability level

Table 6. Means of Dry% and Total acidity content in calyxes content as influenced by the interaction between different drying methods and storage time in the two seasons 2018 and 2019

Roselle variety	Storage time	Drying method	Dry %		Total acidity content (As malic acid %)	
			2018	2019	2018	2019
Sabhya 17 (Dark)	Zero month	Shade	22	22	4.4	4.1
		Sun	21	21	4.3	4.2
		E.Oven	20	20	4.3	4.2
		Solar	20	21	4.3	4.1
	2 month	Shade	21	22	4.3	4.3
		Sun	21	21	4.4	4.4
		E.Oven	22	22	4.4	4.3
		Solar	21	21	4.3	4.3
	4 month	Shade	20	20	4.2	4.1
		Sun	20	20	4.2	4.3
		E.Oven	20	20	4.2	4.4
		Solar	21	21	4.1	4.3
	6 month	Shade	20	21	4.2	4.3
		Sun	20	20	4.2	4.2
		E.Oven	21	21	4.2	4.2
		Solar	21	21	4.2	4.2
Sabhya 17 (Light)	Zero month	Shade	23	22	4.6	4.6
		Sun	22	22	4.5	4.6
		E.Oven	21	22	4.5	4.5
		Solar	22	21	4.5	4.5
	2 month	Shade	22	21	4.6	4.5
		Sun	22	21	4.6	4.5
		E.Oven	23	22	4.5	4.5
		Solar	22	21	4.6	4.6
	4 month	Shade	21	21	4.5	4.6
		Sun	21	21	4.5	4.6
		E.Oven	21	21	4.5	4.5
		Solar	22	21	4.5	4.5
	6 month	Shade	21	21	4.4	4.5
		Sun	21	21	4.4	4.4
		E.Oven	22	22	4.4	4.4
		Solar	22	22	4.5	4.4
L.S.D $_{0.05}$			0.19	0.17	0.15	0.11

Table 7. Effect of different drying methods on calyxes content (pH, ascorbic acid and total anthocyanin content) in the two seasons 2018 and 2019

Roselle variety	Drying method	pH		Ascorbic acid (mg/100g DWS)		Total anthocyanin content (mg/100g DWS)	
		2018	2019	2018	2019	2018	2019
Sabhya 17 (Dark)	Shade	3.67 a	3.72 a	12.08 e	12.01 e	487.3 a	490.5 a
	Sun	3.67 a	3.73 a	12.05 e	12.00 e	486.2 a	488.7 ab
	E.Oven	3.60 a	2.73 b	11.93 f	11.93 f	484.7 b	486.0 bc
	Solar	3.56 a	2.73 b	11.73 g	11.73 g	482.5 c	484.0 c
Sabhya 17 (Light)	Shade	2.77 b	2.81 b	15.33 a	15.28 a	401.5 d	407.5 d
	Sun	2.75 b	2.82 b	15.20 b	15.20 b	401.0 d	403.3 e
	E.Oven	2.74 b	2.83 b	14.88 c	14.98 c	396.2 e	401.8 e
	Solar	2.72 b	2.83 b	14.70 d	14.80 d	389.7 f	398.8 f
L.S.D $_{0.05}$		0.15	0.13	0.05	0.06	2.06	2.29

Means with similar letters of the alphabet are not significantly different according to the least significant difference test at the 0.05 probability level

Table 8. Effect of different storage time on calyxes content (pH, ascorbic acid and total anthocyanin content) in the two seasons 2018 and 2019

Roselle variety	Storage time	pH		Ascorbic acid (mg/100 g DWS)		Total anthocyanin content (mg/100g DWS)	
		2018	2019	2018	2019	2018	2019
Sabhya 17 (Dark)	Zero month	3.61 a	3.22 a	12.00 c	11.98 d	485.2 a	488.0 a
	2 month	3.63 a	3.22 a	11.95 c	11.95 d	485.0 a	487.2 a
	4 month	3.62 a	3.22 a	11.98 c	11.88 e	485.0 a	487.0 a
	6 month	3.62 a	3.22 a	11.98 c	11.88 e	485.5 a	487.0 a
Sabhya 17 (Light)	Zero month	2.75 b	2.81 b	15.15 a	15.18 a	397.5 b	404.5 b
	2 month	2.75 b	2.83 b	14.98 b	15.05 b	397.2 b	402.7 bc
	4 month	2.74 b	2.82 b	15.00 b	15.05 b	397.0 b	401.7 bc
	6 month	2.74 b	2.83 b	14.98 b	14.98 c	396.7 b	401.5 c
L.S.D $_{0.05}$		0.11	0.09	0.08	0.04	2.21	2.81

Means with similar letters of the alphabet are not significantly different according to the least significant difference test at the 0.05 probability level

Table 9. Means of pH, ascorbic acid and total anthocyanin content in calyxes content as influenced by the interaction between different drying methods and storage time in the two seasons 2018 and 2019

Roselle variety	Storage time	Drying method	pH		Ascorbic acid (mg/100g DWS)		Total anthocyanin content (mg/100g DWS)	
			2018	2019	2018	2019	2018	2019
Sabhya 17 (Dark)	Zero month	Shade	3.65	3.71	12.1	12.2	488	491
		Sun	3.68	3.70	12.1	12.2	486	490
		E.Oven	3.68	3.72	12.0	12.0	487	490
		Solar	3.67	3.73	12.1	12.0	488	491
	2 month	Shade	3.67	3.73	12.0	12.0	486	490
		Sun	3.68	3.73	12.0	12.0	486	489
		E.Oven	3.67	3.72	12.1	12.0	486	488
		Solar	3.67	3.72	12.1	12.0	487	488
	4 month	Shade	3.57	2.73	12.0	11.9	484	487
		Sun	3.58	2.73	11.9	11.9	485	486
		E.Oven	3.56	2.72	11.9	11.8	485	486
		Solar	3.57	2.72	11.9	11.8	485	485
	6 month	Shade	3.56	2.72	11.9	11.8	483	484
		Sun	3.56	2.74	11.8	11.7	483	484
		E.Oven	3.55	2.73	11.9	11.7	482	484
		Solar	3.55	2.72	11.8	11.7	482	484
Sabhya 17 (Light)	Zero month	Shade	2.78	2.81	15.4	15.5	402	410
		Sun	2.77	2.81	15.3	15.2	402	407
		E.Oven	2.76	2.80	15.3	15.2	401	407
		Solar	2.77	2.81	15.3	15.2	401	406
	2 month	Shade	2.75	2.80	15.3	15.3	401	404
		Sun	2.75	2.83	15.2	15.2	401	404
		E.Oven	2.74	2.82	15.2	15.2	401	403
		Solar	2.74	2.82	15.1	15.1	401	402
	4 month	Shade	2.75	2.81	15.1	15.0	397	403
		Sun	2.74	2.83	14.8	15.0	396	400
		E.Oven	2.73	2.84	14.8	15.0	396	400
		Solar	2.73	2.84	14.8	14.9	396	401

Roselle variety	Storage time	Drying method	pH		Ascorbic acid (mg/100g DWS)		Total anthocyanin content (mg/100g DWS)	
			2018	2019	2018	2019	2018	2019
	6 month	Shade	2.73	2.83	14.8	14.9	390	401
		Sun	2.72	2.83	14.6	14.8	390	400
		E.Oven	2.72	2.82	14.7	14.8	390	397
		Solar	2.72	2.83	14.7	14.7	389	397
L.S.D $_{0.05}$			0.11	0.14	0.09	0.07	6.02	7.48

Table 10. Effect of different drying methods on calyxes content (TPC, DPPH % and TFC) in the two seasons 2018 and 2019

Roselle variety	Drying method	TPC (mg GAE/g DWS)		DPPH %		TFC (mg/100g DWS)	
		2018	2019	2018	2019	2018	2019
Sabhya 17 (Dark)	Shade	38.6 b	38.4 b	37.2 c	36.5 c	266.2 c	262.0 cd
	Sun	38.7 b	38.4 b	36.5 cd	36.2 c	266.0 c	263.2 c
	E.Oven	37.6 c	38.5 b	36.2 cd	36.0 c	265.2 c	261.7 d
	Solar	37.5 c	38.4 b	35.2 d	35.7 c	264.2 c	261.5 d
Sabhya 17 (Light)	Shade	40.5 a	41.3 a	40.2 a	41.5 a	286.0 a	284.2 a
	Sun	40.2 a	41.1 a	39.0 a	41.5 a	284.0 ab	283.5 a
	E.Oven	39.7 a	40.2 a	38.5 b	41.2 a	283.0 b	282.5 ab
	Solar	39.4 ab	39.9 ab	38.0 b	39.7 b	282.0 b	280.7 b
L.S.D $_{0.05}$		1.38	1.53	1.55	1.40	2.05	2.41

Means with similar alphabetical letters are not significant different according to least significant difference test at 0.05 level of probability

Table 11. Effect of different storage time on calyxes content (TPC, DPPH % and TFC) in the two seasons 2018 and 2019

Roselle variety		Storage time	TPC (mg GAE/g DWS)		DPPH %		TFC (mg/100g DWS)	
			2018	2019	2018	2019	2018	2019
Sabhya (Dark)	17	Zero month	38.3 b	38.6 b	37.2 b	38.7 b	265.7 b	262.5 d
		2 month	36.9 c	36.0 c	36.6 b	36.2 d	264.7 b	261.7 d
		4 month	36.4 c	35.9 c	36.4 b	34.5 e	265.2 b	262.5 d
		6 month	35.0 d	35.2 c	35.0 c	34.0 e	266.0 b	262.7 d
Sabhya (Light)	17	Zero month	41.0 a	40.8 a	39.0 a	41.6 a	284.7 a	284.0 a
		2 month	40.3 a	40.7 a	38.8 a	41.5 a	283.2 a	282.0 b
		4 month	38.9 b	40.1 a	38.7 a	40.7 a	283.5 a	282.2 b
		6 month	38.5 b	40.0 a	38.2 a	40.7 a	283.5 a	282.7 c
L.S.D $_{0.05}$			1.04	1.03	1.07	1.01	1.81	1.04

Means with similar letters of the alphabet are not significantly different according to the least significant difference test at the 0.05 probability level

3.8 DPPH% Radical Scavenging Assay

Tables 10, 11 and 12 shows that DPPH in roselle dried for most storage times possess higher antioxidant activities in light variety of roselle. This may be due to the difference in the composition of antioxidants in the Roselle dried at different drying methods. Most of the drying methods, especially the two methods of drying in the shade and in the sun gave a higher percentage of DPPH for both varieties, each separately in the seasons 2018 and 2019. In a good agreement with [43].

Table 12. Means of TPC, DPPH % and TFC in calyxes content as influenced by the interaction between different drying methods and storage time in the two seasons 2018 and 2019

Roselle variety	Storage time	Drying method	TPC (mg GAE/g DWS)		DPPH %		TFC (mg/100g DWS)	
			2018	2019	2018	2019	2018	2019
Sabhya 17 (Dark)	Zero month	Shade	38.2	38.5	37	36	267	264
		Sun	38.5	38.5	37	37	265	262
		E.Oven	38.9	38.4	37	36	266	263
		Solar	38.9	38.4	38	37	267	263
	2 month	Shade	38.8	38.4	37	36	266	263
		Sun	38.7	38.4	36	36	266	263
		E.Oven	38.7	38.5	36	36	266	263
		Solar	38.8	38.4	37	37	266	264
	4 month	Shade	37.6	38.4	36	36	266	262
		Sun	37.6	38.3	36	36	264	261
		E.Oven	37.5	38.3	36	36	265	262
		Solar	37.7	38.4	37	36	266	262
	6 month	Shade	37.7	38.4	35	35	264	261
		Sun	37.5	38.4	35	36	264	261
		E.Oven	37.5	38.4	35	36	264	262
		Solar	37.5	38.5	36	36	265	262
Sabhya 17 (Light)	Zero month	Shade	40.6	41.4	40	42	288	288
		Sun	40.4	41.4	40	41	286	283
		E.Oven	40.5	41.3	40	41	285	283
		Solar	40.5	41.3	41	42	285	283
	2 month	Shade	40.2	41.3	39	42	284	284
		Sun	40.2	41.2	39	41	284	283
		E.Oven	40.2	41.1	39	41	284	283
		Solar	40.1	41.1	39	42	284	284
	4 month	Shade	39.8	40.3	39	41	284	282
		Sun	39.7	40.3	38	41	282	282
		E.Oven	39.7	40.2	38	41	283	283
		Solar	39.7	40.1	39	42	283	283
	6 month	Shade	39.5	40.1	38	39	283	282
		Sun	39.5	40.0	38	39	281	280
		E.Oven	39.4	39.9	38	40	282	280
		Solar	39.4	39.9	38	41	282	281
$L.S.D_{0.05}$			1.4	1.5	1.6	1.3	4.2	4.8

4. CONCLUSIONS

It is known that Roselle (*Hibiscus sabdariffa L.*) plant has multiple medicinal uses and post-harvest studies have been numerous and our study was concerned with studying the effect of different drying methods and storage periods on the bioactive substances in Roselle calyxes of two local cultivars (Sabhia 17), dark and light varieties. In general, the results showed that drying in the shade was the best for the majority of the estimated bioactive substances, both for the dark variety as well as for the light variety, and came after drying in the shade other drying methods. While, in general, the concentration of the bioactive substances was not affected by the increase in the different storage periods for the majority of those bioactive substances. The study confirmed that dark varieties had superior total anthocyanin content and light varieties had superior total acidity (As Malic acid %).

The study confirms that hibiscus is increasing in medicinal and nutritional uses, and more future studies will show other uses, which is reflected on hibiscus producers and increases their profits from hibiscus cultivation.

CONSENT AND ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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