ROSELE (HIBISCUS SABDARIFFA L.) AS A SOURCE OF NATURAL COLOUR: A REVIEW

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Abstract

Hibiscus sabdariffa L. (Roselle) is a medicinal plant grown in Africa, South East Asia, Central America in Mexico, it is known as Jamaica flowers, Sorrel and Karkdah (in Egypt), belongs to the Malvaceae family. It has been reported to use as a flavouring for sauces, jellies, marmalades and soft drinks or to use as a colourant for foods, which Roselle appear to be good and promising sources of water soluble natural red colourants. Anthocyanins, which are flavonoids are water-soluble natural pigments. Aqueous extracts of Roselle or Hibiscus sabdariffa L. calyces have characteristic intense red colouration due to the presence of anthocyanins, which could be utilised as colouring agent in pharmaceutical products. It has been reported that the Anthocyanins found in the calyces of H. sabdariffa contain delphinidin-3-sambubioside, cynidin-3-sambubioside, delphinidin-3-monoglucoside and cyanidin-3-monoglucoside. The present paper is an overview on its potential use as a natural colour and its health benefits reported in the literature.

Key words: Hibiscus sabdariffa L., Roselle, medicinal plant, anthocyanin, flavonoids.

Introduction

Hibiscus subdariffa Linn. is a shrub belonging to the family – Malvaceae. It is thought of native to Asia (India to Malaysia) or Tropical Africa. The plant widely grown in tropics like Caribbean, Central America, India, Africa, Brazil, Australia, Hawaii, Florida and Philippines as a home garden crop (Gautam, 2004). In addition to Roselle, in English-speaking regions it is called as Rozelle, Sorrel, Red sorrel, Jamanica sorrel, Indian sorrel, Guinea sorrel, Sour-sour, Queensland jelly plant, Jelly okra, Lemon bush and Florida cranberry. In Indian languages, it is called as Gongura, Lal-ambari, Patwa (Hindi), Lal-ambadi (Marathi), Yerra gogu (Telugu), Pulichchai kerai (Tamil), Pulachakiri, Pundibija (Kannada), Polechi, Pulichchai (Malayalam) and Chukiar (Assam) (Mahadevan et al., 2009). Two botanical types of Roselle are recognized, Hibiscus sabdariffa var altissma and Hibiscus sabdariffa var subdariffa (Eltayeib and Hamade, 2014).

In several countries, Roselle is also considered to be one of the most famous folk medicinal plants. Where, many chemical components present in Roselle have potential health benefits and support the ethno medicinal use of Roselle in promoting cardio-vascular health and preventing hypertension, pyrexia and liver disorders, microorganism growth limitation, as well as a diuretic, digestive and sedative. The red varieties of Roselle have antioxidant and cyclooxygenase inhibitory activity. Also, Roselle inters in pharmaceutical and cosmetic industries (Al-Ansary et al., 2016).

Plant description and ecology

The plant has been found to thrive on a wide range of soil conditions. It can perform satisfactorily on relatively infertile soils but for economic purposes, a soil well supplied with organic materials and essential nutrients is essential. It can tolerate relatively high temperature throughout the growing and fruiting periods. The plant requires an optimum rainfall of approximately 45-50 cm
distributed over a 90-120 day growing period (Adanlawo and Ajibade, 2006). The plant is about 3.5 m tall and has a deep penetrating taproot. It has a smooth or nearly smooth, cylindrical, typically dark green to red stems. Leaves are alternate, 7.5-12.5 cm long, green with reddish veins and long or short petioles. Leaves of young seedlings and upper leaves of older plants are simple; lower leaves are deeply 3 to 5 or even 7-lobed and the margins are toothed. Flowers, borne singly in the leaf axils are up to 12.5 cm wide, yellow or buff with a rose or maroon eye and turn pink as they wither at the end of the day. The typically red calyx, consist of 5 large sepal with a collar (epicalyx) of 8-12 slim, pointed bracts (or bracteole) around the base, they begins to enlarge at the end of the day, 3.2-5.7 cm long and fully enclose the fruit. The fruit is a velvety capsule, 1.25-2 cm long, which is green when immature, 5-valved, with each valve containing 3-4 seeds. The capsule turns brown and splits open when mature and dry. Seeds are kidney-shaped, light-brown, 3-5 mm long and covered with minute, stout and stellate hairs (Mahadevan et al., 2009). The plant takes about 3-4 months to reach the commercial stage of maturity before the flowers are harvested. Roselle plants are suitable for tropical climates with well-distributed rainfall of 1500-2000 mm/year, from sea-level to about 600 m in altitude. The plant tolerates a warmer and more humid climate with night time temperature not below 21°C and is most susceptible to damage from frost and fog. In addition, it requires 13 hours of sunlight during the first months of growth to prevent premature flowering (Ismail et al., 2008).

Phytochemistry

Roselle is rich in anthocyanins and protocatechuic acid. The dried calyces contain the flavonoids gossypetine, hibiscetine and sabdaretine. The major pigment, formerly reported as hibiscine has been identified as daphniphylline. Small amounts of myrtillin (delphinidin 3-monoglucoside), chrysanthenin (cyanidin 3-monoglucoside) and delphinidin are also present. Roselle seeds are a good source of lipidsoluble antioxidants, particularly γ-tocopherol (Mohamed et al., 2012). The anthocyanin content of *H. sabdariffa* in five strains of the plant reportedly reached 1.7% to 2.5% of the dry weight during calyx growth (Khafaga and Koch, 1980b). *H. sabdariffa* calyces contain high amounts of organic acids, namely: citric acid, malic acid, tartaric acid and hibiscus protocatechuic acid (Kerharo, 1971; Khafaga and Koch, 1980a; Tseng et al., 1996). The acid content of the calyces increases during growth but decreases when it reaches maturity or ripens. The aqueous extract of *H. sabdariffa* calyces has a very rich red pigmentation due to the presence of anthocyanins and the colour properties has been the subject of intense scientific investigations (Ali et al., 2005; Salazer et al., 2012; Aishah et al., 2013). *Hibiscus sabdariffa* calyces were found to contain a higher amount of iron content (164.78 mg/kg) (Maregesi et al., 2013). The plant is also found to be rich in minerals especially potassium and magnesium. Vitamins (ascorbic acid, niacin and pyridoxine) were also present in appreciable amounts (Puro et al., 2014). The chemical composition of dried Roselle calyces is shown in table 1.

**Medicinal properties**

The plant *H. sabdariffa* is also known as Roselle or Rosella. It is reported to be antihypertensive, antisepsic, sedative, diuretic, digestive, purgative, emollient, demulcent and astringent (Odigie et al., 2003). The calyces are used to treat heart ailments, hypertension and leukemia. They are also reported to have diuretic, aphrodisiac, antisepic, astringent, cholagogue, sedative, laxative, and antimicrobial activity. They are also used as remedy for pyrexia and abscesses. The flowers and fruits are used for treatment of cough and bronchitis (Maregesi et al., 2013). Anthocyanins present in Roselle are delphinidin 3-sambubioside, cyanidin 3-sambubioside, delphinidin 3-glucoside and cyanidin 3-glucoside. They contribute benefit for health as a good source of antioxidants as well as a natural food colourant. The blending of Roselle juice with tropical fruit juices is anticipated to give products with high nutritional value and functional activity (Kilima et al., 2014).

The aqueous methanolic extract of Roselle exhibits antimicrobial activity against many bacterial spp. Roselle - Hibiscus anthocyanins (HAs), which are a group of natural pigments existing in the dried calyx exhibited antioxidant activity and liver protection (Puro et al., 2014). The red colour of Roselle petals, essentially the anthocyanins, is an attractive source of natural food colourants (Goda et al., 1997). Anthocyanins possess a high thermostability and contribute towards antioxidative, antiinflammatory, cardioprotective and hepatoprotective activities (Azevedo et al., 2010). According to many authors, anthocyanins inhibit the growth of human cancer cells and low density lipoprotein (LDL) oxidation. Therefore, the addition of natural anthocyanins as food colourants would not only enhance the decorative value of the food but also improve its beneficial properties (Abeda et al., 2014).

**Value addition of Roselle**

Roselle is cultivated for its leaves, seeds and calyces. Nutitionally young leaves of Roselle contain nutrients such as phosphorus, calcium, magnesium and potassium...
(Atta et al., 2010). The leaves are consumed as a green vegetable and prepared like spinach (Delgado and Parcedes, 2003). However, the seed of Roselle is a valuable food resource on account of its protein, calorie and also substantial amount of fiber and valuable micro-nutrients (Akanbi et al., 2009). Indeed, young leaves and stems are eaten raw or cooked in salads, and as a seasoning in curries. Different food products, fermented foods and beverages of Hibiscus sabdariffa are widely used in different countries. From the fresh flowers of Hibiscus sabdariffa cold and hot beverages are produced. The juice from the calyces of Sorrel (Roselle) is called “zoborodo” (soborodo), a non-alcoholic drink in Nigeria, which involves the production process of solid-liquid extraction leaving the calyx pulp as raffinate, which is a heavy organic material that could be converted as glucose (Ajayi et al., 2012). In Mexico, this beverage is called “flor de jamaica”. In Senegal (a state of West Africa) this Hibiscus sabdariffa known as bissap and drink is prepared through aqueous extraction from a solid-to-solvent ratio. This drink consumption is widespread in Asia and Africa. In Senegal, it is more popular and more consumption is observed during the month of Ramadan (Padmaja et al., 2014). In Egypt, this beverage is called as “drink of the Pharaohs”. In Sudan, it is called as “tea Karkade”. In Mali (Africa) it is called as “da Bilenni”. Tea from the Hibiscus sabdariffa also called Sudan tea, sour tea which is prepared from ground dried calyces also have medicinal properties and is considered as herbal tea and Roselle is also used as main ingredient in many other tisanes (herbal tea) (Diane et al., 2009). ‘Bikalaga’ is a fermented food produced from the seeds of Hibiscus sabdariffa in African countries, including Burkina Faso, Mali Niger, Nigeria, Cameroon and Sudan among others (Parkouda et al., 2008).

Fresh calyx (the outer whorl of the flower) is eaten raw in salads, or cooked and used as a flavouring in cakes and is also used in making jellies, soups, sauces, pickles, puddings etc. The calyx is rich in citric acid and pectin and is useful for making jams, jellies (Pacome et al., 2014). The seeds contain 17 to 20% edible fixed oil, which is similar in its properties to cotton seed oil. On the other hand, the colour extract from the dry calyces is rich in anthocyanin, amino acids, organic compounds, mineral salts and source of vitamin C (Al-Ansary et al., 2016). Calyces extract is also a potential source of natural colourant to replace red synthetic colouring agents for carbonated soft drinks, jams, juices, jellies, sauces, chutneys, wines, preserves and other acidic foods (Delgado and Parcedes, 2003).

In fact, some Roselle varieties/cultivars are identified according to calyces anthocyanin content. For example, the Sudani Roselle variety has dark red calyces, while the calyx has light red colour in Masri variety (Al-Ansary et al., 2016). Roselle, also known as sorrel, Jamaica flower and karkade, has been used by people for preparing soft drinks and in traditional medicine. It has been observed that its components, such as vitamins (C and E), polyphenols acids and flavonoids, mainly anthocyanins, have functional properties. The Roselle calyces production, in developing countries, is of great importance since its production represents a very important income for people from rural communities. Today, several studies have shown that compounds found in aqueous and ethanol Roselle calyces extracts may have antioxidant properties. These compounds could work in several ways in humans; for instance, they could have anticancer characteristics. They may also reduce chronic diseases such as diabetes mellitus, dyslipidemias, hypertension and cardiovascular diseases. Some of these compounds (flavonoids and anthocyanins) are natural which have no toxic or mutagenic effects (Cid and Guerrero, 2014).

The whole plant can be used as beverage, or the dried calyces can be soaked in water to prepare a colourful cold drink, or may be boiled in water and taken as a hot drink. It also has some medicinal properties. The seeds contain 17.8–21% non-edible oil and 20% protein, and are sometimes used for animal feed (Mohamed et al., 2012). The calyx of Hibiscus sabdariffa is widely used by humans, as food, jams, jellies, juice drinks, wine and as medicinal syrups (Akanya et al., 1997). It is used effectively in folk medicines for treatment of hypertension, inflammatory diseases and cancer (Lin et al., 2007). The calyces are used to decrease blood viscosity and reduce hypertension (Christian et al., 2006). Hibiscus pigments reduce the incidence of liver lesions including inflammation, leucocyte infiltration and necrosis (Kong et al., 2003). Anthocyanins are approved as food colourants in the USA under the category of fruit (21 CFR 73.250) or vegetable (21 CFR 73.260) juice colour. The EU classifies anthocyanins as ‘natural colourants’ under classification number E163. The use of anthocyanins may show benefits over that of synthetic colours. A potential use for Roselle extract may include production of fruit juice, drinks and jam (Duangmal et al., 2008).

**Drying of Roselle calyces**

Roselle calyx is usually harvested at high moisture content (85%, w.b.). Therefore, drying is an important post-harvest treatment prior to reduce the moisture content and to increase the shelf life. Drying is a process
comprising simultaneous heat and mass transfer (Suherman et al., 2012). In order to preserve and extend their life, Roselle calyces are sold in dry form. Their main form of consumption is after leaching them with water (Daniel et al., 2012). The different drying methods employed for calyces of Roselle are given in table 2. Saeed et al. (2008) found that at different temperatures (35, 45, 55 and 65°C) and relative humidity (30%, 35%, 40% 45% and 50% RH), the drying kinetics of fresh Roselle calyces were controlled by internal diffusive mechanisms (falling rate period) and a second model of exponential decay behaviour; the drying time was reduced with increased temperature and prolonged with greater relative humidity. Saeed (2010) used a solar dryer to study the effects of drying conditions on the drying constant \((k)\) and coefficient values \((a\) and \(c)\) in order to validate a logarithmic model.

**Extraction of colour**

Colour is one of the most important quality attributes affecting the consumer’s acceptance of food since it gives the first impression of food quality. Many convenience foods such as confectionery products, gelatin desserts, snacks, cake, pudding, ice cream and beverages would be colourless, and would thus appear undesirable without the inclusion of colourants (Hirunpanich et al., 2006). Due to perceived safety and physiological advantage of the natural colourants over synthetic ones, interest are being geared into search of new natural colourants and the verification of the safety of existing ones. Roselle is a tropical plant of considerable economic potential. Its calyces have been suggested as food colourants for food industries; emulsifier for carbonated drinks, jam manufacture, juices and natural food colourants (Duangmal et al., 2008). The calyces are rich in anthocyanin, ascorbic acid and hibiscus acid. It is water soluble with brilliant and attractive red colour and with sour and agreeable acidic taste, which aids in digestion. In this respect, Roselle calyces appear to be good and promising sources of water soluble red colourants that could be utilized as natural food colourants (Abou et al., 2009).

Anthocyanins are one of the most important groups of water soluble pigments visible to the human eye. They are responsible for many of the attractive colours, from scarlet to blue, of flowers, fruits, leaves and storage organs. Hibiscus anthocyanins were identified as having Delphinidin-3-sambubioside \((\text{Dp-3-sam})\) (70% of the anthocyanins) and Cyanidin-3-sambubioside \((\text{Cyn-3-sam})\) as the major pigments, with Delphinidin-3-glucoside \((\text{Dp-3-glu})\) and Cyanidin-3-glucoside \((\text{Cyn-3-glu})\) as the minor ones (Amor and Allaf, 2009). Cahlikova et al. (1015) explained that the active constituents of the extracts of Roselle, which widely used in folk medicine to combat many illnesses and have been shown on several occasions to be anthocyanins and they ascertained through UHPLC-ESI MS/MS that delphinidin-3-sambubioside is the major one but the predominant one is cyaniding-3-sambubioside. Also Roselle extracts are reported to have an antimicrobial effect on different pathogenic and food spoilage micro-organisms due to its metabolities of phenolic compounds such as anthocyanins. They are associated with the prevention of illnesses generated by oxidative stress (Heba et al., 2014). *H. sabdariffa* calyx extracts has been studied extensively as a food colourant (Duangmal et al., 2008; Alobo and Offonry, 2009) and found to be a suitable replacement for various artificial colourants.

Plant materials generally contain a small amount of high added value active solute. Extraction and purification of bioactive compounds from natural sources have become very important for the utilization of phytochemicals in the preparation of dietary supplements or nutraceuticals, functional food ingredients, food additives, pharmaceutical and cosmetic products. The polar character of anthocyanins makes them soluble in several types of polar solvents such as methanol, ethanol, acetone, and water. Solvent extraction of anthocyanins is the initial step in the determination of total and individual anthocyanins prior to quantification, purification, separation, and characterization (Rivas, 2003). The extraction of anthocyanins is commonly carried out under cold conditions using methanol or ethanol containing a small amount of acid in order to obtain the flavylum cation form, which is red and stable in a highly acid medium (Du and Francis, 1973; Amor and Allaf, 2009). Extraction of anthocyanins is commonly carried out under cold conditions with methanol or ethanol containing a small amount of acid with the objective of obtaining the flavylum cation form, which is red and stable in a highly acid medium. However, acid may cause partial hydrolysis of the acyl moieties in acylated anthocyanins, especially in anthocyanins acylated with dicarboxylic acids such as malonic acid (Bronnum and Flink, 1985). Abou et al. (2011) used ethanol acidified with 1.5 N/L HCl (85:15), ethanol acidified with 1% citric acid, 2% citric acid solution and distilled water in extracting the pigments from Roselle calyces. They concluded that the addition of acids to water or ethanol increased the efficiency of anthocyanins extraction compared with distilled water alone. In general, HCl was more effective than citric acid. Ethanol acidified with HCl, showed the strongest
influence on the amount of anthocyanins extracted, followed by 2% citric acid solution and ethanol acidified with 1% citric acid. Frimpong et al. (2014) investigated the potential of aqueous extract of Hibiscus sabdariffa calyces as colouring agent in three pediatric oral pharmaceutical formulations and they found that Aqueous extract of H. sabdariffa calyces at a concentration of 33% w/v solution was successfully used to colour three pediatric oral formulations. Formulations coloured with the extract were susceptible to deterioration on exposure to light, pH and high temperatures. It can be concluded that the extract of H. sabdariffa calyces can be a good substitute for amaranth as a colouring agent for pediatric oral pharmaceutical formulations when buffered at pH 5.0 and protected against high temperatures and light.

Stability of colour

Anthocyanins are highly unstable molecules in food matrix. The colour stability of Anthocyanins is strongly affected by pH, solvents, temperature, anthocyanin concentration and structure, oxygen, light, enzymes, and other accompanying substances (Arueya and Akomolafe, 2014). Colour stability of anthocyanins depends on a combination of various factors including: structure of anthocyanins, pH, temperature, oxygen, light and water activity. Enzymatic degradation and interactions with food components such as ascorbic acid, sugars, metal ions, sulfur dioxide and copigments are no less important (Abou et al., 2011). Among these factors, pH is one of the major factors significantly influenced the pigment colour variations and stability. In general, anthocyanins are more stable in acidic media at low pH values than in alkaline solutions (Aishah et al., 2013). Anthocyanin is relatively unstable and because of their high reactivity it may be easily degraded and form colourless or undesirable brown – coloured compounds during extraction processing and storage. Indeed, temperature, pH, light oxygen, metals, organic acids, sugars, ascorbic acid, enzymes, sulfor dioxide and co-pigmentation and interactions with food components may affect both the structure and stability of anthocyanins (Zuhaili et al., 2012).

Bronnum and Flink (1985) reported that the efficiency of extracting solvent increased with increasing the concentration of citric acid and concluded that pH of extracting medium was the determining factor for anthocyanins extractability. Anthocyanins are easily susceptible to pH changes due to the ionic nature of anthocyanin. Anthocyanins exist as four equilibrium forms, namely the quinonoidal base, the flavylium cation, the carbinol (pseudobase) and the chalcone. Under low pH, the anthocyanin exists primarily in the the form of flavylium cation in red. As the pH is raised (>5), a rapid loss of proton occoured to form quinoidal base that tend to become blue or violet. In addition, the increasing of pH causes the hydration of the flavylium cation to form a carbinol (pseudobase) or chalcone which are colourless (Amelia et al., 2013). Light is another factor, which affects the stability of anthocyanin. Palamidis and Markakis (1975) have studied the role of light on the stability of anthocyanin in grape juice and showed that exposure of the pigments to light accelerates their destruction. Their experiments showed that after placing the juice samples containing anthocyanin in dark for 135 days at 20°C, almost 30% of the pigments were destroyed, but placing the same samples in the same temperature and same period of time in the presence of light destroyed more than 50% of total pigments. Palamidis and Markakis (1975) have studied the effect of temperature on the stability of anthocyanin in soft drinks and have shown that increase in the storage temperature greatly accelerate the destruction of pigments in soft drinks. Maccarone et al. (1985) reported the anthocyanin in red orange juice in 15°C, 25°C and 35°C during a 15 day period and found that the increase in temperature accelerates the destruction of anthocyanins.

Encapsulation of anthocyanin

Encapsulation facilitates light and heat-labile molecules to maintain their stability and improve their shelf lives and activity. It is a rapidly expanding technology, highly specialized, with affordable costs. Among the diverse encapsulation techniques available, only few were

### Table 1 : Chemical composition of dried Roselle calyces.

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Component</th>
<th>Red calyces</th>
<th>White calyces</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Moisture (%)(d.b.)</td>
<td>11.00</td>
<td>9.30</td>
</tr>
<tr>
<td>2.</td>
<td>Crude protein (%)</td>
<td>7.88</td>
<td>7.53</td>
</tr>
<tr>
<td>3.</td>
<td>Crude fibre (%)</td>
<td>13.20</td>
<td>12.00</td>
</tr>
<tr>
<td>4.</td>
<td>Crude fat (%)</td>
<td>0.16</td>
<td>0.12</td>
</tr>
<tr>
<td>5.</td>
<td>Ash (%)</td>
<td>10.60</td>
<td>9.50</td>
</tr>
<tr>
<td>6.</td>
<td>Total carbohydrates (%)</td>
<td>57.16</td>
<td>61.55</td>
</tr>
<tr>
<td>7.</td>
<td>Ascorbic acid (mg/100g)</td>
<td>11.00</td>
<td>15.50</td>
</tr>
<tr>
<td>8.</td>
<td>Titrable acidity (mg/100g)</td>
<td>9.00</td>
<td>11.00</td>
</tr>
<tr>
<td>9.</td>
<td>Total soluble solids (%)</td>
<td>5.00</td>
<td>5.50</td>
</tr>
<tr>
<td>10.</td>
<td>Calcium (mg/100g)</td>
<td>60.00</td>
<td>50.00</td>
</tr>
<tr>
<td>11.</td>
<td>Iron (mg/100g)</td>
<td>25.00</td>
<td>20.00</td>
</tr>
</tbody>
</table>

Source: Mohamed et al. (2012).
evaluated for anthocyanin encapsulation, these include: spray drying using different coating materials, gelation using polymers as sodium alginate, pectin, curdlan and glucan and liophilization (Santos et al., 2013). Spray drying technique has been widely used in the microencapsulation of food ingredients susceptible to deterioration by external agents and consists of entrapping an active agent (solid particles, liquid droplets or gaseous compounds) in a polymeric matrix, in order to protect it from adverse conditions. The immediate drying of the mixture leads to the formation of a matrix system in which the polymer forms a tridimensional network which contains the encapsulated material (Tonon et al., 2010). Microencapsulation has been used by the food industry in order to protect sensitive food ingredients during storage, to mask or preserve aromas and flavours, to protect food against nutritional losses or even to add nutritive materials to food after processing (Re, 1998). The spray dry technique minimizes the loss of nutrients’ content during processing and storage, the powder obtained is soluble and convenient to carry anywhere, it requires less storage space and it is one of the most commonly used methods to transform a wide range of liquid food products into powder. Some of the most used materials include pectin, whey protein, carrageenan, carboxymethyl cellulose (CMC), gelatin and xanthan gum amongst others, trying to protect the core of the particles against adverse environmental conditions, providing at the same time, an easy handling and release rate control (Diaz et al., 2015).

**Conclusion**

Roselle has been reported to use as a flavouring for sauces, jellies, marmalades and soft drinks or to use as a colourant for foods which Roselle appear to be good and promising sources of water soluble natural red colourants. The use of green technologies such as supercritical carbon dioxide (SC-CO₂) extraction provides a promising alternative for conventional solvent extraction. There is a huge demand for quantification and purification of anthocyanins found in the calyces of Roselle viz., delphinidin-3-sambubioside, cynidin-3-sambubioside, delphinidin-3-monoglucoside and cynidin-3-monoglucoside. This will further help in generating entrepreneurship opportunities and upliftment of socio-economic condition of the farming community.

**References**


**Table 2 :** Different drying methods employed for calyces of Roselle.

<table>
<thead>
<tr>
<th>S. no.</th>
<th>Type of drying</th>
<th>Description</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Forced air oven drying</td>
<td>Roselle calyces were dried at 60°C</td>
<td>Babalola et al. (2001)</td>
</tr>
<tr>
<td>2.</td>
<td>Constant Temperature and Humidity Chamber</td>
<td>Roselle calyces were dried at different temperatures (35, 45, 55 and 65°C) and relative humidity (30%, 35%, 40%, 45% and 50% RH)</td>
<td>Saeed et al., 2008</td>
</tr>
<tr>
<td>3.</td>
<td>Tunnel drier</td>
<td>Roselle calyces were dried at 70°C for 4.5 h</td>
<td>Hahn et al. (2011)</td>
</tr>
<tr>
<td>4.</td>
<td>Thin layer drying (Tray drier)</td>
<td>Drying was carried out at temperatures 40, 50 and 60°C and the air velocity was 1.5-1.6 m/s</td>
<td>Suherman et al. (2012)</td>
</tr>
<tr>
<td>5.</td>
<td>Sun and oven drying</td>
<td>Fresh samples of red and light red Roselle calyces were sun dried for three days, oven dried for 24 h at 50°C</td>
<td>Ashaye (2013)</td>
</tr>
<tr>
<td>6.</td>
<td>Hot air drying</td>
<td>Roselle calyces were at 60°C</td>
<td>Langova et al. (2013)</td>
</tr>
<tr>
<td>7.</td>
<td>Oven drying</td>
<td>Roselle calyces were dried at 105°C temperature for 45-60 min</td>
<td>Ismail and Mohammed (2014)</td>
</tr>
</tbody>
</table>


Hypocholesterolemic and antioxidant effects of aqueous extracts from the dried calyx of Hibiscus sabdariffa L. in hypercholesterolemic rats. J. Ethnopharmacol., 103(2) : 252-260.


