## *Original Review Article*

# *Hibiscus sabdariffa*: An Underutilised Powerhouse of Plant Bioactives

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## Abstract

Hibiscus sabdariffa (H. sabdariffa) is a plant containing a plethora of health-promoting phytochemicals such as anthocyanins, organic acids, flavonoids and polysaccharides with potential biological properties. Furthermore, its reported use in folk medicine for the treatment of several non-communicable diseases is well documented. Indeed, a growing body of evidence give credence to its anti-diabetic, anti-hypertensive, cholesterol-lowering and anti-obesity properties. Other pharmacological benefits ascribed to H. sabdariffa include immunomodulatory, diuretic and renal protection properties. Owing to its perceived health benefits, the manufacture of diverse functional foods from H. sabdariffa have been seen in recent years, showing a growing interest in novel technological applications of potential products from the plant. A highlight of some of the patented products alongside possible future application in the food and nutraceutical industries is presented in this review

**Keywords:** Hibiscus sabdariffa, anthocyanins, phenolic acids, flavonoids, health benefits, food products.

## Introduction

*Hibiscus sabdariffa* L. (*H. sabdariffa*) is a short-day annual shrub of the *Malvaceae* family grown in Sub Saharan Africa, Asia and Caribbean (Aurelio *et al.*, 2008). Although it is not clear where *H. sabdariffa* was first discovered, there is some evidence that it was first domesticated by the black populations of western Sudan, and later transported to other parts of the world. In addition, its use for food and curative purposes dates back to 5000 BC, spanning from Egypt, the West Indies, China, India to Latin America (Mohamed *et al.*,2012). Today, the leading producers of *H. sabdariffa* include Sudan, Jamaica, Thailand and China, with the quality of Sudan rated the best in the world. *H. sabdariffa* is known by different names across the world as shown in Table 1.

### *Botanical description and morphology*

The shrub, *H. sabdariffa*, grows up to 2.4 m, and the leaves, which are 7.5 -12.5 cm, are green, having reddish veins and long or short petioles. The flowers, borne singly in the leaf axils, are up

**Table 1:** Vernacular names of *H. sabdariffa* in different countries

| Country | Vernacular name |
|---|---|
| England | Roselle |
| U.S | Roselle |
| France | Oseille |
| Jamaica | Flor de Jamaica |
| Switzerland, Sudan and Arabia | Karkade |
| Nigeria | Zobo |
| Senegal | Byssap |

Source: Ismail *et al.,* 2008

to 12.5 cm wide, yellow or buff with a rose (maroon eye), which turn pink upon withering at the end of the day. Thereafter, the typically red calyx (3.2 - 5.7 cm long), which consists of 5 large sepals with a collar (epicalyx) of 8 to 12 slim, pointed bracts (or bracteoles) around the base, begins to enlarge, becomes fleshy, crisp and juicy, and fully encompasses the velvety capsule that turns brown and splits open when mature and dry (Morton, 1987). The seeds which are covered with minute, stout and stellate hairs, are light brown, 3 mm long and kidney-shaped (Morton, 1987). There is another less popular variety of *H. sabdariffa* referred to as white roselle with its distinct green/whitish calyces which is commonly consumed as a vegetable.

### *Cultivation and harvesting of H. sabdariffa*

The plant thrives in tropical and subtropical regions, and is very susceptible to damage from fog and frost. *H. sabdariffa* requires an average rainfall of about 182 cm (72 inches), and propagation is by seeds, although it can be cultivated by shoot cuttings. The seedlings may be raised in the nursery and later transplanted to the field when they are 7.5 -10 cm (3 to 4 inches) high. It is essential to weed in the first month, while the application of fertilizer varies amongst regions, although *H. sabdariffa* may benefit from nitrogen application. The fruit consisting of the large reddish calyces is harvested 2-3 weeks after the onset of flowering, while the rest of the crop remains in the field until the seeds are ready for threshing.

### *Uses of H. sabdariffa*

#### *(i) Food uses*

The calyces, fresh or sometimes dried, are employed in the production of teas, ice cream, jams, marmalade, sherbets and sauces. In addition, wines, jellies, beverages and other desserts can also be made from the calyces (Tsai *et al.* 2002; Herrera-Arellano *et al.*, 2004). In Nigeria, a refreshing drink known as "Soborodo" is prepared by boiling the calyces along with sugar and spices, while in Mexico a drink processed in similar manner is referred to as "Agua de Jamaica". The seeds can be taken as a coffee substitute or fermented to produce a condiment known as "Mungza ntusa" in

the northern parts of Nigeria (Omobuwajo *et al.*, 2000), while in China and certain parts of western Africa, the seeds are used for oil production (Atta and Imaizumi, 2002). Furthermore, the seeds are used in the production of feed for both poultry and sheep. The leaves are also edible and are eaten raw, dried or cooked in Sudan and Malaysia (Ismail *et al.*, 2008). They also serve as a rich source for animal fodder and fibre.

### *(ii) Traditional and folk medicine*

The calyces of *H. sabdariffa* have been used in traditional medicine to treat various health conditions such as hypertension, diabetes, nerve disorders and heart ailments. Furthermore, several ethnomedicinal studies have reported the use of infusions of the calyces for treatment of hyperlipidaemia, obesity, and urinary tract infections (Hopkins *et al.*, 2013; Patel, 2014). In Guinea, the leaves are deemed to be diuretic, refrigerant and sedative, while the seeds are regarded as antiscorbutic and laxative. In addition, the leaves are employed in the treatment of cough and abscesses in parts of Central Africa and Angola (Duke, 1983).

## *Phytochemistry*

*H. sabdariffa* is a rich source of bioactive phytochemicals (Tables 2 & 3) which may be responsible for the reported health benefits. The phytochemical profile of *H. sabdariffa* calyces reported differs between studies, probably due to factors such as variations in geographical locations, varieties, genetics, ecology and harvesting conditions. The main bioactive constituents in the calyces related to its pharmacological activities are the anthocyanins, organic acids, flavonoids and polysaccharides (Borrás-Linares *et al.*, 2015). Moreover, the seeds is documented to be rich in polyunsaturated fatty acids and lipids soluble antioxidants (Mahadevan *et al.*,2009).

## *Anthocyanins*

These are a group of flavonoid derivatives responsible for the red, blue and purple pigments found in *H. sabdariffa*, and they account for about 1.7 to 2.5 % dry weight of the calyces. The first anthocyanin to be characterised from the calyces of *H. sabdariffa* was "hibiscin" which was later renamed delphinidin 3-*O*-sambubioside (DS) (Yamamoto and Osima, 1932). Thereafter, three different anthocyanins were identified in the calyces namely cyanidin 3-*O*-sambubioside (CS), delphinidin 3-*O*-glucoside and cyanidin 3-*O*-glucoside (Du and Francis, 1973). In most published studies, delphinidin 3-*O*-sambubioside and cyanidin 3-*O*-sambubioside have been reported as being the main anthocyanins present within the calyces, accounting for over 75 % of the total anthocyanins (Ramirez-Rodrigues *et al.*, 2011; Sindi *et al.*, 2014).

However, a study also reported the absence of delphinidin-3-*O*-glucoside in the extracts of some strains (Da-Costa-Rocha *et al.*, 2014). The chemical structure of the main anthocyanins and some phytochemicals found in *H. sabdariffa* are presented in Figure 1.

## *Organic acids*

The calyces of *H. sabdariffa* contain a myriad of organic acids which include malic, citric, ascorbic, hibiscus and hydroxycitric acids (Wong *et al.*, 2002). In addition, tartaric acid, oxalic

**Table 1:** Phytochemicals present in *H. sabdariffa*

| Class | Compound | Reference(s) |
|---|---|---|
| Anthocyanins | Delphinidin 3-*O*-sambubioside (DS) | (Du and Francis, 1973; Ramirez-Rodrigues *et al*., 2011) |
| | Cyanidin 3-*O*-sambubioside (CS) | (Borrás-Linares *et al.*, 2015; Wong *et al.*, 2002) |
| | Delphinidin 3-*O*-glucoside | (Sindi *et al.*, 2014) |
| | Cyanidin 3-*O*-glucoside | (Rodriguez-Medina *et al.*, 2009) |
| | Cyanidin-3,5-*O*-diglucoside | (Segura-Carretero *et al.*, 2008) |
| Organic acids | Hibiscus acid | (Ramirez-Rodrigues *et al.*, 2012; Rodriguez-Medina *et al.*, 2009) |
| | Hibiscus acid glucoside | (Ramirez-Rodrigues *et al*., 2011; Ramirez-Rodrigues et al., 2012) |
| | Hibiscus acid 6-methyl ester | (Borrás-Linares et al., 2015; Ramirez-Rodrigues et al., 2011) |
| | Hydroxycitric acid | (Borrás-Linares *et al.*, 2015; Mahadevan *et al.*, 2009) |
| | Malic acid | (Jung *et al.*, 2013; Wong *et al*., 2002) |
| | Oxalic acid | (Ali *et al*.,, 2005; Wong *et al.*, 2002) |
| | Citric acid | (Ali *et al.*, 2005; Wong *et al*., 2002) |
| | Succinic acid | (Wong *et al*., 2002) |
| | Tartaric acid | (Mahadevan *et al*., 2009) |
| Phenolic acids | 3-*O*-caffeoylquinic acid | (Borrás-Linares *et al.*, 2015; Rodriguez-Medina *et al.*, 2009) |
| | 4-*O*-caffeoylquinic acid | (Ramirez-Rodrigues *et al.*, 2011) |
| | Chlorogenic acid | (Borrás-Linares *et al.*, 2015; Jiménez-Ferrer *et al.*, 2012) |
| | 5-*O*-caffeoylshikimic acid | (Borrás-Linares *et al*., 2015; Rodriguez-Medina *et al*., 2009) |
| | N-Feruloyltyramine | (Borrás-Linares *et al.*, 2015; Rodriguez-Medina *et al.*, 2009) |
| | Caffeic acid | (Ramirez-Rodrigues *et al.*, 2011; Ramirez-Rodrigues *et al.*, 2012) |
| | Coumaroylquinic acid | (Borrás-Linares *et al.*, 2015) |
| | Gallic acid | (Ramirez-Rodrigues *et al*., 2012) |
| | Protocatechuic acid | (Mahadevan et al., 2009; Ramirez-Rodrigues *et al*., 2011) |
| Flavonols | Quercetin | (Fernandez-Arroyo et al., 2012; Fernandez-Arroyo *et al*., 2011) |
| | Quercetin 3-*O*-glucoside | (Borrás-Linares *et al*., 2015; Ramirez-Rodrigues *et al*., 2011) |
| | Quercetin 3-sambubioside (Q3A) | (Rodriguez-Medina *et al*., 2009) |
| | Myricetin | (Borrás-Linares *et al*., 2015) |
| | Myricetin-3-arabinogalactoside (M3A) | (Rodriguez-Medina *et al*., 2009) |
| | Rutin | (Rodriguez-Medina *et al*., 2009) |
| | Kaempferol-3-*O*-glucoside | (Fernandez-Arroyo *et al*., 2011) |
| Sterols | Ergosterol | (Ali *et al*., 2005; Mahadevan *et al.*, 2009) |
| | Stigmasterol | (Ali *et al*., 2005) |

**Table 2: Volatiles present in *H. sabdariffa***

| Class | Compound | Reference(s) |
|---|---|---|
| Volatiles | 1-octen-3-ol | (Ramírez-Rodrigues *et al.*, 2011) |
| | 1-Hexanol | ( Ramírez-Rodrigues *et al.*, 2011Ramirez-Rodrigues *et al.*, 2012; Ramírez-Rodrigues *et al.*, 2011) |
| | Hexanal | (Ramírez-Rodrigues *et al.*, 2011) |
| | Heptanal | (Ramírez-Rodrigues *et al.*, 2011) |
| | Eugenol | (Ramírez-Rodrigues *et al.*, 2011) |
| | Linalool | (Ramírez-Rodrigues *et al.*, 2011) |
| | 2-Hexenol | (Chen *et al.*, 1998) |
| | Limonene | (Chen *et al.*, 1998) |
| | 4-Methyl-2,6-di-*tert*-butylphenol | (Jung *et al.*, 2013) |
| | 2-Pentylfuran | (Jung *et al.*, 2013) |

acid, succinic acid and malic acid have also been identified in the calyces (Ali *et al.*, 2005). Citricacid and malic acid were the first acids to be isolated in the calyces, and their contents vary widely between studies (Buogo and Picchinenna, 1937). The reported concentrations of ascorbic and malic acids in *H. sabdariffa* varied between 80 and 120 mg/100 g, while succinic, oxalic and tartaric acid contents ranged from 170 – 510 mg/100 g ( Wong *et al.*, 2002; Mohamed *et al.*, 2012). Hydroxycitric acid and its lactone form (+) -allo-hydroxycitric acid (hibiscus acid) are the main organic acids found in the calyces of *H. sabdariffa*. Hydroxycitric acid - (2S, 3R) is different from the (2S, 3S) - hydroxycitric acid isolated from the leaves of *Garcinia spp.* (Da-Costa-Rocha et *al*., 2014).

### *Phenolic acids*

Chlorogenic acid is the main phenolic acid present in *H. sabdariffa* which belongs to the family of esters formed between certain trans-cinnamic acids (caffeic acid, ferulic acid and p-coumaric acid) and quinic acid (Clifford *et al.*, 2003; Borrás-Linares *et al*., 2015). Chlorogenic acid and its derivatives have been identified in many studies involving extracts of *H. sabdariffa* (Salah *et al.*, 2002; Rodriguez-Medina *et al*., 2009; Ramirez-Rodrigues *et al*., 2011). Another phenolic acid characterised from the dried flowers of *H. sabdariffa* and assigned the structure of 3, 4-dihydrobenzoic acid is protocatechuic acid, while gallic and ellagic acids have also been reported in *H. sabdariffa* (Lin *et al.*, 2011; Peng *et al.*, 2011; Lin *et al.*, 2012).

### *Flavonoids*

*H. sabdariffa* calyces contain different classes of the flavonoids namely flavonols, flavones and flavan-3-ols. These include quercetin and its glucosides, alongside myricetin, rutin, kaempferol, luteolin and its glucoside all being present in *H. sabdariffa* (Salah *et al*., 2002; Rodriguez-Medina *et al*., 2009; Fernandez-Arroyo *et al*., 2012). The flavan 3-ols present in *H. sabdariffa* include catechin and gallocatechins gallates (Yang *et al*., 2009).

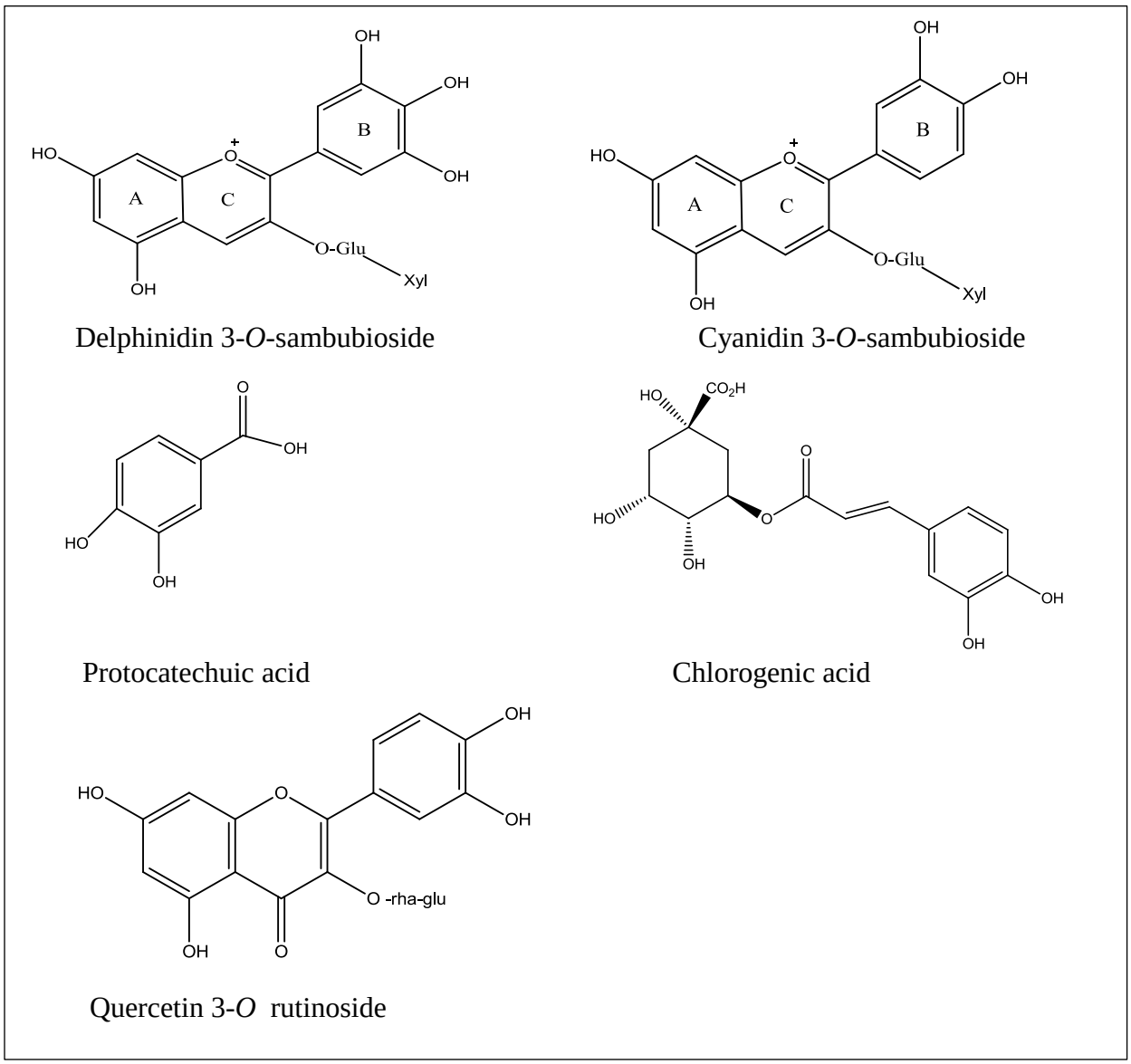


**Figure 1:** Chemical structures of some phytochemicals found in *H. sabdariffa*

### *Polysaccharides*

The petals of *H. sabdariffa* yield 65 % (dry weight) of mucilage which, on hydrolysis, produces galacturonic acid, glucose and rhamnose (El-Hamidi *et al.*, 1967). Furthermore, three water-soluble polysaccharides have also been isolated from the flower buds, with the neutral fractions composed of arabinans and arabinogalactans. The major fraction was shown to be a pectin-like molecule (Mr = 105 Da) linked together by α-1,4-galacturonic acid and 1,2-rhamnose bonds.

Furthermore, side chains of galactose and arabinose are connected to the main chain through C- 4 bond of every third rhamnose (Ali *et al*., 2005).

### *Volatile composition*

The volatile composition in *H. sabdariffa* calyces was analysed by Gonzalez-Palomares *et al*. (2009). Twenty volatile compounds were identified in the ethanol extract, which include terpenoids, esters, hydrocarbons and aldehydes. However after drying, some of the volatiles were lost as only fourteen volatile compounds were identified. In another study, a total of 28, 25, 17, and 16 volatiles were identified in the dried hot extract (DHE), dried cold extract (DCE), fresh hot extract (FHE), and fresh cold extract (FCE) samples, respectively (Ramírez-Rodrigues *et al*., 2011). The most potent aroma compounds common to all four extracts were 1-octen-3-ol and nonanal. Furthermore, linalool and 2-ethyl-1-hexanol were detected only in beverages from fresh hibiscus, while furfural and 5-methyl furfural derived from the drying process were found only in dried hibiscus extracts. The same observation regarding furfural and 5-methyl furfural production after drying of *H. sabdariffa* calyces was reported by Chen *et al.* (1998). Furthermore, the analysis of four differently treated *H. sabdariffa* samples: (untreated, frozen, hot-air-dried at 50°C, and hot-air-dried at 75°C), revealed more than 37 volatile compounds characterized by GC-MS. These were the fatty acid derivatives, sugar derivatives, phenolic derivatives, and terpenes. The results also showed higher amounts of the aliphatic C6 lipid derivative (responsible for green aroma notes) in the fresh calyces, while only trace amounts were found in the frozen and air-dried samples.

### *Pharmacological and biological properties of H. sabdariffa*

*H. sabdariffa* has been proven to exhibit some pharmacological properties, resulting in its being a suitable candidate for therapeutic application. A growing body of evidence give credence to its anti-diabetic properties (Peng *et al*., 2011; Adisakwattana *et al.*, 2012; Ademiluyi and Oboh, 2013), anti-hypertensive properties (Ajay *et al.*, 2007; Saltzman and Blumberg, 2009; McKay *et al.*, 2009; Inuwa *et al*., 2012), cholesterol-lowering and anti-obesity properties (Carvajal-Zarrabal *et al.*, 2009; Hernández-Pérez and Herrera-Arellano, 2011; Sabzghabaee *et al*., 2013). Other pharmacological benefits ascribed to *H. sabdariffa* include immunomodulatory, diuretic and renal protection properties (Patel, 2014).

### *H. sabdariffa and translational research*

To determine the level of translational research on *H. sabdariffa* products, a patent search at the Espacenet patent database of the European patent office was performed in 2013 (Da-Costa-Rocha *et al*., 2014). The results showed a range of patents for the manufacture of diverse functional foods and nutraceuticals from *H. sabdariffa,* which shows a growing interest in novel technological applications of potential products from the plant. A brief highlight of some of the patented products alongside possible future application in the food and nutraceutical industries is discussed below.

### *(i) Beverage industry*

The beverage industry comprises of four main sectors as presented in Figure 3. The soft drinks industry can be sub-divided into five main sectors (bottled water; carbonated soft drinks;

dilutables, also known as squash and including powders, cordials and syrups; 100 % fruit juice, and nectars with 25–99 % juice content; still drinks, including ready-to-drink (RTD) teas, sports drinks and other non-carbonated products with less than 25 % fruit juice). The alcoholic beverage industry is also divided into sub-categories namely, wine, beer, spirits, cider, sake and flavoured alcoholic beverages – sometimes referred to as pre-mixed spirits (Roethenbaugh, 2005).

*H. sabdariffa* has found a place in the beverage industry (hot drinks and soft drinks sectors) owing to its appealing red colour, refreshing properties and the awareness of its potential health benefit. However, the highlighted portion in Figure 3 shows the sectors yet to be fully exploited. Some of the products of *H. sabdariffa* in the beverage industry currently in the market are described below.

***(ii) Hibiscus Lemon Bissap***

The product is manufactured by the company Adina for Life founded in 2004 and based in California, U.S.A. The company uses certified organic hibiscus blossoms from Senegal under fair trade agreements as ingredients in its drink. The earnings from this product have enhanced the livelihood of the peasant farmers, and offered them decent incomes to improve their standards of living. The drink marketed as a New Age Beverage, with all natural ingredients and good for you appeal serves retailers throughout the United States including Whole Foods and Wegmans (Ramirez *et al.*, 2010; Rodrigues, 2010).

***(iii) Squash Hibiscus Pressé***

Produced and marketed in New Zealand, Hibiscus Presse has as ingredients, *H. sabdariffa* extract from water, fructose and ascorbic acid. The label on the 375 mL plastic bottle appeals to consumers, enlightening them about hibiscus' use in folklore and folk medicine in the Caribbean, China, Egypt, Sudan, and Asia. It also informs consumers that "Hibiscus is stimulating scientific inquiry into possible health benefits and its antioxidant properties" (Rodrigues, 2010).

***(iv) Simply Hibi***

The beverage available in 500 mL glass bottles is produced by Hibi Organics based in the UK and the raw material sourced from a distinct variety of hibiscus grown by farmers in Uganda. The product referred to as Hibiscus Elixir is prepared from infusions of the calyx blended together with sugar to make a concentrate which needs to be diluted before consuming it. In addition, the company in conjunction with Britania Allied Industries in Kampala, one of the biggest names in the East African Juice Market, produces Simply Hibi, a single strength juice as part of the 'Splash' range of juices spread abroad by the network of Splash distributors across East Africa. The label informs consumers that the product contains the same high quality, goodness and great taste as the Simply Hibi enjoyed in the UK (Rodrigues, 2010).

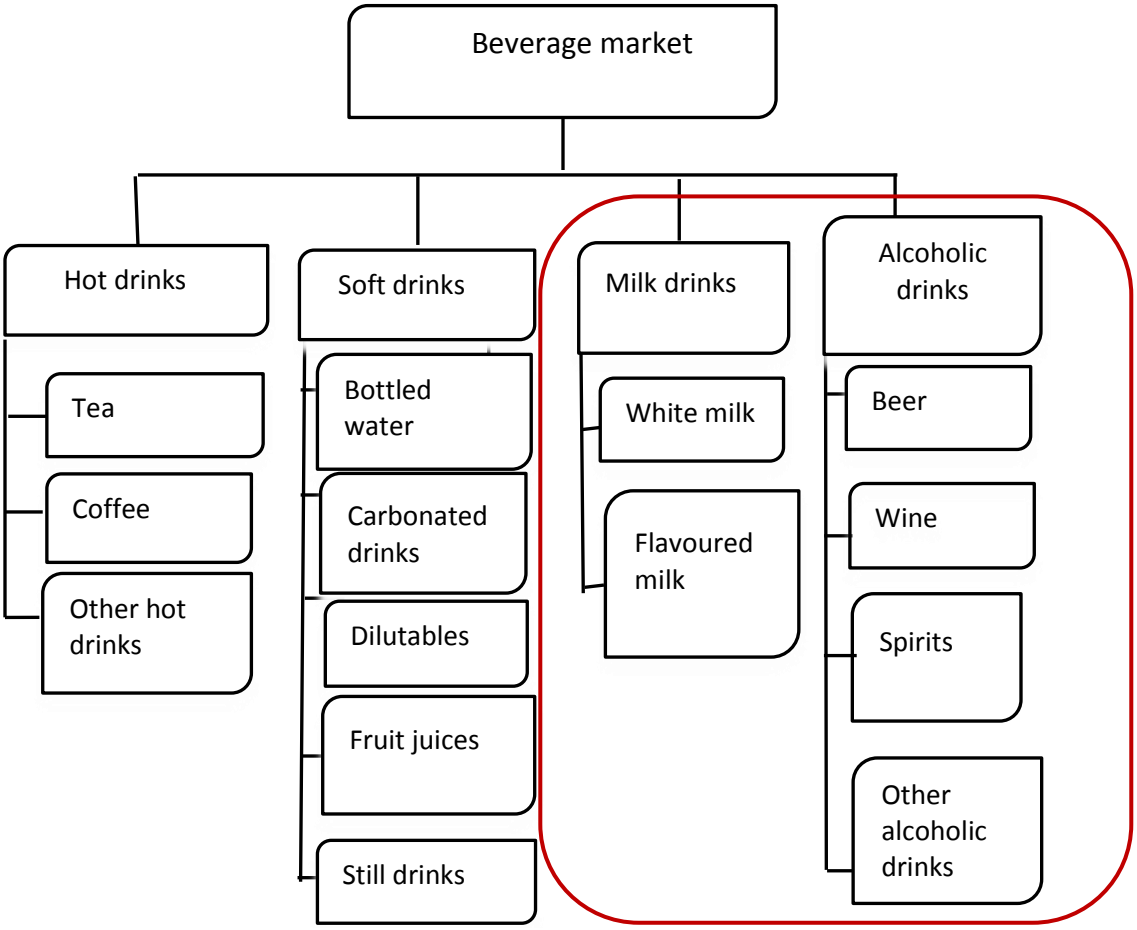


**Figure 3:** Schematic representation the beverage sector and segments. (Source Rodrigues, 2010) The highlighted portion shows sectors of the market yet to be fully exploited in the production of hibiscus-based drinks.

### *(iv) Yomm Hibiscus drink*

Produced by Yomm Beverage in Canada, the refreshing hibiscus drink comes in four different flavours: original, strawberry, lemon and sugar-free. The ingredients include *H. sabdariffa* extract, water, organic agave syrup, organic cane sugar and natural flavour, and the 335 mL bottle contains 0.270 g and 0.095 g of polyphenols and anthocyanins as stated on the product label.

### *(v) Hibiscus Tea*

Known as a caffeine-free herbal drink, hibiscus tea tends to be widely available and produced by different tea companies in tea bags or as loose flower petals. It is known by different brand names and while some contain only hibiscus, some contain it as a major component plus other ingredients to give different flavours.

## Conclusion

Although the use of *H. sabdariffa* has gained foray into the food beverage industry, there are other potential application of *H. sabdariffa* in the beverage industry as highlighted in Figure 3. Its high content of anthocyanins can be exploited and used as a natural colourant for beverages like milk- and yogurt-based drinks as well as in the production of hibiscus wine. The application of *H. sabdariffa* in food processing can promote the manufacture of novel functional foods that may ultimately provide health benefit at low cost (Patel, 2014).

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