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Therapeutic and economic Impacts of Roselle (*Hibiscus sabdariffa* L.) Anthocyanin; A Review

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Hibiscus sabdariffa is first introduced in Malaysia as an alternative to sandy soils for the replacement of tobacco plants in Terengganu. Advances in nutritional and medicinal plant research over the last two decades have experienced tremendous development. Anthocyanins are present naturally in a variety of plants that are linked with antioxidant activities. Their vivid color is often seen as a candidate for natural food colorants. The increased interest has focused on its health potentials. Among the most common plant flavonoids are the anthocyanins, which account for the red, yellow, and blue colors apparent in numerous plants, including roselle. Consumption of roselle anthocyanins can prevent lifestyle-related diseases, such as diabetes, cancer, neurological, and cardiovascular disease. Natural and synthetic food color additives rise at 4.6 % annually and will cross \$2.3 billion in short runs. The global food color market is estimated at approximately \$1.14 billion. Carotenoids and anthocyanin are the two most crucial candidates, with a combined 31% of the global market. The global trend for using natural plant remedies has generated an enormous need to research medicinal plants' properties and their usage. Hence, this study seeks to explore the role of roselle anthocyanin in therapeutics and their economic potentials.

Keywords: Calyx, Carotenoids, Color, Flavonoids, Anthocyanin

INTRODUCTION

Roselle (*Hibiscus sabdariffa* L.) is an associate of the Malvaceae family (Mariod et al. 2021). The plant is grown commercially in several countries, including Afghanistan, Indonesia, Malaysia, Sudan, Egypt, Mexico, and other parts of the world (Shruthi & Ramachandra, 2019a). In developing nations, a large populace relies on medicinal plants to meet necessary health care demand. Traditional medicines are gaining popularity among most of the world's population mostly due to facts that they are inexpensive, broadly available, and have fewer adverse effects on health. now a day's people believed that food not only satisfies hunger but also stipulate an

array of medical benefits (Siró et al. 2008; H. Y. Wu et al. 2018). Globally, attention has shifted in recent years to plant research in order to uncover the immense potential of medicinal plants used in various traditional systems. Numerous medicinal plants have been studied for their potent phytochemicals agents in the treatment of an array of diseases; one such plant is *Hibiscus sabdariffa*, which is well-known for its delicacy and medicinal properties (Cahlikova et al. 2015; Riaz & Chopra, 2018).

Hibiscus sabdariffa in English-speaking regions is called Roselle, red Sorelle or Sorrel in Jamaica sorrel, while in Florida is called cranberry, and Indian sorrel (N et al. 2009; Shruthi

& Ramachandra, 2019b). More than 300 cultivated varieties of *Hibiscus* species are widely consumed globally because of their actual content of bioactive compounds, specifically flavonoids (Maciel et al. 2018; Sindi et al. 2014). The roselle is utilized as a diuretic, mild laxative, digestive, antiseptic, sedative, and therapy of nerve and heart disorders for a long time (Puro et al. 2014). Besides jelly and syrup, red calyces have often been used to produce ice cream (Kouakou et al. 2015). Naturally, flavonoids are commonly distributed as dietary polyphenol. Over 4000 flavonoids have been depicted and classified according to their phenol structures, flavonoids are classified into many major groups, including phenolic flavonols, anthocyanine, Chalcone, Catechin, Flavone, and isoflavones (Kouakou et al. 2015)



Figure 1: Roselle calyx (Mardi, 2012).

Anthocyanins in roselle play a vital role in the overall health benefits, such as antioxidant, anti-diabetes, anticancer, anti-hypertension, and anti-inflammatory properties (Idris et al. 2012; Izatus Shima et al. 2017; Lislivia et al. 2017; Satirah et al. 2016). Besides anthocyanins, roselle calyces are rich in flavonoids, tannins, hormones, phenols, triterpenoids, and alkaloids and potent in essential and non-essential compounds (Brahma et al. 2014; Ijeomah et al. 2012; Mungole & Chaturvedi, 2011; Obouayeba et al. 2014). Anthocyanins constitute a significant class of flavonoids comprising a variety of secondary metabolites and natural pigments that vary in colors depending on the pH (Tanaka Y et al. 2008), ranging from orange, red, and purple to blue. There have been over 600 known anthocyanins in nature (Smeriglio et al. 2016). However, in plants, six standard anthocyanin derivative, namely delphinidin,

cyanidin, pelargonidin, peonidin, malvidin, and petunidin, are the commonest anthocyanins (Kong et al. 2003).

Roselle anthocyanin is utilized as a colorant in food industries, expanding at a yearly development pace of 4.6%, projected to hit at USD 2.3 billion. Today, the worldwide interest in natural food coloring is worth about \$1.14 billion. The carotenoids industry has more than 31 % of the overall industry's general interest, followed by 22 % anthocyanin (Ambati et al. 2019). Advances in medicinal plant research over the last two decades have experienced tremendous development. The global trend for using natural plant remedies has generated an enormous need for research on medicinal plants' properties and their use. Plants supply thousands of innovative compounds, including fragrances, flavors, colors, fibers, drinks, and construction materials, in addition to medicines (Sipahli, 2016). Hence, this study seeks to explore the role of roselle in therapeutics and its economic potentials.

Anthocyanin

Anthocyanins (Greek *anthos* = flower and *kanos* = blue) are the leading and most crucial water-soluble plant pigments (Brahma et al. 2014). Natural dyes of anthocyanin are one of the prevalent plant kingdom families. They are accountable for the red, green, purple, and blue hues of certain vegetables and fruits. Anthocyanin refers to a broad category of chemicals, classified collectively as flavonoids, which are Polyphenolic subgroups (Tanaka & Ohmiya, 2008), (Smeriglio et al. 2016). In acidic conditions, anthocyanin is present in red shades; likewise, the blue color anthocyanin exists in alkaline conditions.

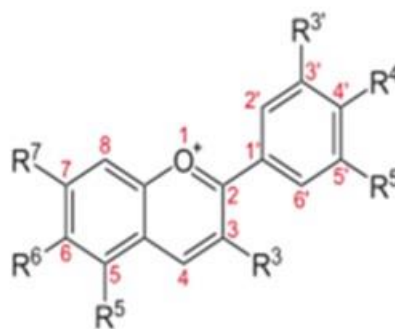


Figure 2: Basic anthocyanin structure

Although anthocyanins are a significant color category of flavonoids present in the plant kingdom, four variety of fruits and flowers rich with anthocyanins such as grapes, raspberries, roselle, and purple cabbage, among others, are

now being studied to ascertain their perspective as a source of natural color, given the growing demand for the replacement of synthetic colorants in food, cosmetics, and other items (Ambati et al. 2019; Kong et al. 2003).

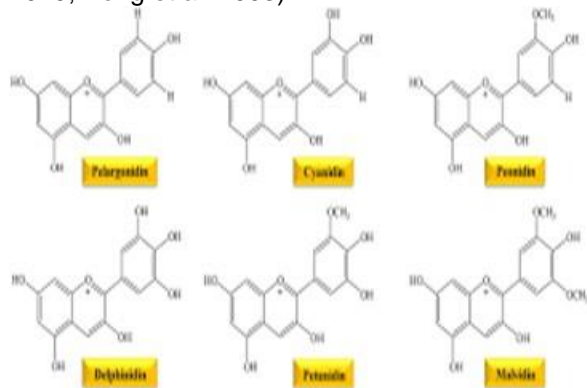


Figure 3: Six common anthocyanidin precursors structure (Smeriglio et al. 2016).

Anthocyanin-rich fruits and flowers have been utilized historically to treat various diseases and be used as natural colorants. On the other side, anthocyanins' herbal therapeutic properties have been thoroughly researched. Anthocyanins have antidiabetic, anticancer, anti-inflammatory, antimicrobial, and have an effect against cardiovascular disorders (CVDs) (He et al. 2011; Khoo et al. 2017; Pascual-teresa et al. 2010; Rahnema, T. & Abbaszade, 2018). Consequently, possible medicinal products are anthocyanins derived from edible plants. Besides, anthocyanin is abundant in various fruit and herbs and is one of the six most commonly identified plant anthocyanidins, including cyanidin, Delphinidin, pelargonidin, malvidin, peonidin, and petunidin shown in Fig 3 respectively (Pascual-teresa et al. 2010). Chemical compositions of the most prevalent anthocyanins in hibiscus were elucidated and were determined to be delphinidin 3-O-sambubioside and cyanidin 3-O- (Grajeda-Iglesias et al. 2016). There are 25 diverse roselle varieties from which anthocyanins' fundamental chemical structure has been discovered and their antioxidant and antibacterial activities have been revealed. Borrás et al. concluded on identifying Delphinidin sambubioside as the most abundant anthocyanin and suggested its essential contribution to the calyces' color (Ambati et al. 2019; Aurelio et al. 2008; Gradinaru et al. 2003; Kong et al. 2003).

Commercial benefits of roselle

Food and agricultural organization (FAO)

reported that Thailand and China are the world's leading producers of roselle. Roselle is of the highest consistency from Sudan, but insufficient packaging and distribution inhibit this fruit from achieving global fame. Thailand concentrated heavily on plant development, and their product is superior (Gautam, 2004; Shruthi et al. 2016; Tsuda, 2012). Roselle is one of the most popular ingredients used in commercial herbal tea blends marketed in the US (McKay & Blumberg, 2007). The Roselle calyces are of considerable significance to people from rural areas since they provide a significant income source. The industry of roselle is vigorous and rising in India (Shruthi & Ramachandra, 2019b). The resulting depleted flower of roselle calyx produces anthocyanins, which provide sparkling red color to the petals and make this plant an attractive and economical natural food coloring source (Grajeda-Iglesias et al. 2016). It is projected that the overall market value of the roselle industry in Malaysia is RM10 to RM15 million, roughly 65 % to 80 % of the value remaining with the processors. Thus, there is a strong demand for roselle in the local sector (Osman et al. 2011).

Anthocyanin is frequently used in the food industry as a substitute for red synthetic food coloring. Anthocyanin and its derivatives have been classified in the Codex Alimentarius Commission in the European Union as a natural coloring agent with the code E163 (Aryanti et al. 2019).

Roselle may also be a great natural source for developing new drugs and may provide a cost-effective means of treating cancers and other diseases. Anthocyanins are a critical point of roselle value and are an essential active compound (Abdel-samie, 2018; Sindi et al. 2014). Overall, US adults' estimated average consumption of anthocyanins is 12.5 mg/day. The mean intake of men ranged from 19.8mg/day (the Netherlands) to 64.9mg/day (Italy), while for women, the range was 18.4mg/day (Spain) to 44.1mg/day (Italy) (McKay & Blumberg, 2007).

Nutritional importance of roselle calyx

More than just exquisite fruit, for centuries, Roselle was used in traditional foods, beverages, and medicine. Julia Morton noted in the book *Fruits from warm climates* that Roselle comes from regions such as India and Malaysia (Shruthi & Ramachandra, 2019a). Many roselle pieces are eaten, including seeds, leaves, roots and flowers, but the red calyces are the best (Salami & Afolayan, 2020).



Figure 4: Healthy roselle drink

Hibiscus sabdariffa is commonly utilized in different countries for different food items; processed food and drinks are made from the Hibiscus flowers (Ajayi et al. 2012). This drink is known in Mexico as "Jamaica flower." The roselle drink is prepared from a solid-to-solvent ratio in Senegal, West Africa. In Asia and Africa, this drink is very widespread. It is more common in Senegal, and there is more consumption during the Ramadan month (Padmaja et al. 2014). In Egypt, this beverage has been named the "drink of the pharaoh." In Sudan, it's called "Karkade Tea." In Mali, it is called "da Bilenni" (Africa). *Hibiscus sabdariffa* tea is also called Sudanese; dry calyces sour tea also has medicinal properties. Roselle is also the principal ingredient for many other teas (herbal tea) (Shruthi & Ramachandra, 2019b).

Roselle is high in protocatechuic acid and anthocyanins. The dried calyces include gossypetin, hibiscetin, and sabdaretin of the flavonoids. Daphniphylline is the significant pigment previously reported as hibiscin. There have also been small concentrations of myrtilin (3-monoglycoside delphinidin), chrysanthenine (3-

monoglycoside cyanidin) delphinidin. Roselle seeds, in particular β -tocopherol, are an important cause of fat-soluble antioxidants (Mohamed, B. B. & Dahab, 2012). It also possesses flavonoids and polyphenol (Cissé M et al. 2009; Rahnemoon1 et al. 2018; Salazar-González et al. 2012; Shruthi et al. 2016).

Foods rich in anthocyanin may improve health by providing a variety of nutrients shown in Table 1 and 2 (Yousuf et al. 2016). The diet of anthocyanins appears to improve optimal health effectively, so it may be recommended for people and the poultry industry to be nontoxic feed additives (Changxing et al. 2018).

Table 1: Functional properties of fresh calyces of Roselle (Shruthi et al. 2017).

S/No	Parameter	Average value
1	Total anthocyanin content (mg CyaG.100g-1)	718.72±1.19
2	Total phenolic content (mg GAE.g-1)	20.85±0.08
3	Antioxidant activity (%)	92.23±0.77
4	Total flavonoids (mg CyaG.100g-1)	38.34±0.11

The roselle calyces have powerful organic acids like citric acid, tartaric acid, and malic acid (Shruthi et al. 2016). The plant contains minerals, particularly potassium and magnesium. Vitamins often became present in appreciable numbers (Puro et al. 2014). Roselle flowers have bitter tastes that are commonly available in juices, jams and in an increasing number of countries (Ajayi et al. 2012). The plant primarily produces anthocyanins such as Delphinidine-3-glucoside, Sambubioside, and cyanidin-3-sambubioside, mainly responsible for their antioxidant properties (Aurelio et al. 2008; Mohamed et al. 2012).

Table 2: Nutritional Composition of Roselle (Shaik et al. 2018)

Composition	Fresh Calyces	Fresh Leaves	Flowers	Seeds
Ascorbic acid (mg)	6.7	54	ND	Trace
Ash (g)	1.0	6.90	9.75	7.0
Calcium (mg)	12.63	213	ND	356
Carotene (mg)	0.3	4135ug	-	-
Carbohydrate (mg)	10.00	9.20	4.38	51.3
Energy (Cal)	44	43	-	411
Fat (g)	2.61	0.30	0.59	16.0
Moisture(g)	9.20	85.60	4.38	8.2
Niacin (mg)	3.77	1.2	-	1.4
Vitamin I, E	-	-	-	1000

Medicinal benefit of roselle

The available evidence indicates that the anthocyanins and polyphenol found in roselle calyces have a variety of biological effects. Over the past decade, the science and research community has shown interest in plant-driven flavonoids because of their biological properties with little to no adverse effects than synthetic drugs. Therefore, *Hibiscus sabdariffa* calyces as shown in Table 3 and Fig 7 were used to treat cardiovascular diseases, high blood pressure, and leukemia. Diuretic, aphrodisiac, and antiseptic activities are also reported, including cholagogue, diuretic, laxative, and antimicrobial activity. It is sometimes used as an antipyrexia and abscess treatment. Goal and bronchitis are handled with flowers and fruits of roselle (Maregesi et al. 2013). Roselle Anthocyanins can stimulate the immune system and increase health; thus, can be beneficial for treating disorders.

Free Radical Scavenging Activity of Roselle

Antioxidants are deemed effective carcinogenic inhibitors as well as other pathogenic conditions related with oxidative mechanisms. Numerous studies have shown that nutrient and/or medicinal products with antioxidants can protect human health in many cases (Ames et al. 1993). Therefore several research have been conducted to explore the antioxidant potential of *H. sabdariffa* and its components since calyces are consumed across the globe with culinary and medicinal purposes and roselle calyces have the potential for therapeutic use (Clifford, 2000; Formagio. et al. 2015), similarly Hai-Yao Wu indicated that the roselle extract is anthocyanin-rich and has a high antioxidant capacity (DPPH IC₅₀ = 4.06 mg/mL, ABTS IC₅₀ = 3.7 mg/mL) (H. Y. Wu et al. 2018).

Antimicrobial functions

Hibiscus is rich in vitamin C or ascorbic acid, a mineral that our body requires to enhance and improve our immune system's function. Fresh or dry calyx absorbs vitamin C in high volumes, believed to enhance the immune system, antibacterial and anti-inflammatory characteristics (preventing cold and flu). Due to its healing effect, which helps treat fever-induced pain (X. Wu et al. 2006).

Abdallah (Abdallah, 2016), in his study, evaluated the antibacterial activity of methanolic extract of roselle calyces against hospital isolates of multidrug-resistant (MDR)-*Acinetobacter baumannii*. The author reported that the extract was more effective than gentamicin, thus exhibiting potent antibacterial activity against the

MDR strains of *A. baumannii*. Therefore, roselle can be used as an anti-bactericidal drug.

Anti-inflammatory

Inflammation is the body's physiological response to injury or disturbance caused by external factors. Diabetes stimulates pro-inflammatory compound production (hs-CRP, IL-6, TNF-, and IL-18). (Mardiah et al. 2015) showed that the tumor necrosis factor level (TNF-), implying roselle's anti-inflammatory activity, decrease in dose of 72 mg roselle/day/200 g body weight and 288 mg/day/200 g body weight. Yang et al. (Peng et al. 2016) have proved the prevention of earlier diabetic nephropathy by albuminuria, increased creatinine clearance, and fat repositioning and glycation (AgE) in the kidney.

Hibiscus sabdariffa polyphenol extract (HPE). HPE reversed the accumulation of collagen and decreased the growth factors for the tubular connective tissue (CTGFs) and glomerular diagnostic cluster 31 (CD31), reduced the angiotensin II receptor (AT-1), and improved oxidative stress.

Aid in Digestion

Roselle seed capsule is known for its diuretic and tonic properties, it improves the flow of both urination and bowel (due to its diuretic properties). It also treats Constipation threats and colorectal cancer prevention (Puro et al. 2014; Sindi et al. 2014; Wong, 2019).

Weight Loss

Its Herbal tea is also ideal for weight loss. You are expected to gain weight by consuming carbohydrates foods that contain sugar and starch. Studies have, however, shown that hibiscus extract reduces starch and carbohydrate absorption and can contribute to weight loss. The use of roselle inhibits the development of amylase that contributes to carbohydrates and starch absorption. It is also used in many items for weight loss (Changxing et al. 2018; Wong, 2019; X. Wu et al. 2006)

Antidepressant Effects

Roselle possesses antidepressant qualities such as flavonoids to calm the nervous system and eliminate anxiety and depression by a relaxed feeling in the body (Wong, 2019).

Treatment of Cough, Colds, and Fever

The fresh hibiscus contained about 6.7 mg of ascorbic acid, which is one of the essential nutrients the body requires. "Healing Herbal

Teas." The vitamin C. Hibiscus has anti-inflammatory and moderate anti-bacterial properties, as well. Thus, its tea is also helpful to cure cigarettes and colds as a substitute. Due to its cooling effect, the fever pain which accompanies such a disease may be reduced in a particularly effective way (Wong, 2019).

Antihypertensive effect of roselle

The use of hibiscus in pre-hypertensive and highly hypertensive adults reduces blood pressure. It also states that 1/3 of adults suffer from high blood pressure. Research by Odigie IP has shown that it has anti-hypertensive and cardiovascular characteristics, which may favor hypertensive and cardiovascular patients at high risk (I.P. et al. 2003). According to Tufts University studies in Boston, Hibiscus tea can lower blood pressure up to 10 points due to its anti-inflammatory effects. You need three cups per day for a few weeks to achieve this dramatic progress. It also has diuretic effects, which simultaneously raise urination and simultaneously reduce blood pressure (Koponen et al. 2008; McKay & Blumberg, 2007; Shruthi & Ramachandra, 2019b). Other significant beneficial impacts of roselle were listed in the Table 3 below.

Anti-carcinogenic

Some other "study examined the effect of roselle anthocyanins on human tumor cells and discovered that anthocyanins induce apoptosis in HL-60 cancer cells by activating the p38 MAP kinase. A kinase that phosphorylation the target protein C-Jun, activating subsequent apoptotic protein cascades containing Fas-mediated signaling, resulting in the release of cytochrome C from the mitochondria and caspase-3 cleavage (Chang et al. 2005). Delphinidin 3-sambubioside from *Hibiscus sabdariffa* induces dose-dependent apoptosis in human "promyelocytic leukemia cells (HL-60) via a mitochondrial dysfunction pathway mediated by reactive oxygen species (ROS) (Hou et al. 2005). The preceding two findings corroborated one another.

Toxicological Functions

Roselle tea is a widely consumed diet in many parts of the world, assuming it is safe and natural with some potential health benefits. However, due to the possibility of herb-drug interactions, the natural product may not be safe for pharmaceutical individuals or vulnerable groups (children and women). Aqueous roselle calyx extract has reduced acetaminophen, diclofenac, and hydrochlorothiazide elimination, all anti-inflammatory medications.

Table 3: Medicinal Benefit of Roselle Anthocyanin

Biological Activity	References
1. Anti-diabetic	(Idris et al. 2012; Lee et al. 2009; Lislivia et al. 2017; Nichenametla et al. 2006; Satirah et al. 2016; Shima et al. 2017).
2. Anti-cancer	(Idris et al. 2012; Lislivia et al. 2017; Nichenametla et al. 2006; Satirah et al. 2016; Shima et al. 2017; Youdim et al. 2000).
3. Anti-inflammatory	(Idris et al. 2012; Lislivia et al. 2017; Nichenametla et al. 2006; Satirah et al. 2016; Shima et al. 2017; Silva et al. 2017; Yousuf et al. 2016).
4. Antioxidants	(Ayolié K et al. 2015; Idris et al. 2012; Lislivia et al. 2017; Satirah et al. 2016; Shima et al. 2017; Yousuf et al. 2016).
5. Antimicrobial	(Pisano et al. 2015; Salleh et al. 2001; Silva et al. 2017)
6. Ant diuretic	(Puro et al. 2014; Sindi et al. 2014).
7. Laxative	(H. Y. Wu et al. 2018)
8. Protect against Cardiovascular	(Shaik et al. 2018; Youdim et al. 2000; Yousuf et al. 2016).
9. Neurological disorder	(McKay & Blumberg, 2007; Nichenametla et al. 2006; Sindi et al. 2014;
10. Atherosclerosis	Zha & Koffas, 2017).
11. Anti-obesity	(Ajayi et al. 2012; Changxing et al. 2018; X. Wu et al. 2006). (H. Y. Wu et al. 2018)



Figure 7: Anthocyanin therapeutic effects and its mechanisms of action (Changxing et al. 2018).

CONCLUSION

Advances in nutritional and medicinal plant research over the last two decades have experienced tremendous development. Anthocyanin from the roselle of *Hibiscus sabdariffa* is very effective in treating diseases like cancer, diabetes, inflammation, antioxidant, cardiovascular disease, and many other diseases, according to this study. Similarly, it plays a vital role in nutrition and economic benefits, mainly the pigment from roselle, which is now being used to substitute the synthetic coloring used due to its adverse effects. However, despite the numerous benefit of anthocyanin, it's highly unstable due to certain factors such as pH, Temperature, Light, Storage, and enzymatic activities, which lead to the loss of its biological activities. Therefore, further research is recommended on the stability of anthocyanin.

DECLARATION OF INTEREST

The authors declared no competing interest with regards to the publication of this paper.

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AUTHOR CONTRIBUTIONS

NHM designed and supervised the review. AAL write the review manuscript. MMK co-supervised the review and proof read the manuscript. All authors reviewed and approved the final version.

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