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Nutritional and Phytochemical Properties of *Beta vulgaris* Linnaeus (Chenopodiaceae) – A Review

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ABSTRACT

Background: *Beta vulgaris* L. (Chenopodiaceae) is a nutritious vegetable that is known by various names all over the world. This review summarizes and analyzes the nutritional as well as phytochemical properties of *Beta vulgaris* L that makes it suitable as food and medicine for man.

Methods: Related literature from 1988-2020 was gotten and compiled from academic search databases; Google Scholar, Web of Science, PubMed and Scopus. The articles were searched for with the aid of keywords (Nutritional, *Beta vulgaris,* Phytochemical, and Proximate).

Results: Studies indicate that *Beta vulgaris* L. contains carbohydrates, proteins, fatty acids, vitamins, fibres that makes it a good source of food for man and its leaves a healthy source of feed for animals; Phenolic acids (such as Caffeic acid, Syringic acid and Ferulic acid), Flavonoids (such as Quercetin, Rutin, and Myricertin) and Betalains (such as Betanin, Isobetanin, Vulgaxanthin I and II). The plant also contains sucrose (carbohydrate) which makes its root suitable for the industrial production of sugar as it is the second most used plant for the production of raw sugar after *Saccharum officinarum*. Even with all these properties, many are not aware of the medicinal functions of this plant which include being a natural aphrodisiac, anti-diabetic, anti-bacterial, and anti-cancer agent.

Conclusion: This paper provides a review on the nutritional and phytochemical characteristics of *Beta vulgaris* L. which should be useful for further study of the usefulness of this plant.

***Keywords*: Betalain, *Beta vulgaris*, Nutritional, Phytochemical, Proximate composition**

1. INTRODUCTION

Beta vulgaris L. is one of the most famous plants of the taxonomic family Chenopodiaceae; which has over a hundred genera [1]. It is a dicotyledonous, biennial plant with tuberous root stocks. It is grown for food, not just for sugar production and bioethanol [2]. The plant can adapt and grow in soils with high salt levels and low water availability; it can also survive in hot or cold environment with low light availability [3]. It is known as garden beet in the United States of America, as beetroot in Europe [4], and Swiss chard in Montenegro [3]. It is sometimes also referred to as Sugar beet [5], Red beet [6], [7], [8], Beet greens [9], Golden beet [10], Beet, chard, or spinach beet [2]. The taproot portion of the Beta vulgaris plant which matures for planting within fifty to sixty days and has a weight of about 100 - 150 g is popularly known as beetroot [10, [11], while the combination of its leaves and stalks together is referred to as beet green [12]. The plant is locally referred to as *Alubosa eleje, Isu dandan*, or *Koba-kogbe* by the Yoruba ethnic group of Nigeria. The plant is divided into *Cultivar* groups which are then subdivided into various varieties. The common cultivar groups are the *Conductiva* group [9]. The *Cicla* group and the *Flavescens* group [13]. *Beta vulagris* is a dietary supplement due to its nutritional as well as phytochemical constituents. It is consumed by athletes as it is high in sugar and energy content. Sugar is a widely used substance, with its main source as sugar cane and sugar beet. Sugar beet has a relatively sweet taste and is the second widely used raw material in sugar production. It is used to produce table sugar in some sugar mills of countries such as Egypt, Iran, and France. Currently, the sugar mills in some countries such as Nigeria rely only on *Saccharum officinarum* (Sugarcane) for their production of table sugar rather than on Beta vulgaris. Beta vulgaris is a better choice as it has more sucrose than sugar cane, maximum sugar yield, profitable plant production operation and efficient in bio-fuel like ethanol production. Sugar beet also leads as it contains more anti-oxidant

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Figure 1: *Beta vulgaris* L

properties especially when compared with sugarcane making it a healthier alternative for sugar production [14]. Today, beetroot is grown in many countries worldwide not just for sugar production but for a wide range of applications. It is regularly consumed as part of the normal diet, and commonly used in manufacturing as a food colouring agent known as E162 [2]. Beetroot has been proven to have anti-oxidant, carminative, cytotoxicity and anticancer, renal-protective, anti-hypertensive, anti-inflammatory, radio-protective, anti-fungal, anti-depressant, anti-microbial, expectorant, anti-diabetic, anti-anemic activities [1], [10], [12], [15]. In Nigeria for example, it is consumed majorly as a natural aphrodisiac. Unfortunately, its leaves are disposed as wastes and not eaten as vegetables that are beneficial health-wise to both humans and livestock [16]. This paper reviews the Nutritional and phytochemical properties of Beta vulgaris and its suitability as food and medicine for man and livestock.

2. DISCUSSION

2.1 Nutritional Properties of *Beta Vulgaris*

2.1.1 Proximate Composition of the Roots and Leaves of Beta vulgaris L.

Analysis on the proximate composition of *Beta vulgaris* have been done by various authors. The roots and leaves of the plant have been the most researched on. Table 1 shows the quantitative result obtained by various authors analyzing the roots of the plant. Plants may fail to produce the same constituent if they were grown in different situations [17], therefore the difference in the values from different authors maybe from its source (which entails the environment, condition, and time it was grown [17], [18], [19]. The dataset in table 1 was analyzed with Python v3.7 for correlation and it was revealed that there is a strong correlation between the protein content and the ash content of the roots. An increase in the protein content would cause a corresponding increase in the ash content and vice versa. From the table, the roots of the plant has abundance of moisture as it is a vegetable and all vegetables are known for their high moisture content which aids the maintenance of the protoplasmic content of the cells even though they make them susceptible for microbial attack [20]. The moisture content of any crop or product is a very important determinant of their shelf-life. During storage especially refrigeration, moisture gains access into some food products which increase as the storage time increases and makes its deterioration faster [21]. Proteins which are made up of Amino-acids are essential of human as well as animal survival [22]. They are also essential in the repair of worn-out tissues in the body. The total protein content of the *Beta vulgaris* plant is also dependent on the amount of fertilizer applied to the field. At optimal irrigation, the calculated value of optimal crop evapotranspiration is thus: reducing the amount of fertilizer applied by half (50 %) of the quantity required by the plant would decrease the protein content of the plant by 1.7 %, while increasing the amount of fertilizer by half (150 %), would increase the protein content by 28 % [3]. The processing of beetroot into candy can reduce its moisture content by a value of 69.6 % thereby increasing its shelf-life. It would also decrease its protein content and increase its carbohydrate contents by values of 6.7 % and 634.8 % [1].

Table I: Table comparing the various proximate parameters of *Beta vulgaris* roots by some authors.

Proximate Parameters	[21]	[20]	[10]	[2]	[23]	[1]
Moisture content (%)	79.40±0.53	87.4	96.5	87.4±0.3	87.4±0.35	85.56
Protein (%)	13.23±0.00	1.35	0.10	1.35±0.2	1.35±0.02	1.04
Fibre (%)	-	2.56	0.81	1.9±0.2	1.9±0.01	2.20
Ash (%)	6.18±0.01	1.4	0.54	1.4±0.2	1.4±0.02	1.18
Lipids (%)	-	0.3	0.27	0.3±0.1	-	0.21
Carbohydrate (%)	11.97	6.99	1.78	7.59±0.4	-	9.05

Carbohydrate is the second most abundant biological molecule in the roots and is responsible for the regulation of nerve tissues and the provision of fuel (energy) for physical activities that is readily accessible. They are also sources of structural materials in the body [22]. The bulk of the sugar (Carbohydrate) present in the roots of *Beta* *vulgaris* is sucrose, which makes it suitable for sugar production. The root also contains glucose and fructose in minute quantities [24]. This claim was supported by Jurgen and his colleagues when they analyzed seven different varieties of the plant [6]. A high sucrose and low fructose contents are required in drinks just like the energy drink produced by Jha and Gupta (2016). This is because fructose decreases human exercise capacity [2], [25]. Crude fibres are made up of lignin, hemicellulose and cellulose [22]. The ash content of the roots which is the total amount of ash present is an indication of the total mineral content of the plant [19]. The crude fat is an indication of the presence of fats which is known to supply most of the energy we need in our day to day activities. In addition to this, it helps to lower cholesterol level, support the functions of the heart and the nervous system [19]. The roots of the plant also contain folic acid that aids in cancer prevention. The folic acid together with its vitamin B content promotes the proper functioning of the nervous system [1]. Addition of Epsom salt (hydrated magnesium sulphate) to the soil can also increase the protein, lipid, fibre, ash and moisture content but decrease the carbohydrate content of the plant [26]. The leaves of *Beta vulgaris* are usually due for planting after 60 days and have been shown to also possess some proximate characteristics that show they are suitable to be used as a vegetable foe food and feed for animals. Beet leaves harvested after 60 days have more moisture but lower ash, protein, lipids, carbohydrate and energy as days progresses [27].

2.1.2 Vitamin Composition of the Roots of Beta vulgaris L.

The roots of the plant also contain both water and fat soluble vitamins. In decreasing order of concentration, the vitamins are; Vitamin B_2 >> Vitamin C >> Viamin B_3 > Vitamin E > Vitamin B_5 > Vitamin B_1 > Vitamin B_6 >>> Vitamin K. Vitamin B_1 (Thiamine) is a precursor in the metabolic production of carbohydrates and keto-acids. Lack of this vitamin in the body could lead to cardiac complications, appetite loss, tiredness and weakness, constipation and nausea. Vitamin B_2 (Riboflavin) performs the role of a coenzyme in the metabolic production of proteins and carbohydrates. Lack of this vitamin could lead to intolerance to light and blurry vision. Vitamin B_3 (Niacin) is required in biological processes such as tissue respiration, glycolysis and in the synthesis of fats. Vitamin C (Ascorbic acid) which is the second predominant vitamin in the roots makes the root a good antioxidant which helps the body to fight off infections and diseases. Vitamin C encourages the formation of strong bones and immune system as it is involved in the activities of all cells in the body [28].

2.1.3 Mineral Composition of the Roots of Beta vulgaris L.

The mineral composition of the roots of *Beta vulgaris* is shown in table II. The root is a rich source of sodium, potassium, calcium and magnesium. Calcium in *Beta vulagris* is a major component of bones, blood and extracellular fluids. It is required for the contraction of muscles, clotting and coagulation of blood and in some enzymatic metabolic processes. It also plays an important part in nerve-impulse transmission and in the mechanism of neuromuscular system. It is very important that the normal calcium level in the diet should be balanced throughout life [20]. Sodium and Potassium is required in the maintenance of nerve irritability, pH and Osmotic balance of body fluids, enhancement of the normal retention of protein during growth, control of glucose absorption, and the regulation of muscles [18], [28].

Table II. Mineral Composition of Beetroot in mg/100g [2, 20].

Minerals	[20]	[2]
Iron	0.76±1.40	0.75±1.20
Potassium	31.20±0.46	30.12±0.29
Calcium	13.82±0.98	12.20±1.20
Manganese	0.86±2.04	0.79±1.98
Copper	0.08±0.56	0.09±0.47
Sodium	73.60±1.12	72.58±1.12
Zinc	0.29±1.25	0.21±1.01
Magnesium	18.60±2.40	-

Magnesium is an activator of many enzyme systems and maintains the electrical potential in nerves. In humans, Mg is required in the plasma and extracellular fluid, where it helps maintain osmotic equilibrium. It is required in many enzyme-catalyzed reactions, especially those in which nucleotides participate where the reactive species is the magnesium salt. Lack of Mg is associated with abnormal irritability of muscle and convulsions and excess Mg with depression of the central nervous system [20]. Zinc is an important mineral that plays a valuable role in managing diabetes which arises from the malfunctioning of Insulin. Zinc is very important in the production of Insulin in the body [29]. Copper is also a component of many enzyme systems such as cytochrome oxidase, lysyl oxidase and ceruloplasmin, an iron-oxidizing enzyme in blood. The observation of anemia in Cu deficiency may probably be related to its role in facilitating iron absorption and in the incorporation of iron into haemoglobin [20]. Ingestion of beetroot, a natural source of nitrate, increases the availability of nitric oxide (NO) as a potential strategy for managing diseases in which NO bioavailability has diminished, like hypertension and endothelial function [15]. Due to the low fatty and calorific value of the beet plant, and high concentration of their micronutrients, the plant has the nutritious advantage since almost all international reports and recommendation on diet and nutrition supports the ingestion of fruits and vegetables to replace high-energy foods [20].

2.2. Phytochemical Properties of the Leaves and Roots of *Beta Vulgaris* L.

The phytochemicals present in this plant are responsible for its various pharmacological activities. In decreasing distribution of secondary metabolites present in the roots of *Beta vulgaris*, Alkaloids >> Terpenoids >> Steroids > Flavonoids > Tannins > Saponins > Glycosides. Organic acids were also found to be present in the roots in decreasing concentration of shikimic acid >> malic acid > citric acid >> fumaric acid [24]. The roots of the plant contains phenolic acids (such as caffeic acid, ellagic acid, syringic acid, vanillic acid, and ferulic acid); flavonoids (such as myricetin, kampferol, and quercetin). In decreasing order, the distribution of secondary metabolites present in the leaves of *Beta vulgaris* is thus*:* Flavonoids > Chlorophyll > Tannins > Oxalate > Anthocyanins >> Saponins > Phenolics > Carotenoid >> Phytate [30]. The leaves are also endowed with omega-3 such as linolenic acid [27]. The stem of the plant in terms of phenolic acids content doesn't contain ellagic acid, but contains gallic acid and chlorogenic acid in addition to the phenolic acids present in the root and rutin in combination with the flavonoids present in the root [31]. The major classes of flavones found in beet root are betagarin, betavulgarin, cochliophilin A, and dihydroisorhamnetin. It was reported that betagarin 5,2-dimethoxy-6,7-methylenedioxyflanone) and betavulgarin (2-hydroxy-5-methoxy-6,7-methylenedioxyisoflavone) were isolated from the leaves of the plant [32]. Phytic acid may be present as either a complex with protein or as phytate salt. Phatates have the ability to chelate with some metal ions especially the divalents such as magnesium and calcium to form insoluble complexes, which are not easily digested and may pass through the digestive tract unchanged, thus reducing the bioavailability of these minerals. Phytates also form strong complexes with proteins and this can lead to their reduced digestibility [24], [31]. Apart from being used as a preservative, phytic acid is also used as food additives [20]. Various processing techniques can affect the concentrations of the phytochemicals and other anti-nutrients in the beet plant [20]. For example, boiling the methanol extract of the leaves of *Beta vulgaris* in water and 5 % sodium chloride solution could both cause a breakdown of tissue structure and changes in compound matrix and thereafter leaching-out-process which in turn decreases the initial phenolics present. The solutions could also cause the leaves to lose hydrolysable tannins to the surrounding leachate and lead to a decrease in total tannin content. Boiling the leaves in the salt solution of 5 % sodium chloride solution would cause the hydrolysable flavonoids to leach out from the tissues of the leaf causing a decrease in the initial flavonoids content while boiling it in water could increase the level of free flavonols and change the compound matrix of the leaf tissues to increase the amount of flavonoids. Boiling the leaves of *Beta vulgaris* in water and 5 % sodium chloride solution would both cause an increase in Anthocyanins but more in the salt solution due to the hydrolysis of various components during boiling that promote the release of anthocyanin forms. The two solutions would decrease the chlorophyll content of the leaves with a greater reduction observed in the salt solution due to the breakdown of the chloroplast at high temperature during the boiling process. Boiling the leaves in the two media would decrease thee ascorbic acid present in the leaves due to unstable nature and high solubility of ascorbic acid at high temperature. The nitrate, phytate and oxalate content of the leaves would decrease by boiling it in water and then in 5 % sodium chloride solution. Therefore, boiling the leaves of *Beta vulgaris* in water would increase its flavonoid, anthocyanin, and carotenoid contents while boiling the leaves in 5 % NaCl solution would increase its anthocyanin and carotenoid contents only more than the boiling water [30]. Also, due to the changes in the amount of phenolics and ascorbic acids, boiling the methanol extract of the leaves of the plant could cause a 9.7 % and 11.1 % reduction in water and salt solution respectively [1]. Alkaloids have pharmacological effects and are utilized in drug production. They have bitter tastes that enable insects to not feed on the leaves of the plant [20]. Hydrophilic Flavonoids, water soluble derivative of flavones containing conjugated aromatic system often bound to sugar as glycosides. They function as anti-oxidants giving protection against disease by reducing oxidative stress caused by metal ions on low density lipoprotein. Flavonoids found in natural plant are modifiers that eliminates carcinogens, mutagens and microbials [33]. It acts on microbes by binding to the extracellular and soluble protein of their cell wall thereby inactivating its toxins. It also increases myocardial oxygen consumption, cardiac flow, anti-allergy, and anti-spasmodic activities while lowering arterial pressure [33].

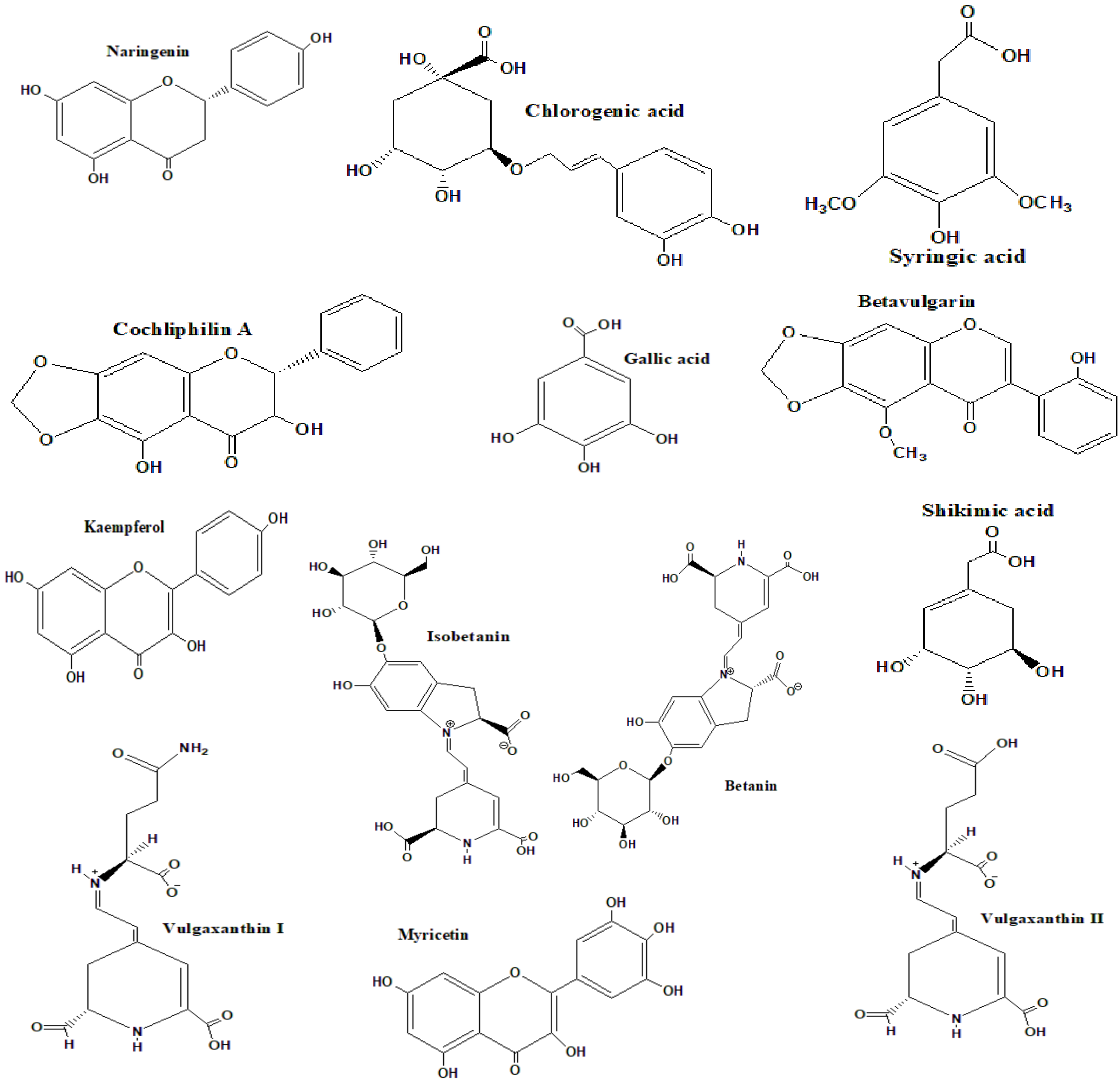

Figure 2: Chemical Structures of Phytochemicals in *Beta vulgaris*

Beta vulgaris is popular for its abundance of a nitrogenous pigment which is water soluble called betalains [25]. Betalain is a member group of the secondary phytochemical; phenolic acids [1]. Two major categories of betalains are found to exist in the plant. The first is betacyanin, which is a red pigment [35] (most of the total betacyanins present in the root of the plant is Betanin which has a higher stability in the extract form than in its pure chemical form) [11]; and the second known as Betaxanthin which is a yellow pigment [35]. The predominant betalains present in the plant are Vulgaxanthin I (betaxanthin), isobetanin and betanin (betacyanins) [31]. More than 80% of all the pigments in red beetroot are composed of betacyanins, mainly betanin and its isomer, whereas Vulgaxanthin I represents the predominant betaxanthin (yellow pigment) [15]. Betalains and anthocyanins have never been found together in the same plant species [15]. Betalains are used in the processing of food products such as ice-cream, yoghurt, candies, e.t.c. [25]. Their pigments are also used in the production of local cosmetics in Nigeria such as lip balms as natural colouring agent. Betalains are abundant in the roots of *Beta vulgaris* more than its stem. In comparison, the amount of betanin is more than the concentration of Vulgaxanthin I in both the stem and the leaves [31]. Due to its low toxicity, high water solubility, and natural colorant characteristics, Betalains are used in food industries as an additive [31]. The pigments major effects are the anti-oxidant property where it enriches the low density lipo-protein which increase the body resistance to oxidation (oxidative stress related disease and disorder), stimulates the immune system, gives kidney and liver protection, increases cognitive functioning and guard of one's blood vessels against damage and inflammation.

3. CONCLUSION

Beta vulgaris is no doubt a very important plant that is underutilized all over the world. This review has buttressed the Nutritional and Phytochemical properties of the leaves and roots of *Beta vulgaris* that makes it suitable as food and vegetable respectively as compared to Sugarcane and Cucumber. Its proximate properties have shown that its root and leaves are good sources of food and feed for animals. Most of its medicinal value stems from its phytochemical characteristics inherent in the plant. More research is still required on the leaves and other part of the plant to ensure the full utilization of this plant. More awareness into the proximate and phytochemical characteristics of this plant still needs to be made to the general public.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Contribution of the Authors

Iwuozor Kingsley wrote the Introduction, Nutritional properties of the plant, Abstract and Conclusion.
Afiomah Chidera wrote the phytochemical properties of the plant.

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