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Bioactive compounds of beetroot and utilization in food processing industry: A critical review

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ABSTRACT

Beetroot is recognized as health promoting food due to presence of essential components such as vitamins, minerals, phenolics, carotenoids, nitrate, ascorbic acids and betalains that promote health. Betalains occur in two forms i.e. betacyanin (red-violet pigment) and betaxanthin (yellow-orange pigment) and are recognizable commercially as a food dye due to non-precarious, non-toxic, non-carcinogenic and non-poisonous nature. Beetroot is premeditated as a boon for the food industry and used as food colorant or additive in food products such as ice-cream, yogurts and other products. The beetroot extract is used to improve the redness in tomato pastes, soups, sauces, desserts, jams, jellies, sweets and breakfast cereals. Overall objective of this review is to provide a brief knowledge about the valuable phytochemicals and bioactive compounds present in beetroot and their association with health benefits, beetroot processing for food application and their effect on beetroot pigment.

1. Introduction

Beetroot (*Beta vulgaris* L.) belongs to family Chenopodiaceae and was originated in Asia and Europe. Chenopodiaceae family includes approximately 1400 species divided into 105 genera (Chawla, Parle, Sharma & Yadav, 2016) and the members of dicotyledonous family. Beetroot is a flowering, true biennial or, rarely perennial plant and has several varieties with bulk colors ranging from yellow to red (Gokhale & Lele, 2014). Species of genus *Beta* are *B. vulgaris* ssp. *maritima, B. vulgaris* ssp. *vulgaris, B. vulgaris* ssp. *adanensis* (Ford-Lloyd & Williams, 1975), *B. macrocarpa, B. macrocarpa* Guss., *B. patula, B. patula* Ait., *B. intermedia, B. intermedia* Bunge, *B. macrorhiza, B. macrorhiza* Stev., *B. trygina, B. corolliflora, B. corolliflora* Zoss., *B. patellaris, B. patellaris* Moq., *B. procumbens, B. procumbens* Chr. Sm., *B. webbiana, B. webbiana* Moq., *B. tranzschel*, *B. lomatogona* F., *B. trigyna* W. and *B. nana* Boiss (Tranzschel, 1927; Ulbrich, 1934; Lange, Brandenburg & De Bock, 1999). Three subspecies of species *B. vulgaris* that are present commercially are *B. vulgaris, B. maritima* and *B. adanensis. B. vulgaris* ssp. *vulgaris* is most vital and known as the common beet/sugar beet/garden beet commercially (Arnaud, Fenart, Cordellier & Cuguen, 2010). The edible portion of beetroot (*B. vulgaris* L.) is the root, having an average height of 1–2 m; the main root is long, tapered, and stout; and side roots form a dense texture. The roots are generally globe or cylindrical shaped with red-purple/golden yellow/red-white in color depending on the variety of the beets. Leaves of beetroot arise from the crown of hypocotyl and are varied in size, shape and color. Seeds are known as multi-germ seeds as one seed can give rise to more than one seedling. Corky exterior of seed contains phenolic compounds and inhibit germination as physical barrier. Stems are decumbent, erect and multi branched. The flower is very small with five petals (Kezi & Sumathy, 2014). Beets are available throughout the year. It is a cool season vegetable and a fairly tolerant to high temperature, optimum temperature ranges from 15 to 19 °C. The lower temperature promotes the development of deep red pigmentation in the beetroot (Yashwant, 2015). Harvest time of beetroot is 75–90 days in summer and 100–120 days in winter. The sugar content of beetroot depends on the nitrogen availability and nitrogen is applied in the early stages of growth. Harvesting technique is similar to that of potatoes and the yield of harvesting depends on the fertilization, climate, disease infestation and variety of the plant (Yashwant, 2015).

Beets are vegetable that have world-wide distribution. World production of beetroot was found to be 269,714 million tonnes in 2014. France, produced 37,844,567 tonnes and the Russia produced 33,513,369 tonnes of beetroot in 2014, with other major producers are Germany (29,748,100 tonnes), United States of America (28,381,270 tonnes), Turkey (16,743,045 tonnes), Ukraine (15,734,050 tonnes), Poland (15,488,875 tonnes), Egypt (11,045,639 tonnes), United Kingdom (9,430,000 tonnes) and China

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(8,000,400 tonnes) respectively (Food & Agriculture Organization of United Nations, 2014).

Beetroot is a root vegetable with carotenoids, nitrates, flavonoids, vitamins, minerals such as potassium, sodium, phosphorous, calcium, magnesium, copper, iron, zinc, manganese and water soluble pigments betalains like betacyanins (red-violet color) and betaxanthins (yellow-orange color), all of which have numerous nutritional and health benefits (Panghal, Virkar, et al., 2017). Several researchers have reported that beetroot is an important source of health promoting phytochemicals (Clifford, Howatson, West, & Stevenson, 2015). The polyphenols, carotenoids and vitamins of beetroot have antioxidant, anti-inflammatory, anticarcinogenic and hepato-protective activities (Slavov et al., 2013) and also have anti-diabetic, cardiovascular disease lowering, hypertensive and wound healing benefits. Therefore, utilization of beetroot as an ingredient in different food products imparts beneficial effects on human health and provides opportunity for development of different functional foods.

1.1. Historical background

Plant foods are vital to human survival. During the third century, beetroot was used for food and beverages although they had been grown for thousands of years for medicinal purposes. According to the written records in Europe, beetroot were cultivated prior to the tenth century (Yashwant, 2015). It originated in 8th century from Mesopotamia and was indigenous to Asia Minor and Europe. Several varieties of beetroot such as yellow beets were originated in 1700 s and sugar beets were developed by Prussians in the 1800 s (Chawla et al., 2016). Now, red beets are more popular and these are native to the Mediterranean region. These are widely cultivated in Europe, America and throughout Asia (Chawla et al., 2016; Zohary et al., 2012).

1.2. Varieties of beetroot

There are four main varieties of beetroot including, Detroit Dark Red, Crimson Globe, Crosby Egyptian and Early Wonder. Detroit Dark Red beetroot has smooth roots, uniform, with dark red flesh. Crimson Globe beetroots have little shoulders; flesh is medium dark red with diverse zones. Crosby Egyptian beetroot is a flat globe and internal color is dark purplish red with indistinct zones. Their maturity reaches in 55–60 days after sowing. Early Wonder root is flattened and the interior flesh is dark red with some lighter red zones. The topmost is heavy green leaves with red veins globe having rounded shoulders with a smooth texture (Chawla et al., 2016).

2. Nutritional composition of beetroot

Vegetables contain significant amount of essential nutrients like vitamins, minerals, fibers; phytochemicals and health promoting benefits (Panghal, Kumar, et al., 2017). Beetroot is one of the important roots vegetable and rich in carbohydrates, fat, protein, micronutrients and several functional constituents having substantial health-promoting properties. Beetroot processing and products consumption is increasing steadily due to its recognition as an important source of natural antioxidants.

2.1. Macronutrients

Studies have shown that the nutritional composition of fresh beetroot varies due to different varieties, genetics, ecological conditions and harvesting conditions. Early studies reported that beetroot contains carbohydrates (9.96 g/100 g) such as starch, fructose, sucrose, glucose, dietary fiber; protein (1.68 g/100 g), fat (0.18 g/100 g) and leaves also contain carbohydrates (5 g/100 g), starch (4.5 g/100 g) and protein (14.8 mg/100 g) (Agarwal & Varma, 2014; Richardson, 2014). Beetroot contain the considerable amount of both essential and non-essential amino acids. These are tryptophan (0.019 g), isoleucine (0.048 g), leucine (0.068 g), lysine (0.058 g), threonine (0.047 g), methionine (0.018 g), phenylalanine (0.046 g), tyrosine (0.038 g), valine (0.056 g), cystine (0.019 g), arginine (0.042 g), histidine (0.021 g), alanine (0.060 g), glutamic acid (0.428 g), glycine (0.031 g), proline (0.042 g), aspartic acid (0.116 g) and serine (0.059 g) per 100 g of edible portion (Nemzer et al., 2011). Beetroot contains total saturated fatty acids (0.027 g), total monounsaturated fatty acids (0.032 g), total polyunsaturated fatty acids (0.060 g) and phytosterols (25 mg) per 100 g of edible portion (U.S. Department of Agriculture, 2014).

2.2. Micronutrients

Micronutrients are comprised of vitamins and minerals. Early studies reported that beetroot contains various type of vitamins such as vitamin A (2 μg), thiamine (0.31 mg), riboflavin (0.27 mg), niacin (0.331 mg), pantothenic acid (0.145 mg), vitamin B6 (0.067 mg), ascorbic acid (3.6 mg), folate (80 μg) and minerals such as sodium (77 mg), calcium (16 mg), iron (0.79 mg), phosphorus (38 mg), potassium (305 mg), magnesium (23 mg) and zinc (0.35 mg) per 100 g of edible portion (Yashwant, 2015). Furthermore, beet leaves are more nutritious than beetroots. Beetroot leaves contains vitamins such as vitamin A (3.93 mg), vitamin K (280 mg) and minerals includes calcium (2220 mg), iron (16.90 mg), magnesium (350 mg), potassium (1400 mg) and phosphorus (330 mg) per 100 g. These are used to reduce blood pressure, important for cardiovascular health and act as a tool to fight against cancer. A recent study also observed the effectiveness of protein extraction (Agarwal & Varma, 2014); biochemical screening of beetroot leaf (Maraie, Abdul-Jalil, Alhamdany & Janabi, 2014) and the antimicrobial and antioxidant activities of the beet plant extracts (Richardson, 2014).

3. Bioactive compounds in beetroot

Beetroot contains highly active pigments, betalains (Guldiken et al., 2016), ascorbic acid (Clifford et al., 2015), carotenoids (Ninfali & Angelino, 2013), polyphenols, flavonoids, saponins and high levels of nitrate (644–1800 mg/kg) (Lidder & Webb, 2013). Some bioactive compounds have been found at low levels such as glycine, betaine and folate. The bioactive compounds identified by researchers (Wootton-Beard & Ryan, 2011; Clifford et al., 2015), are presented in Fig. 1 and their structures are presented in Fig. 2.

3.1. Phenolic compounds

Phenolic compounds are a large class of plant subordinate metabolites and significant for quality of plant based foods. Beetroot has high amount of phenolic compounds and flavonoids. The total content of phenolic acids in beetroot has been reported to be 50–60 μmol/g dry weight (Kathiravan, Nadanasabapathi & Kumar, 2014). In addition, beetroot peel have the second highest dry weight concentration of total phenols. The highly unstable phenolic compounds isolated from the peel of the red beetroot were 5,50,6,60-tetrahydroxy-3,30-biindolyl; a dimer of 5,6-dihydroxyindolecarboxylic acid and betalains comprised of vulgaxanthin I, vulgaxanthin II, indicaxanthin, prebetanin, isobetanin, betanin and neobetanin. In addition, two phenolic amides *N-trans*-feruloyltyramine and *N-trans*-feruloylhomovanillylamine were isolated from the seed wall of beetroot (Nemzer et al., 2011). *Beta vulgaris* var. *cicla* was reported to enclose a significant quantity of hydroxybenzoic and hydroxycinnamic acid derivatives, the two major classes of phenolics acids. These phenolic acids are epicatechin, catechin hydrate, rutin, vanillic, *p*-coumaric, protocatechuic, caffeic acid, syringic acids, proline and the monoterpenedehydro-vomifoliol (Maraie et al., 2014). Phenolic compounds were recognized in betalain extracts from intact *B. vulgaris* cv. Detroit Dark Red plants extract contains 4-hydroxybenzoic acid (0.012 mg/g), chlorogenic acid (0.018 mg/g),

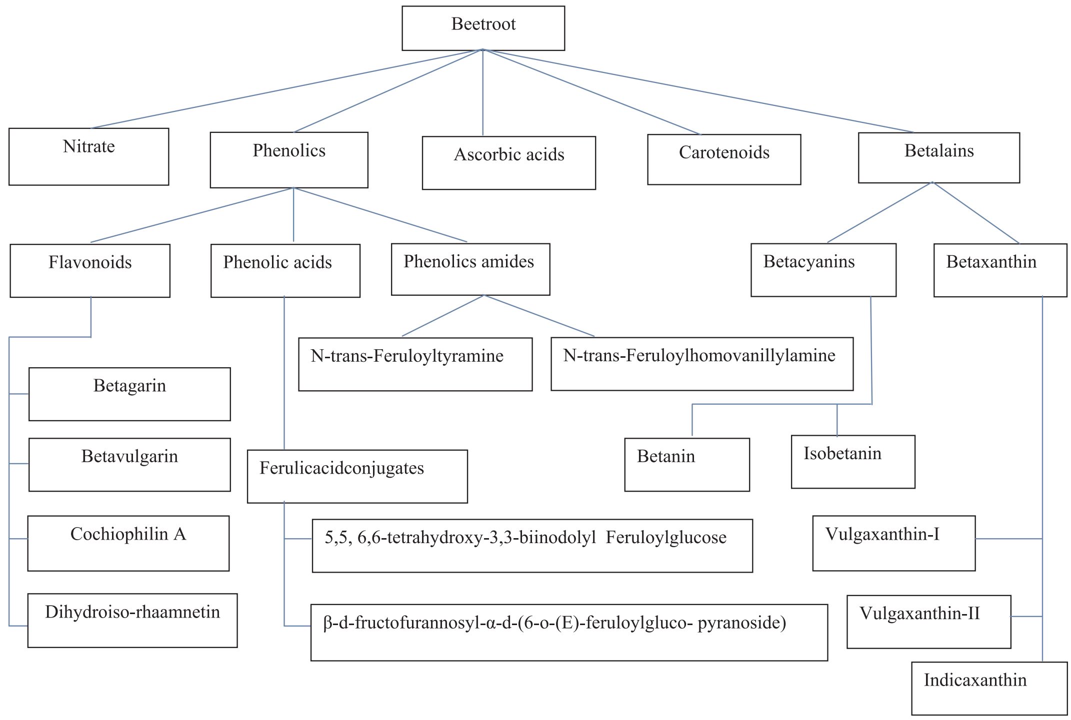

Fig. 1. Bioactive compound in beetroot (Ninfali and Angelino, 2013; Clifford et al., 2015).

caffeic acid (0.037 mg/g), catechin hydrate (0.047 mg/g), epicatechin (0.032 mg/g) and rutin (0 mg/g), whereas extract of hairy root cultures possess 4-hydroxybenzoic acid (0.396 mg/g), chlorogenic acid (0.0 mg/g), caffeic acid (0.203 mg/g), catechin hydrate (0.372 mg/g), epicatechin (0.857 mg/g) and rutin (1.096 mg/g) (Georgiev et al., 2010). The phenolic contents were quantified in Detroit beetroot pomace extract using the HPLC results showed that ferulic acid (132.52 mg), vanillic acid (5.12 mg), *p*-hydroxybenzoic acid (1.13 mg), caffeic acid (7.11 mg), Protocatechuic acid (5.42 mg), catechin (37.96 mg), epicatechin (0.39 mg) and rutin (0.25 mg) per 100 g of dry weight of beetroot pomace. Health benefits of these phenolic compounds are briefed in Table 1. Vasconcellos and co-workers (Vasconcellos et al., 2016) compared the total phenolic content in beetroot juice, chips, powder and cooked beetroot. Root parts generally contain the least content of phenolic compounds. Beetroot juice (3.67 GAE mg/g) and cooked beetroot (2.79 GAE mg/g) were reported to possess higher total phenolic content values than beetroot chips (0.75 GAE mg/g) and powder (0.51 GAE mg/g) due to loss of compounds during drying process.

3.1.1. Flavanoids

Flavonoids are the biologically active compounds with good antioxidant potential and numerous health benefits (Chhikara et al., 2018). Vulic et al. (2014) reported that the main classes of flavonoids in beetroot were betagarin, betavulgarin, cochliophilin A, and dihydroisorhamnetin. Two flavanones were isolated from beetroot leaves, the betagarin (5,2-dimethoxy-6,7-methylenedioxyflavanone) and betavulgarin (2′-hydroxy-5-methoxy-6,7-methylenedioxyisoflavone). Other flavonoid compounds separated from beetroots were 3,5-dihydroxy-6,7-methylenedioxyflavanone, 5-hydroxy-6,7-methylenedioxyflavone, 2,5-dihydroxy-6, and 7-methylenedioxyisoflavone (Lim, 2016). The ethyl acetate fraction of B. vulgaris ssp. perennis reported were quercetin, rutin and 4′-hydroxy-5-methoxy-6,7-methylenedioxy flavanone (Maraie et al., 2014).

3.1.2. Saponins

Saponins are bioactive compounds produced by plants to counteract pathogens and herbivores. Early studies identified eleven triterpene saponins in the *B. vulgaris.* All the saponins were including oleanolic acid derivatives. Betavulgarosides I, II, III, IV, V, VI, VII, VIII saponins were identified from root whereas betavulgarosides I, II, III, IV, V, IX, and X saponins were identified in the leaves (Mroczek, Kapusta, Janda & Janiszowska, 2012; Lim, 2016). Mikolajczyk-Bator et al. (2016) also reported that 26 triterpene saponins were characterized in beetroots in which 17 triterpene saponins had not been previously reported in beetroots and 7 triterpene saponins were identified as new compounds.

3.2. Phytochemicals

Phytochemicals in peel extract were found to be 5,5,6,6-tetrahydroxy-3,3-biindolylandin, in the aerial parts of *B. vulgaris* cicla were norisoprenoids (+)-dehydrovomifoliol and 3-hydroxy-5α,6α-epoxy-β–ionone (Lim, 2016). Poly 3-hydroxyalkanoate component was isolated from beetroot which was composed of 3-hydroxybutyrate with a molecular weight ($Mn = 9{,}124$ Da) and polydispersity index (PDI) equals 1.01 (Lim, 2016). Beetroot leaves contain beetins which are virus-inducible type 1 ribosome-inactivating proteins (Iglesias, Citores, Di Maro & Ferreras, 2015) and are composed of a single polypeptide chain with a varying degree of glycosylation. These compounds are of great significance in health of human being due to physiological action on human body (Table 1).

3.3. Betalains

Betalains are water-soluble nitrogenous plant pigments. Two betalains i.e. betacyanin (red pigment) and betaxanthin (yellow pigment) compounds has been on the basis of their chemical structures and compositions. Beetroot is one of the richest sources of betanin pigment, used for imparting a desirable red or yellow color. The varieties and redness of beetroot depend on the ratio of betacyanin and betaxanthins (Szopinska & Gawęda, 2013). Betaxanthin is further categorized into two types i.e. vulgaxanthin-I and vulgaxanthin-II (Ravichandran et al., 2013). Several betacyanins were found in the peel of beetroots such as betanin, prebetanin, isobetanin, and neobetanin (Nemzer et al., 2011). About 75–95% betanin of the total betacyanin are considered as active

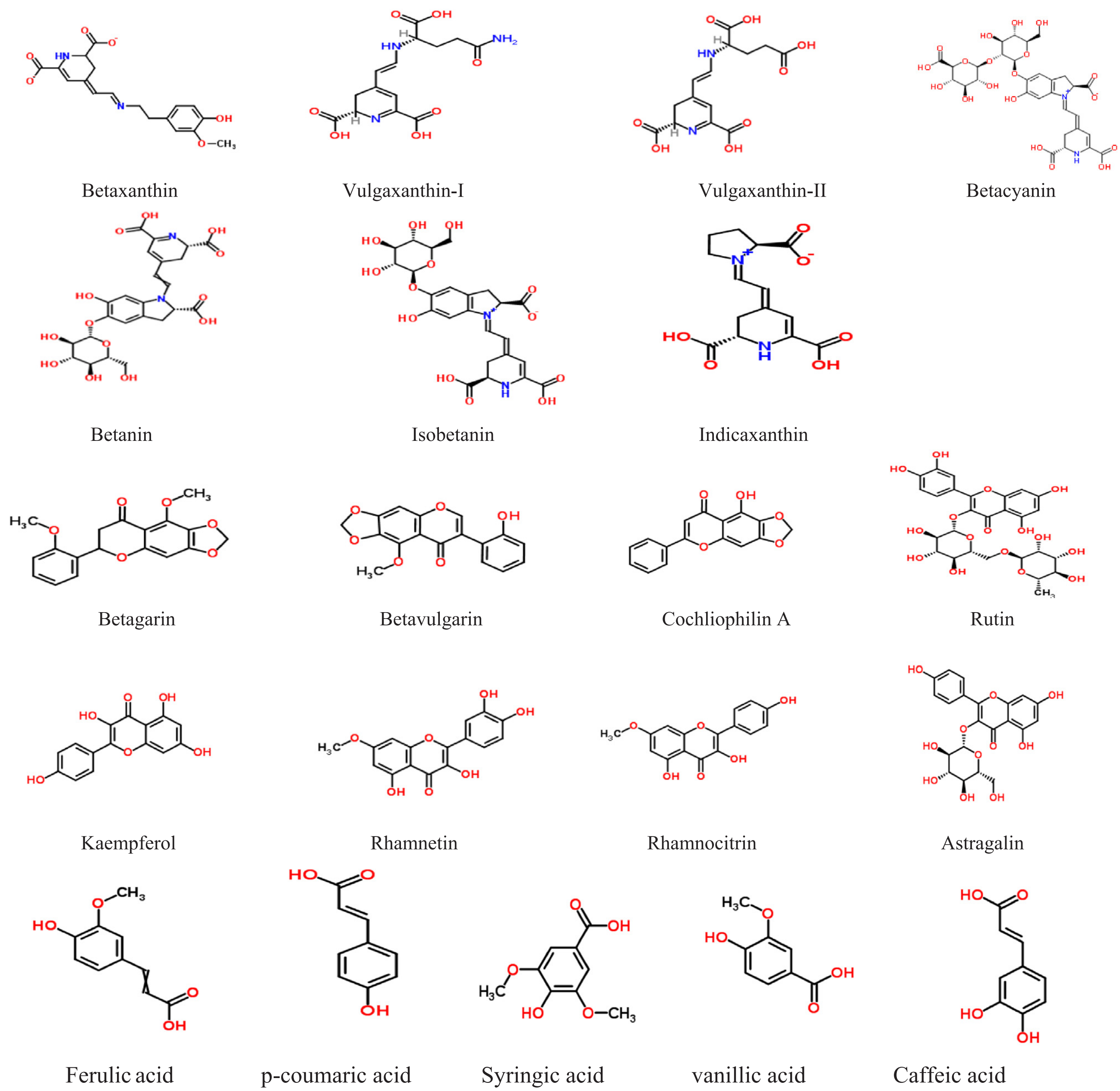

Fig. 2. Structures of Phytochemicals Presents in Beetroot.

compounds of beetroot. Betalain synthesis process initiates from tyrosine. The massive accumulation of tyrosine (hydroxylated by tyrosine hydroxylase) produces dihydroxyphenylalanine (DOPA) which is converted to the cycloDOPA by the diphenol/DOPA oxidase activity of tyrosinase catalyzes. The betalamic acid is formed by the cleavage of the aromatic ring of DOPA (Hatlestad et al., 2012). Betacyanin is formed by condensation of cycloDOPA with betalamic acid and betaxanthin is obtained by condensation of an amino acid with betalamic acid. Betacyanins are non-glycosylated betanidin or isobetanidin chromophores. The whole biosynthesis process involves two key enzymes tyrosinase and DOPA. Early study analyzed the betalain content in betalain extracts from hairy root cultures and intact *B. vulgaris cv.* Detroit Dark Red plants. The intact beetroot plant extracts produced 39.76 ± 0.98 mg/g of dry extract (DE) of betalains (20.75 mg/g of DE betacyanins and 19.01 mg/g of DE betaxanthins), whereas hairy root extract contained 47.11 mg of betalains/g DE (16.33 mg/g DE betacyanins and 30.78 mg/g DE betaxanthin). The extracts from hair roots had higher betalain content as compared to intact *B. vulgaris cv.* Detroit Dark Red plants (Georgiev et al., 2010). The data for individual betalain content in pressed juice from beetroot were found to be vulgaxanthin-I (104.1 mg/100 g), vulgaxanthin-II (57.4 mg/100 g), betanin (312.5 mg/100 g), isobetanin (71.3 mg/100 g), betanidin (18.2 mg/100 g) and isobetanidin (4.6 mg/100 g). The total betalain content was found to be 606.34 mg/100 g dry matter (Slavov et al., 2013).

3.4. Carotenoids

Carotenoids are a group of phytochemicals that are liable for different colors of the fruits and vegetables, playing a vital role in the prevention of mortal diseases. Carotenoids present in beetroot act as antioxidant, anticarcinogens and immuno-enhancers (Table 1). Carotenoids widely spread in beetroot are potent antioxidants. They have been reported to have mutagenesis inhibition activity responsible for decreased risks of cancer (Sardana et al., 2018). Beetroot leaves contain β-carotene and oxygenated derivatives known as xanthophyll such as lutein. Rebecca et al. (2014) reported 1.9 mg/100 g of carotene in

Table 1
Uses and health benefits of bioactive compounds present in different varieties of beetroot.

Compounds	Plant parts	Uses and health benefits	Source
Phenolic compounds: *N-cis*-Feruloyl 3-o-methyldopamine, *N-cis*-Feruloyltyramine, *N-trans*-Feruloyl 3-o-methyldopamine, *N-trans*-Feruloyltyramine, 5,50,6,60-tetrahydroxy-3,30-biindolyl, Coumarins (scopoletin, esculetin, umbelliferone, peonidin, cyanidins)	Seed, Peel	Contribution to stress resistance, Antimicrobial properties, Antiviral activity, Anti-inflammatory activity, Antitumor activity, Anticancer activity	Nemzer et al. (2011)Maraie et al. (2014)
Ascorbic acid	Root, Leaf	Enhance the human immune defense system by enhancing the random migration of human polymorpho-nuclear leucocytes to the site of infection.	Clifford et al. (2015)
Flavonoids: Betagarin, betavulgarin, cochliophilin A, quercetin, dihydroisorhamnetin, rutin, tiliroside, astragalin, rhamnocitrin, rhamnetin, kaempferol	Root, Leaf, Peel	Antioxidants activities, Antibacterial activity, Antiviral activity, Anti-inflammatory activity, Hepato-protective activity, Anticancer activity	Slavov et al. (2013), Vulic et al. (2014)
Carotenoids	Root, Leaf	Their role in the prevention of chronic diseases such as CVD, Cancer, HIV and Osteoporosis, It act as anticarcinogens and immunoenhancers ● Pro-vitamin A Activity ● Antioxidant function ● Xenobiotics/Drug metabolism	Rebecca et al. (2014)
Betalains: Betacyanin (betanin, prebetanin, isobetanin and neobetanin) Betaxanthin (vulgaxanthin-I, vulgaxanthin-II and indicaxanthin)	Root	The important role in chemoprevention against lung and skin cancers. To regulate the vascular homeostasis	Nowacki et al. (2015), Hobbs et al. (2013), Ravichandran et al. (2014)
Nitrate	Root	Maintains NO mediated vasodilatation in hypoxic condition, Protect from ischemic-reperfusion injury in liver, heart, brain and kidney Reduce pulmonary hypertension Improve whole body exercise efficiency	Gilchrist et al. (2013)
Saponins: Oleanolic acid, Hedrageninaglycone, betavulgarosides I, II, III, IV, V, VI, VII, VIII, IX, and X	Root, Leaf	Biological effects on: Cell membrane permeability, Cholesterol metabolism, Protein digestion, Transverse-tubular system and sarcoplasmic reticulum membrane Biological properties includes: Virucidal activity, Hypolipideamicactivity, Hypoglycemic activity, Antifungal activity and Antimicrobial activity	Mroczek et al. (2012), Lim (2016)
Ferulic acid	Root	Biomedical effects including Antioxidant, antiallergic, hepatoprotective, anticarcinogenic, anti-inflammatory, antimicrobial, antiviral, vasodilatory effect, antithrombotic and helps to increase the viability of sperms	Kumar and Pruthi (2014)
Taurine	Leaf	Preventing the serum cholesterol, liver cholesterol, triglycerides & reduced lipid accumulation.	Schalinske and Smazal (2012)
Triterpenes/Steroid: Beta-amirin acetate, Boehmerylacetate, Friedelin	Leaf, Root	Health benefits of Triterpenes by inhibiting or slowing down growth of cancer, colon cancer, breast cancer, oral mucosa cancer, HIV, hepatoprotective, inflammatory response, antioxidant activities, antibacterial activities, analgesic and anti-nociceptive and anxiolytic	Mroczek et al. (2012)Lim (2016)
Sesquiterpenoids: 6-myoporol, 4-hydroxy dehydro-myoporone, Ipomeamarone.	Root	Several mechanisms are proposed for the reduction of inflammation, tumorigenesis and also responsible for prevention of neurodegeneration, antimigraine activity, analgesic and sedative activities and treatment of ailments such as diarrhoea, flu, and burns	Chadwick, Trewin, Gawthrop and Wagstaff (2013)
Alkaloid: CalystegineB1, Calystegine B2, Calystegine C1, Calystegine B3, Ipomine	Root, Leaf	Reversible alterations in the estrous cycle pattern and antiprosgesterogenic activity	Lim (2016)

beetroot.

4. Antioxidant activity

Beetroot is a gold mine of antioxidants like many other colored vegetables (Singh & Hathan, 2014; Guldiken et al., 2016). Fidelis et al. (2017) demonstrated that beetroot juice (5.45 pH, 9 °Brix) possess higher amount of total phenolics (1169 mg GAE/L), flavonoids (925 mg catechin equivalent/L) and pigments (854 mg/L) accounting for better antioxidant profile observed in terms of DPHH (325 mg ascorbic acid equivalent/L) as compared to citrus fruits, yellow passion fruit, apple and cranberry. Betanin with its aglyconebetanidine have been found to have great antioxidant activity (Wootton-Beard & Ryan, 2011) and found to be effective in preventing lipid peroxidation (Kathiravan et al., 2014). Vasconcellos et al. (2016) reported total antioxidant activity of beetroot chips (95.70%), beetroot powder (95.31%), cooked beetroot (85.79%) and beetroot juice (80.48%). There was no significant difference between beetroot chips and beetroot powder and their values were higher than cooked beetroot and beetroot juice.

5. Health benefits of beetroot

Beetroot contains bundle of bioactive compounds accounting for natural antianemic, anti-inflammatory, anti-hypertensive, antioxidant, anticarcinogenic, antipyretic, antibacterial, detoxicant and diuretic properties (Hobbs, George & Lovegrove, 2013; Lidder & Webb, 2013).

These properties expressed by different parts of the beetroot plant and are presented in Table 1.

Betalains possess a broad spectrum of therapeutic, anticarcinogenic, hepato-protective and antitumor properties (Wootton-Beard et al., 2011) by insulating the injured tissue and had no obvious consequences towards normal cell lines (Nowacki et al., 2015). The aspect of betalains pigments in chemoprevention of lung and skin cancers were demonstrated and reported that it can obstruct the cell proliferation of various human tumors cells. The flavonoids present in beetroot such as vitexin, vitexin-2-O-rhamnosideand vitexin-2-O-xyloside exhibited excellent antiproliferative activity on cancer cell lines (Slavov et al., 2013). They exert anticarcinogenic activities, reduce inflammatory response slightly and modulate immune response (Iglesias et al., 2015).

The nitrates present in beetroot have capability to lower down the blood pressure, protect against ischemia-reperfusion damage and modulation of mitochondrial function (Satyanand et al., 2014). It reduces the bad cholesterol, oxidized LDL cholesterol and normalizes the blood pressure (Guldiken et al., 2016). Beetroot extracts have antihypertensive and hypoglycaemic activity (Ninfali & Angelino, 2013). Function of betalains is to reduce the homocysteine concentration (Machha & Schechter, 2011) which regulates the vascular homeostasis, maintains platelet function, thrombotic activity, vascular tone and delicate stability among the release of vasodilating and vasoconstricting agents. The risk factor of endothelial dysfunction is cardiovascular disorders which implicated in hypertension and atherosclerosis (Krajka-Kuzniak, Szaefer, Ignatowicz, Adamska, & Baer-Dubowska, 2012).

Eating beetroot in diet reduces the chances of inflammation (an innate response including infection, erythema, edema, trauma, fever and pain that causes due to cell damage by the antigens) (Monteiro & Azevedo, 2010). Betalains extracts guard slim lining of one's blood vessels and diminish the inflammation while current pharmacological therapies are associated with adverse side effects (Miraj, 2016). The anti-inflammatory effect of beetroot ethanolic extract on gentamicin-induced nephrotoxicity was elucidated (El Gamal, et al., 2014). The water, after boiling beetroot is an excellent application for skin infection and outbreaks of pimples and pustules. Beetroot is healthy boost for the entire digestive system. The potential mechanism is based on significant reduction of cleaved caspase 3, Bax and increased Bcl-2 protein expression (El Gamal et al., 2014). Red beet provides phytochemicals that stimulate the hematopoietic, immune system, kidney and liver protection (Miraj, 2016).

Phytochemicals present in beetroot are beneficial in reducing age-associated oxidative stress as well as maintain the cognitive functions like perception, learning, communication and decision-making. Beetroot is a nitric oxide (NO) generator having potential to improve cerebrovascular flow (Presley et al., 2011). It has been reported that dietary nitrate (NO_3^-) supplementation affect cerebral haemodynamics (Haskell et al., 2011), enhance neurovascular coupling in response to visual stimuli and improve perfusion to brain areas which associated with executive function (Presley et al., 2011; Aamand et al., 2013). The consumption of beetroot enhanced the plasma nitrate level about 96% (Satyanand et al., 2014). Some nitrite is converted into nitric oxide when swallowed into the acidic medium of the stomach, whereas remain nitrite is absorbed to proliferate circulating plasma nitrite (Wylie et al., 2013).

The beetroot juice is good for the skin and a mixture of little vinegar to beet juice clears dandruff, relieve running sores and ulcers. It also comprises high amounts of boron which is directly related to the production of human sex hormones. The dietary supplementation with beetroot juice, positively impact the biological responses to exercise and improves the cardiovascular health (Wylie et al., 2013). These properties are due to prompt of endogenous synthesis of nitric oxide (Gilchrist et al., 2013). Beetroot juice is reported to help in purification of the blood and identified as a great blood builder being rich in iron content, regenerates and reactivates the red blood cells and delivers fresh oxygen to the body (Coles & Clifton, 2012). Beetroot contains macronutrient and micronutrient that are responsible for excellent physiological properties. Folic acid present in beetroot helps to prevent cancer and with vitamin B cooperation contributes to the proper functioning of the nervous system (Szekely et al., 2016). The regular consumption of beetroot products in the food protects against oxidative stress-related ailments and maintains good digestion (Chandran, Nisha, Singhal & Pandit, 2012). The copper content in beetroot helps to make the iron more available to the body. Beetroot used as a treatment for fevers and constipation (Yashwant, 2015).

Pharmacological research by many researchers advised that beetroot was effective and advantageous in the treatment of various ailments. Furthermore, anti-stress, anti-anxiety and anti-depressive effects of beetroot extract of leaves were investigated in mice. It exhibits anxiolytic and antidepressant activity in stressed mice along with the good antioxidant property. Uridine, extracted by sugar beetroot can be used with omega-3 to overwhelmed or prevent depression by changing mood and relaxing the body (Sulakhiya et al., 2016; Miraj, 2016). The antiviral, antimicrobial effects (Slavov et al., 2013) and antiradical activities (Ciz et al., 2010; Slavov et al., 2013) of betalains pigments have been reported. Saponins of beetroot has effective impact on different human cancers such as prostate, renal, breast, colon, lung, leukemia and melanoma (Podolak et al., 2010).

6. Beetroot processing for food application

The global functional foods and beverages market value was 129.39 billion USD in 2015 and is growing at a CAGR (compound annual growth rate) of about 8.6% (Panghal, Janghu, et al., 2018). Beetroot usage for food application have been investigated by various researchers and food industries due to prevailing effect of their color, flavor and nutritional aspect (Table 2) making it a super food and a miracle vegetable. Deep red-colored beets are used as a food source for humans, both raw as salad and cooked as stews. Beetroot is consumed throughout the world. In Eastern Europe, beetroot soup is a popular meal and pickled beets are a traditional food of the South America. Nowadays large proportion of beetroot is being used commercially in the production of pickles. Small proportions of beetroot are utilized as juice (Yashwant, 2015). In Australian sandwiches, beetroots are commonly found. Fresh leaves and stem of beetroot are steamed and eaten and older stems are stir-fried. Beetroot can be considered as a replacement of synthetic colorants (Slavov et al., 2013) and can become a marketing tool in the food industry. Consumers are also favoring for green consumerism with fewer synthetic additives (Yadav et al., 2014). Natural colorants are regarded as safe substances for consumption. Therefore natural colorants are more anticipated than synthetic colorant for commercial application as food additives. Synthetic colorants have negative effects on the human health, causes allergy and have carcinogenic response on prolonged consumption (Panghal, Yadav, Khatkar, Sharma & Chhikara, 2018). Natural colors are water-soluble facilitating their incorporation into aqueous food systems. Along with this natural food colorants are more attractive, improve visual acuity properties and have potential health effects due to potent antioxidants. The beets are prevailing in two primary forms for foods and beverage manufacturers: ground dehydrated beets and beet juices. Dehydrated beets grounded into a powder and beet juices can be spray dried into powder form (Georgiev et al., 2010; Kazimierczak et al., 2014). Fresh beetroot or beetroot powder or extracted pigments are used to advance the red color of tomato pastes, soups, sauces, desserts, jams, jellies, sweets ice-cream, and breakfast cereals (Singh & Hathan, 2014; Sruthi et al., 2014).

Beetroot juice is utilized to coloring a variety of foods like dairy products, yogurts, processed cheese, and candy. It changes color on thermal treatment so it is used only in ice-cream, sweets, and another confectionary. It may be implemented in the mayonnaise recipe, either raw or freeze-dried form, in the place of synthetic antioxidants (Szekely et al., 2016; Raikos et al., 2016). The dietary supplementation with

Table 2
Beetroot based food products and their processing.

Food products	Ingredients used and processing methods	Sources
Yoghurt	Skimmed milk was preheated at 80–85 °C for 15 min, cooled at 42–45 °C then inoculated and incubated for 12 h and refrigerated. The colored yoghurt was prepared by adding beetroot powder into the yoghurt at different concentration levels (0, 6, 8 and 10%) and stored at 4 °C	Yadav et al. (2016)
Ice-cream	Beetroot juice was included in the production of strawberry flavored ice-cream and stored. Ice cream was prepared by the raw materials, milk (5% fat), butter (80% fat) and skimmed milk powder. Milk was preheated 55–60 °C, skim milk powder, butter, stabilizer were added and hemogenized to 2500 and 500 psi then pasteurized at 80 °C for 30 s, cooled overnight, reheated and beetroot juice was mixed.	Manoharan, Ramasamy, Kumar, Dhanalashmi and Balakrishnan (2012)
Beetroot jelly	Jelly was successfully developed by adding 2% pectin, 0.5% citric acid, and 61% sugar in the clear beetroot extract while heating. Heating was continued with constant stirring uptill the TSS reached to 65° Brix and desired consistency was reached.	Chaudhari and Nikam (2015)
Beetroot Candy	Beetroot candy was prepared with 65% sugar, 3% pectin and 0.5% citric acid. Beetroot paste was first heated to boil with sugar and pectin was added to the boiling paste and was continuously stirred. The paste was then heat desiccated for 55 min with continuous stirring and at the end point of desired consistency citric acid was added. Finally it was allowed to cool to ambient temperature and the thick paste was rolled into candies of desired shape	Fatma, Sharma, Singh, Jha, and Kumar (2016)
Snacks	Beetroot fortified multigrain snacks were prepared by mixing refined wheat flour, wheat flour and defatted soya flour and spices and salt, hot oil and beetroot paste were added to make dough and then frying at 170 °C after giving a desire shape.	Dhadage, Shinde and Gadhave (2014)
Beetroot cream cheese spread	Cream cheese prepared by adding the 1 Tbsp of lemon juice in 1 Cup of boiled milk and stirred until the whey water & cheese separates and beetroot puree was made by adding roasted beetroot, onion and garlic.	Sandhya and Priya (2017)
Biscuits fortified with Red beetroot	Biscuit dough was prepared by mixing of powdered sugar, eggs, and margarine, water containing vanillin, baking powder, salt and the biscuits are fortified with red beetroot	Youssef and Mousa (2012), Amnah (2013)

beetroot juice enhances the tolerance to high-intensity exercises and physical activities (Satyanand et al., 2014). Beetroot colors has no allergic or other side-effects and also cheap. In various studies beetroot was utilized for manufacturing different food products are discussed in Table 2.

Sugar beets are used for manufacturing of sugar and their byproduct such as pulp, molasses, fiber etc, are used as feed. When sugar beetroot is grown in areas of livestock production, greens of the plant may also be used for fodder. The highly complicated process of sugar production is started with fluming, flushing and ended with the refinery and the end products of this process are sugar, molasses, and bagasse. Molasses are used for alcohol production and in other forms of fermentation (Tsialtas & Maslaris, 2010; Wenninger, 2011). Fiber is normally the remainder, i.e., (bagasse-moisture-sucrose and other soluble solids-ash).

7. Effects of processing on bioactive compounds

The processing methods have a significant impact on antioxidant activity and bioaccessibility of phytochemicals. Beetroot processing such as vacuum-microwave drying, fermentation and irradiation enhance the antioxidant capacity and pigment stabilization while hot air drying decreases the color retention (Latorre, Narvaiz, Rojas & Gerschenson, 2010; Gokhale and Lele, 2011). The factors influencing the stability of antioxidants or betalains pigment during processing and storage are pH, temperature, water activity oxygen, metals and ion radiation (Fig. 3). The first order reaction of betanine degradation has been confirmed (Wootton-Beard et al., 2011; Guldiken et al., 2016).

7.1. pH

The optimum stability of betalains was demonstrated at pH range from 3 to 7 suggesting its use in different food formulations especially in acidic foods. Betalains are stable in extracts at 5 pH, however, below pH 3, the color of betanin moves towards violet and above pH 7, color shift towards blue due to longer wavelength (Wootton-Beard et al., 2011). Betanin is degraded at alkaline condition by hydrolysis of aldimine bond producing ferulic acid with an amine group. Betanin degradation rate was found to be three-fold higher at pH 3 than pH 5 under fluorescent light. It was found that betalain was more stable between pH 5.5 and 5.8 in the presence of oxygen. Under anaerobic conditions, betalain was stable at 4–5 pH (Manchali, Murthy, Nagaraju & Neelwarne, 2013, Ravichandran et al., 2014; Paciulli, Medina-Meza, Chiavaro & Barbosa-Cánovas, 2016).

7.2. Water activity

Water activity controls the rate of bio-chemical conversion. Water activity affects the betalain stability by controlling the water-dependent hydrolytic reactions for aldimine bond cleavage. Decrease in water activity (below 0.63) during different processing treatments like spray drying and concentration enhance the betalains stability (Kearsley & Katsaboxakis, 1980). Raise in water activity from 0.32 to 0.75 enhances the rate of betalain degradation. However in encapsulated beetroot pigment, highest degradation of betanin occured at a_w 0.64 (Serris & Biliaderis, 2001).

7.3. Temperature

Thermal processing is usually used in development of different processed products. Temperature affects betalains stability and increase in temperature results in betalains degradation as well as degradation of PPO (polyphenol oxidase) enzymes. However, thermal degradation is also affected by temperature range, heating extent, oxygen presence, and concentration of pigments (Herbach et al., 2006).

7.4. Light

Color are oxidized and degraded in presence of light. There is a reverse relationship between light intensity in the range 2200–4400 lux and betalain stability. Immersion of light in the UV and visible range excites electrons of the betalain chromophore to a more energetic state, initiating higher reactivity or lowered activation energy of the molecule. However, light effect is negligible under anaerobic conditions (Manchali et al., 2013; Ravichandran et al., 2014; Paciulli et al., 2016).

7.5. Metal

Some metal cations were identified to facilitate or accelerate betanin degradation, such as iron, copper, tin, and aluminum etc. Early study indicates that beetroot juice is less vulnerable to the metal ions

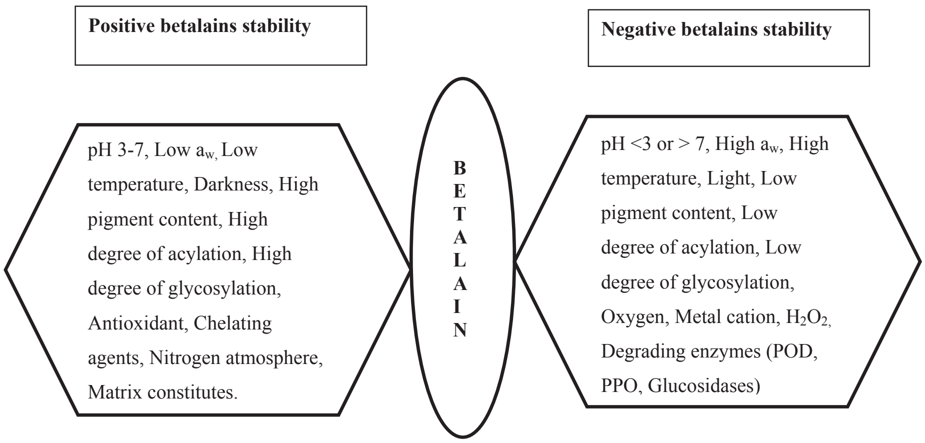

Fig. 3. Factors governing betalains stability (Wootton-Beard et al., 2011, Manchali et al., 2013; Slavov et al., 2013).

because of the existence of metal complexing agents. Chelating agents (citric acid and EDTA) were reported to stabilize betanin against metal catalysed degradation (Manchali et al., 2013; Ravichandran et al., 2014; Paciulli et al., 2016).

8. Conclusion

Beetroot is grown and consumed in both raw and cooked form all over the world owing to their high nutritive and medicinal value. Beetroot provides valuable essential nutrients and adequate amount of beneficial bioactive compounds accounting for health promotion, disease prevention and treatment response. Antioxidant activity of bioactive compounds and successful utilization of beetroot in disease prevention and health promotion is increased in last few decades. There is a need for further research to explore and utilize natural colorants, antioxidants and dietary fiber present in beetroot for functional food formulation. High amount of bioactive compounds in beetroot pulp can be utilized as functional food source against many diseases like diabetes, cancer, cardiovascular disease and various other oxidative stresses induced chronic diseases. *Beta vulgaris* can be used to make different and innovative value added products, so that consumer may receive the health benefits through the food products which are incorporated with *Beta vulgaris.*

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Conflict of interest

All authors declare that they have no conflicts of interest.

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