



REVIEW ARTICLE

Red Beetroot: Composition and Health Effects - A Review

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Abstract

Red beetroot belongs to the Beta L. genus, the *Betoideae* subfamily of the goosefoot family (*Amaranthaceae*). Beetroot (*Beta vulgaris* L.) is a vegetable consumed worldwide due to its high content of biologically active substances, such as betalain, inorganic nitrates, polyphenols, folates, as well as its minerals and vitamins present in the tuberous root. The beet, like its cousin the turnip, is known for its edible leaves and roots. They are consumed in many ways, such as whole, cooked, canned or minimally processed products, depending on the region. Beetroot is used as a vegetable, and its juice and extracts also serve as traditional medicine, food colorant and additive to cosmetics. This plant has high antioxidant and antiinflammatory properties, and could be an important aid in the treatment of many diseases.

Keywords

Red beetroot, Bioactive compounds, Betalains, Antioxidants, Polyphenols, Health benefits

Introduction

At present, there is an ever increasing global tendency towards a healthy diet including so-called "functional foods", and the consumers are looking for a safer way to improve their general health and living standard.

The health benefits of a diet high in fruits and vegetables are probably inexhaustible. These include cardiovascular health, protection against free radicals, prostate, lung, mouth, and throat cancer, constipation, and may help in preventing diverticulosis (the development of tiny, easily irritated pouches inside the colon), diabetes and obesity [1]. Many studies confirm that the consumption of fruits and vegetables helps protect against several chronic diseases associated with aging, such as

cancer, cardiovascular and hepatic diseases, brain, and immune dysfunction, fulfilling the role of functional foods. These natural protective effects have been attributed to various components, such as fibres, minerals, vitamins, carotenoids, betalains, anthocyanins, polyphenols, and other phytochemicals [2]. In recent years there has been a growing interest in the biological activity of red beetroot (*Beta vulgaris* L.) and its potential utility as a health promoting and disease preventing plant, being recognized as a functional food [3,4].

Red beetroot (beet, garden beet, table beet) is a traditional and popular vegetable in many parts of the world. This is the red root vegetable that is most typically associated with the word "beet". It is especially popular in Eastern and Central Europe where it is the main ingredient of borscht, vinaigrette salad, Russian "herring under fur" salad, pickled cabbage with beetroot [5,6]. Today, beetroot is regularly consumed as part of the normal diet, either fresh or after thermal processing or fermentation, and commonly used in manufacturing as a food colouring agent known as E162 [3,7].

Although red beet is consumed in various ways, and in considerable quantities, not all consumers know its true benefits, and the advantages of its consumption.

Beetroot (*Beta vulgaris* L.) contains high amounts of biologically active substances including betalains, carotenoids, phenols, B-vitamins (B₁, B₂, B₃, B₆ and B₁₂), folate minerals, fibres, as well as sugars with low energetic value [8], and inorganic nitrate [3]. All parts of this plant have different medicinal uses, such as anti-oxidant, anti-depressant, anti-microbial, anti-fungal, anti-inflammatory, diuretic, expectorant and carminative

[6], hepatoprotective [9], or protector of cardiovascular health. Other benefits reported by [8,10] include the inhibition of lipid peroxidation and chemo-preventative effects [11,12].

The aim of this review article is to briefly present the importance and therapeutic properties of red beetroot for human consumption.

Origin and Description

Red beetroot belongs to the *Beta vulgaris ssp. Vulgaris L. subspecies, Beta vulgaris L. species, Beta L. genus, Betoideae* subfamily of the goosefoot family (*Amaranthaceae*), and the *Caryophyllales* order.

The plants of the *Beta* genus are presumed to have originated in North Africa and spread through the Mediterranean Sea route, occupying the seashores of Europe, Asia and the Americas [5].

Red beetroot (*Beta vulgaris ssp. vulgaris L.*) is a herbaceous biennial (flowering in the second year of growth) or, rarely, perennial plant up to 120 cm (up to 200 cm in second year) in height, but cultivated forms are mostly biennial. The roots of the cultivated forms are dark red, white, or yellow, and moderately to strongly swollen and fleshy or brown, fibrous, sometimes swollen and woody in the wild subspecies [5,8,13].

Red Beetroot Nutrients

Red beets is a vegetable with a low fat content, but rich in carbohydrates, starch, soluble fibers, proteins, being a product with moderate caloric value. Beet roots are rich in vitamins C, A, E, K. They have an important content of B-vitamins (B₁ - thiamine, B₂ - riboflavin, B₃ - niacin, B₅ - pantothenic acid, B₆ - pyridoxine, B₉ - folates and B₁₂ - cyanocobalamin), as well as folic acid and powerful antioxidants, such as triterpenes, sesquiterpenoids, carotenoids, coumarins, flavonoids (tiliroside, astragalalin, rhamnocitrin, rhamnetin, kaempferol), betalains and phenolic compounds. Other bioactive compounds that are found in beets are: saponins, alkaloids (calystegine B₁, calystegine B₂, calystegine C₁, calystegine B₃, ipomine), amino acids (threonine, valine, cystine, methionine, isoleucine, leucine, lysine, phenylalanine, histidine, arginine, glutamic acid, proline, alanine, tyrosine - in leaves), tannins. Beet roots are a good source of minerals, like manganese (good for bone health), magnesium, potassium, sodium, phosphorus, iron, zinc, copper, boron, silica and selenium [5,11,12,14,15].

The chemical composition differs depending on the red beetroot variety. The range of the chemical composition and distribution of the nutritional compounds of red beetroot depends on the anatomical part of the plant (leaf, stem, root, peel) [16]. Beetroot leaves are richer in carotenoids compared to tubers. This is explained by the fact that carotenoids are accumulated in chloroplasts of green part of plants as a mixture of α - and β -carotene, β -cryptoxanthin, lutein, zeaxanthin,

violaxanthin, and neoxanthin [17].

Green leaves and stems are a perfect solution in obesity problems and weight management, as they are typically low in calories. The high level of vitamin A, K and C is important for the production of a protein essential for bone health. Green leafy vegetables are a major source of iron and calcium for any diet. Leafy vegetables are used in preventing chronic diseases, such as cancer, cardiovascular disease and diabetes, as they have anti-inflammatory and anticarcinogenic activity. Beetroot leaves are used to reduce blood pressure [18,19].

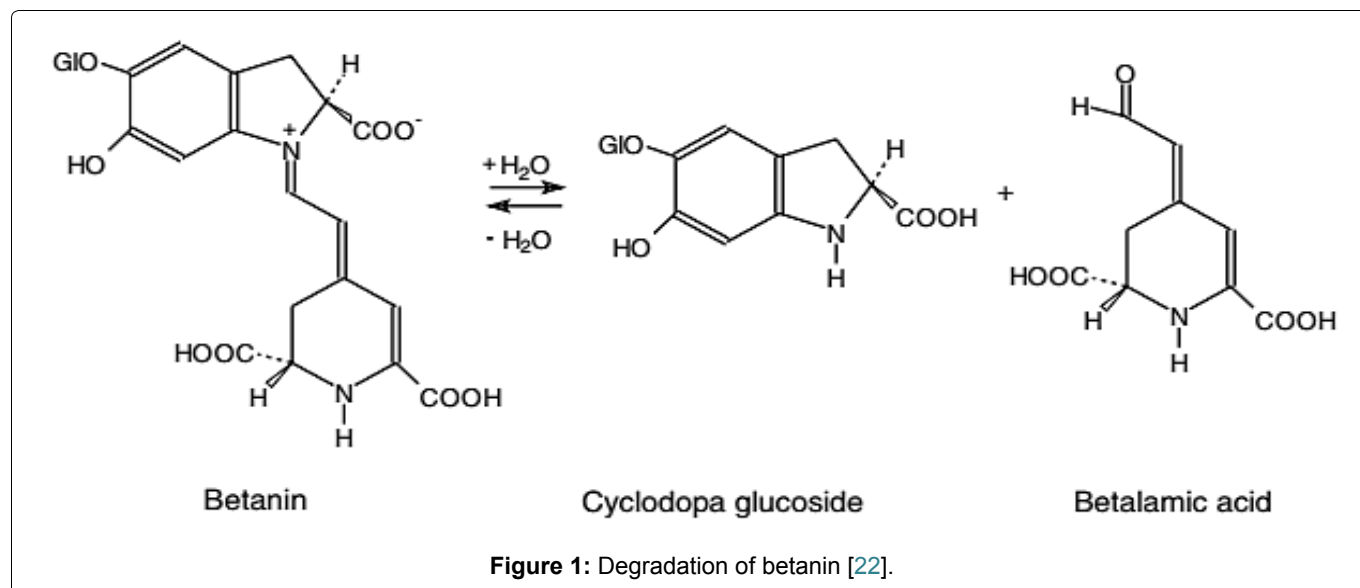
Red beet is a significant source of polyphenols, which together with the betalains, show a high antioxidant effect and radical scavenging capacity.

The composition of the various nutrients of red beet is shown in Table 1.

Carotenoids are an important class of compounds, also called tetraterpenoids, which are organic pigments. The carotenoids from red beetroot are not representative being in small quantities [20]. The carotenoids

Table 1: Composition of raw red beetroot flesh per 100 g [5,8,11,52,67].

Compounds	Value	
	Tubers	Leaves
Water (g)	91.3 ± 4.29	91.00 ± 4.00
Protein (g)	1.89 ± 0.3	2.20 ± 0.5
Carbohydrate, by difference (g)	7.23 ± 2.33	4.33 ± 1.5
Fiber, total dietary g	3.25 ± 0.55	3.7
Sugars, total (g)	6.76 ± 1.23	0.50
Total lipid (fat) (g)	0.15 ± 0.05	0.13
Ash (g)	1.08 ± 0.72	2.33
α -Carotene (μ g)	22.0 ± 2.0	3.5 ± 0.5
β -Carotene (μ g)	0	11.64
Lycopene (μ g)	30 ± 0.3	0
Lutein + zeaxanthin (μ g)	0	1.503
Betaine (μ g)	128.7 ± 22.0	0
Folate (μ g)	109	15
Niacin (mg)	0.334	0.400
Vitamin A, IU	0	6.326
Vitamin B ₆	0.067	0.106
Vitamin C (mg)	7.2 ± 2.5	30
Sodium, Na (mg)	78.0 ± 5.0	226
Potassium, K (mg)	325 ± 4.5	762
Phosphorus, P (mg)	40.00	41
Magnesium, Mg (mg)	23.0 ± 2.0	70
Calcium, Ca (mg)	16 ± 3.5	117
Manganese, Mn (mg)	0.359 ± 0.04	0.391
Zinc, Zn (mg)	0.365 ± 0.015	0.38
Copper, Cu (mg)	0.075	0.191
Iron, Fe (mg)	0.80	2.57



in red beetroot are β -carotene and lutein, which are strong antioxidants against several cancers [12].

Even lycopene, the red carotenoid has reported a significant attention from the antioxidant point of view, it seems that red beetroot is not a very valuable source of lycopene. So, considerable amounts of lycopene are in tomato, watermelon, red-fleshed guava, papaya [21].

Betalains

Betalains are a class of water-soluble and nitrogen-containing pigments, synthesised from the amino acid tyrosine, and fall into two structural groups, i.e. red-violet (betacyanins) or yellow (betaxanthins); they only occur in 10 families of the *Caryophyllales* order (former name for *Centrospermae*) and some fungi species, such as *Amanita muscaria* [2,22-24].

Betalains are found in different plant organs, and accumulate in cell vacuoles, mainly in epidermal and sub-epidermal tissues [22,25]. In mature cells, the vacuoles may occupy almost 90% of the cell volume, so that the rest of the cell contents are flattened against the cell membrane. The pigments are stored in vacuolar juice or in chromatoplasts visible in parenchymal cells, in the vicinity of plasmalemma. Betalains are water-soluble, vacuolar, secondary metabolites, being phenolic chromoalkaloids with health benefits for humans, especially in point of their antioxidant, anti-inflammatory, antiviral, even anti-tumoral activities.

Betalains are secondary metabolites derived from the amino acid L-tyrosine: Betaxanthins are immonium derivatives of betalamic acid with different amines and amino acids, and betacyanins, where the betalamic acid appears condensed with cyclo-dihydroxyphenylalanine (cyclo-DOPA) [26,27]. Betaxanthins are yellow and their absorbance spectrum has a maximal wavelength (λ_m) at approximately 480 nm, independent of the amino acid's nature. By contrast, betacyanins are purple, with an absorbance spectrum centered at $\lambda_m = 540$ nm.

The color stability of betalains is strongly influenced by pH and heating. They are stable at pH 3-4 to 6-7, but their thermostability is the greatest between pH 4 and 5 [24,28]. As a result of betanin degradation, cyclo-DOPA and betalamic acid are formed (Figure 1). This reaction is reversible. Betanin is light and air dependent. These effects are cumulative, but some protection may be offered by antioxidants such as ascorbic acid. Small amounts of metal ions increase the rate of betanin degradation. Therefore, a chelating agent or some protein systems can stabilize the color. In addition, studies on the stability of betalains demonstrate that the susceptibility to temperature of betaxanthin is higher than that of betacyanin [29,30].

Betalains are also used as additives in the food industry on account of their natural colorant properties, high solubility in water and lack of toxicity. Red beetroot is considered as the most important source of this colorant [2]. Betalains can be used either to avoid food discoloration, or to enrich food [31,32]. To improve the red color of tomato paste, sauces, soups, desserts, jams, jellies, ice creams, sweets and breakfast cereals, fresh beet/beet powder or extracted pigments are used [32,33].

Betanin extract (EEC No. E162), approved as a red food colorant by the European Union, has been in use as a colorant for food products, such as hard candies, yogurts, ice creams, salad dressings, readymade frostings, cake mixes, meat substitutes, powdered drink mixes, gravy mixes, marshmallow candies, soft drinks and gelatin desserts, juice and Burakovyi kvas [25,34,35].

The major advantages of betalains as dietary antioxidants are their bioavailability, which is greater than that of most flavanoids, and their superior stability in comparison to anthocyanin. Although they are used as food colorants, they are still understudied in terms of their antioxidant potential [36,37].

These pigments have drawn much attention because

of their bioactivity, which range from antioxidant capacity, boosting immune system and prevention of cardiovascular diseases, neurodegenerative disorders to cancer chemoprevention [26,38]. They have antimicrobial and antiviral effects [39], and can also inhibit the cell proliferation of human tumors [37,40]. Several studies indicate that betalains from red beets are antimutagenic, having anti-mutagenic effect against the direct acting mutagen, Methyl-Nitro-Nitrosoguanidine (MNNG or MNG) [12,38]. These effects are due to the main role of an osmolyte and vital methyl group donor (transmethylation) [11,12,41,42]. As an osmolyte, betaine protects cells, proteins, and enzymes from environmental stress (eg, low water, high salinity, or extreme temperature) by maintaining a high intracellular osmotic concentration [11,42-44]. It is actively accumulated in most tissues in response to osmotic stress and is centrally important in cell volume regulation, and, as such, betaine is a bodily requirement [44]. Cancer chemopreventive potential and antitumor effect of betanin is based on the stability to manage oxidative stress involved in the origin and aggravation of cancer. Betaine has antiproliferative action with the induction of cell apoptosis [38].

Health Promoting Properties

The scientific interest in beetroot over the past few decades has been discontinuous, even if beetroot was medicinally used in Ancient Greece and Rome. Thus, in the last two decades, several studies have shown that red beet (*Beta vulgaris L.*) is a good source of natural antioxidants, being in the top ten most potent vegetables [16,45].

Modern lifestyle has brought about changes in the health state of various segments of the population, such as heart disease, cancer, and diabetes. Thus, it has become vital to introduce fruits and vegetables into the daily diet [46]. These are rich sources of bioactive compounds, possessing high antioxidant potential, which recommends them as food medicine.

The health benefits of red beet demonstrated by *in vitro* and pre-clinical studies include: anti-oxidant, anti-oxidative stress, anti-depressant, anti-cancer, anti-mutagenic, anti-carcinogenic, radioprotective properties [47], as well as anti-hypertensive, anti-hypercholesterolemic, anti-hyperglycaemic, hematopoietic, anti-bacterial, anti-inflammatory, diuretic, anti-nephrotoxicity, hepatoprotective, anti-proliferative, immunomodulatory properties [14,48]. The consumption of red beet can also contribute to protection from age related diseases [49,50].

To benefit from all the health properties, red beetroot may be consumed as: Raw, juice, salad, boiled, baked, as chips or dried in any other combinations, even in various food dishes.

The leaves are an excellent source of vitamin A, K, C and E, as well as minerals, which helps cure many condi-

tions and illnesses such as anemia and blood pressure, cancer, dandruff, gastric ulcers, kidney ailments, liver toxicity or bile ailments like jaundice, hepatitis, food poisoning, diarrhea or vomiting.

Betalain is the main bioactive compound belonging to the class of red and yellow pigments, which could be present in red beets. Betalain contains two categories of pigments, betacyanins the violet one and betaxanthin the yellow to orange pigment.

Betanin exhibits an antioxidant activity that is ten times higher than tocopherol, and three times higher than catechin. In a test of linoleate peroxidation by cytochrome c, the compounds are cationized, which increases their affinity to membranes, an extremely beneficial attribute for antioxidants [51].

Betalains, especially betacyanins, play an important role in human health because of their pharmacological activities as an antioxidant, anti-cancer, anti-inflammatory, hepatoprotective [35], anti-lipidemic and antimicrobial agent. They inhibit cervical ovarian and bladder cancer cells *in vitro*, and can also inhibit the proliferation of cells in human tumors [52,53]. Consumption of red beetroot reduced the incidence of tumors in skin, lung, liver, colon, and esophagus.

As a natural pigment used worldwide as a colorant in cosmetics and drugs, red beetroot extract is of considerable interest due to its anticarcinogenic effects. Furthermore, when it is used in combination with anticancer drugs such as doxorubicin (Adriamycin), it has the potential to act synergistically and mitigate treatment-related drug toxicity [23,50,51].

Recent studies have provided evidence that beetroot ingestion (like juice or supplemented bread) enjoys beneficial physiological effects that may improve clinical outcomes for several pathologies, such as hypertension, atherosclerosis, neurodegenerative disorders, type 2 diabetes [3,50,54,55]. Due to the B vitamins, beetroot helps to reduce the effect of dementia and the loss of memory by increasing the blood flow to the brain [3,53].

As a nitrate source, beetroot ingestion provides a natural means of increasing *in vivo* nitric oxide (NO) availability, which could prevent and manage pathologies such as: hypertension and endothelial function [3,55].

Betalains increase resistance to oxidation which enrich human low-density lipoproteins and metmyoglobin. Betalains along with other phenolic compounds decrease the oxidative damage of lipids and can also reduce inflammation in joints, bones and blood vessels. This reconstruction in cases of inflammation helps patients suffering from asthma and osteoporosis. That why the betalains exhibit anti-inflammatory effects, antiradical action, thus helping regulate oxidative stress-related disorders in humans [47,49].

Beetroot is viewed as a promising therapeutic treatment in a series of clinical pathologies associated with oxidative stress and inflammation [3,56].

Netzel, et al. [56] reported that the ingestion of a single dose of red beet juice resulted in an increase of antioxidant compounds including betalains in urinary excretion.

It contains high concentrations of red betalains (anti-oxidants), vitamin C, tyrosine, iron and folic acid. Some individuals are unable to metabolize red betanin, leading to the production of red urine (known as beeturia).

Betanin from red beets was found to inhibit lipid peroxidation in membranes or linoleate emulsions catalysed by the "free iron" redox cycle (cytochrome c), H₂O₂-activated metmyoglobin, and lipoxygenase, respectively [51].

Oxidative stress and inflammation are involved in the development of obesity. Beetroot (*Beta vulgaris var. rubra*) is a food ingredient containing betalain pigments that show antioxidant activity. The *in vitro* effect of beetroot juice and chips on the oxidative metabolism and apoptosis in the neutrophils from obese individuals was investigated by Zielińska-Przyjemska, et al. [57].

Beets are high in vitamin C and fiber, and they also contain some essential minerals, like manganese and potassium. Potassium is essential for healthy nerve and muscle function, reducing the muscle usage of adenosine triphosphate, which is the body's energy source. While the fiber helps to move waste through the intestines and prevent constipation. Similarly, the antioxidants compounds of beets protect against colon cancer.

The claimed therapeutic use of beetroot includes its carminative, emmenagogue, hemostatic and renal protective properties [8].

In the study of Peeling, et al. [58], investigations were made on the beetroot's ability to enhance the oxygen-carrying capacity of the blood inducing high sporting performance, especially in racing and kayak athletes.

Another important quality of red beetroot consumption is macular degeneration prevention, which is related to carotenoids, known to be able to reduce the risk of cataracts formation.

The nutrients and vitamins helps in the detoxification of blood and liver, and have the ability to cure diseases of the digestive system, liver and kidney diseases, particularly the buildup of fatty deposits in the liver caused by alcohol abuse, protein deficiency or diabetes. Beetroot contains natural minerals that provide strength to bones [8,9,52,53].

The juice of beetroot is also consumed as a natural remedy for sexual weakness [8].

An important pilot study on cereal bars based on red beetroot and its impact on the individuals at risk for cardiovascular diseases revealed some important findings [55]. It analyzed the stability and antioxidant activity of phenolic compounds, showing that they depend on the physicochemical conditions in the digestive tract segments. The duodenal digestion did not affect the overall total phenolic compounds found in beetroot formulations. A part of the phenolic compounds were susceptible to the alkaline pH in the duodenal fluid, and part of them could be transformed into other compounds. So, the conclusion of the study was that the consumption of beetroot-cereal bars promoted the bioconversion of NO₃⁻ to NO, which is a reducing factor in cardiovascular disease development.

Processing Technology of Red Beetroot

Global warming and other environmental factors could affect the storage time of the vegetal material. Processing is for certain an important and quite essential method to preserve vegetables, especially those which are seasonal. Processing could also provide the same natural nutrients like the raw product if the processing method is correctly chosen and conducted. Red beetroot could be preserved by baking, boiling, drying, frying. All the processing methods could affect the nutritional value of the red beet root. But, if the right type of processing is chosen, the consumer could benefit from its extraordinary properties.

The antioxidant potential and the bioaccessibility of the phytochemicals could be influenced by the processing method. So, several studies reported the impact of red beetroot juice processing by vacuum-microwave drying, irradiation and fermentation [59,60], which enhanced the impact on the antioxidant capacity and pigment stabilization. Other studies investigated high temperature and long time exposure effects, which were found to cause a decrease of color retention in red beetroot [61].

Table 2 shows some of the changes in antioxidant capacity and the main compounds of red beetroot.

The results of several studies on the effects of red beetroot processing revealed that:

- Betalains are susceptible to pH, oxygen, metal ions, temperature, water activity, exposure to light and enzymatic activities [62,63];
- High temperature, pH changes or enzyme presence could convert betanin to betanidin [64];
- Phenolic concentration is dependent on the individual treatments and is correlated with the antioxidant activity results;
- A high amount of polyphenols, antioxidants and other value added compounds are present in red beetroot by-products, such as pomace and peel,

Table 2: Processing impact on red beetroot compounds and antioxidant capacity.

Red beetroot variety	Type of processing	Total phenolics	Betalains		Author
			Betacyanins	Betaxanthins	
Cardeal-F1	Extraction of beet root pomace	6.66 ± 0.30 ^b	1.25 ± 0.03 ^b	0.74 ± 0.02 ^{a,b}	Vulic, et al. [68]
Egyptian		1.87 ± 0.08 ^a	0.46 ± 0.02 ^a	0.29 ± 0.01 ^a	
Bicor		11.98 ± 0.57 ^d	1.99 ± 0.16 ^c	1.76 ± 0.04 ^{b,c}	
Kestrel		8.23 ± 0.39 ^c	0.62 ± 0.16 ^a	0.46 ± 0.01 ^a	
With different maltodextrin ratios: 3:1/4:1/5:1	Microencapsulation of extract		28.82 mg/100 g		Azeredo, et al. [69]
			90.71 mg/100 g		
			106.09 mg/100 g		
			135.98 mg/100 g		
Red beetroot	Juice extraction	1169 mg GAE/L From these Flavonoids- 925 mg catechin equivalent/L pigments- 854 mg/L	Antioxidant activity 325 mg ascorbic acid equivalent/L by DPHH assay		Fidelis, et al. [70]
	Freeze -drying beetroot chips	0.75 ± 0.06 GAE mg/g	95.70%		Vasconcellos, et al. [71]
	Spray drying beetroot powder	0.51 ± 0.07 GAE mg/g	95.31%		
	Boiling at 100 °C/40 min	2.79 ± 0.23 mg/g	85.79%		
	Juice extraction	3.67 ± 0.61 mg/g	80.48%		Santos Baiao et al. [55]
	Cereal Bar	88.13 ± 5.16 mg/60 g	91.97 ± 0.56% by TAPassay		
	Drying-chips	25.58 ± 0.72 mg/60 g	91.03 ± 2.15% by TAP assay		
	Juice extraction	10.79 ± 1.89 mg/60 g	83.98 ± 3.18% by TAP assay		
	Blanching 90 ± 2 °C/7 min	14.1 ± 1.1 mg gallic acid/100 g FW	543.6 ± 4.2 mg Fe ²⁺ /100 g FW by FRAP assay		Paciulli, et al. [66]
	High pressure processing 650 MPa/3 min	14.7 ± 2.9 mg gallic acid/100 g FW	610.9 ± 100.2 mg Fe ²⁺ /100 g FW by FRAP assay		
	650 MPa/7 min	12.9 ± 1.1 mg gallic acid/100 g FW	490.9 ± 28.6 mg Fe ²⁺ /100 g FW by FRAP assay		
	650 MPa/15 min	16.3 ± 4.4 mg gallic acid/100 g FW	540.3 ± 13.3 mg Fe ²⁺ /100 g FW by FRAP assay		
	650 MPa/30 min	19.6 ± 3.7 mg gallic acid/100 g FW	634.3 ± 23.7 mg Fe ²⁺ /100 g FW by FRAP assay		
Red beetroot	Convection drying at 50 °C	1.95 ± 0.005 mg/ml GAE	0.348 ± 0.005 mg/g	0.224 ± 0.0022 mg/g	Nistor, et al. [30]
	60 °C	1.82 ± 0.0025 mg/ml GAE	0.424 ± 0.0048 mg/g	0.31 ± 0.0017 mg/g	
	70 °C	1.43 ± 0.0015 mg/ml GAE	0.261 ± 0.0032 mg/g	0.171 ± 0.0018 mg/g	
	50/40 + MW315 ^e	2.03 ± 0.0035 mg/ml GAE	0.509 ± 0.0035 mg/g	0.616 ± 0.0022 mg/g	
	60/40 + MW 315 ^f	5.33 ± 0.0045 mg/ml GAE	0.631 ± 0.0042 mg/g	0.795 ± 0.0019 mg/g	
	70/40 + MW315 ^g	3.06 ± 0.0015 mg/ml GAE	0.655 ± 0.0029 mg/g	0.601 ± 0.0017 mg/g	

^amg GAE/g of dry weight of beetroot pomace, ^bmg betanin equivalents/g of dry weight of beetroot pomace, ^cmg vulgaxanthin-I equivalents/g of dry weight of beetroot pomace, ^dRatio V:Y ratio of violet (V) to yellow (Y) pigments, ^e50/40 + MW315-free convection at 50 °C/forced convection at 40 °C with microwave at 315 W power, ^ffree convection at 60 °C/forced convection at 40 °C with microwave at 315 W power, ^gfree convection at 70 °C/forced convection at 40 °C with microwave at 315 W power.

which are inedible waste products in juice manufacture.

With the increasing consumer demand for fresher, safer, and higher quality food, there is a strong interest in the food industry in developing non-thermal process-

ing techniques to replace traditional thermal methods. Microwave treatment, ohmic heating, high pressure carbon dioxide (HPCD) are just a few of the methods that have received considerable attention for potential applications [65,66].

Conclusions

Red beetroot is grown and consumed in raw and cooked form all over the world, both for its palatability, and its high nutritive and medicinal value. It is well known as a health promoter, disease preventer and treatment. So, it is used as a functional food source against many diseases like diabetes, cancer, cardiovascular disease and other chronic diseases.

Red beetroot is one of the richest foods from the vegetal kingdom, containing essential components like: Vitamins, minerals, phenols, carotenoids, nitrate, ascorbic acids and betalains. The effect of these phytochemicals depends on the bioaccessibility of these nutrients during gastrointestinal digestion.

Processed red beetroot manifests high stability and antioxidant activity. So, red beetroot could be used as a potential material to develop functional and innovative foods. Used as such or in combination with other food matrices, red beetroot could create synergism with other products and increase their nutritional value. Red beetroot could be used as a product itself, as well as a preservative in order to replace nitrate in meat products.

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