Journal of Biosciences and Medicines, 2019, 7, 61-79
http://www.scirp.org/journal/jbm
ISSN Online: 2327-509X
ISSN Print: 2327-5081

Red Beet (*Beta vulgaris*) Impact on Human Health

D. Babarykin[1*], G. Smirnova[1,2], I. Pundinsh[3], S. Vasiljeva[2], G. Krumina[1], V. Agejchenko[1]

[1]Institute of Innovative Biomedical Technology, Riga, Latvia
[2]Institute of Biology, University of Latvia, Riga, Latvia
[3]Baldones lauki Ltd., Steading "Ozolaji", Baldones Region, Latvia
Email: *dmitry.b@parks.lv

How to cite this paper: Babarykin, D., Smirnova, G., Pundinsh, I., Vasiljeva, S., Krumina, G. and Agejchenko, V. (2019) Red Beet (*Beta vulgaris*) Impact on Human Health. *Journal of Biosciences and Medicines*, **7**, 61-79.
https://doi.org/10.4236/jbm.2019.73007

Received: February 1, 2019
Accepted: March 5, 2019
Published: March 8, 2019

Abstract

The last decade is characterized by an explosive growth of interest in the impact of red beet root on human health. In the review information on the chemical composition and nutritional value of red beet as well as pigments biological effects are presented. Analyzed reports abound on antioxidant, anti-inflammatory and chemo-preventive *Beta vulgaris* phytochemical activity, its impact on gastrointestinal and cardiovascular system as well as endurance exercise performance. In details the red beet nitrates bioconversion and its role in blood pressure regulation have been described. The first information on red beetroot juice impact on iron metabolism is summarized. Beet processing methods, which led to the appearance of a lot of conventional red beet products, functional food, and dietary supplements, are described. Fractionated red beetroot juice on the molecular mass basis is prospective for senile sarcopenia as well as senile cognitive decline and Alzheimer's disease prevention. The aim of this review is to discuss red beetroot biological effects and new trends in the studies, targeted on development of new functional food products as well as medicines.

Keywords

Red Beetroot, Biological Effects, Gastrointestinal Tract, Iron Absorption, Iron Deficiency Anemia, Athletes' Stamina

1. Introduction

The beet, *Beta vulgaris* is a plant in the *Chenopodiaceae* family. It is best known in its numerous cultivated varieties, the most well-known of which is the purple root vegetable known as beetroot or table garden beet. However, other cultivated strains include the leafy vegetables chard and spinach beets, as well as the root vegetable sugar beet, which is important in sugar production.

Beetroot can be eaten raw, used for juice extraction, baked or boiled. Red beets are delicious roasted, pickled, eaten in salads, or made into soup, which is popular in many Eastern and Central European countries. In contrast to fruits, the main sugar in beetroot is sucrose.

Beets have been used in traditional medicine for hundreds of years to treat constipation, gut and joint pain, dandruff [1]. Modern pharmacology shows that red beet extracts exhibit antihypertensive and hypoglycaemic activity as well as excellent antioxidant activity. The promising results of their phytochemicals in health protection suggest the opportunity for their use in functional foods.

2. Chemical Composition and Nutritional Value

This review includes description of beetroot phytochemicals with the greatest functional importance.

Proximate nutritive values of red beetroot are as follows: vitamin A—20 I.U., thiamine—0.02 mg, riboflavin—0.05 mg, niacin—0.4 mg, vitamin C—10 mg, calcium—27 mg, iron—1.0 mg, phosphorus—43 mg, total fiber 87.4 g, fat—1 g, carbohydrates—9.6 g, protein—1.6 g, calories—42 kcal per 100 g. Not only does the beet root have nutritional value, its leaves also do [2], but they are eaten unreasonably rarely. However, the uniqueness of red beets does not lie in their nutritional value. 100 g of this plant contains: alkaloids (128.8 mg), steroids (16.4 mg), glycosides (0.652 mg), flavonoids (6.15 mg), terpenoids (115.5 mg), saponins (3.789 mg), beta-carotene (11.64 mg), vitamins A (2.6 mcg), K (3.2 mcg), C (4.36 mg), E (0.18 mg), B3 (0.03 mg), B6 (90 mg), B2 (0.034 mg), pantothenic acid (0.151 mg), potassium (20 mg), iron (0.76 mg). [3]. Sometimes it is necessary to take into account beet root as reducing nutritional value due to its high level of oxalic acid [4]. Nevertheless, functionally the most important red beetroot phytochemicals, which provide benefits beyond normal health maintenance, are secondary metabolites betalains, betaine and nitrates.

Betalains are unique nitrogen-containing pigments found exclusively in families of *Caryophyllales* order and some higher order fungi, where they replace anthocyanin pigments [5]. *Beta vulgaris* betalains include two classes of compounds: betacyanins, which are red violet and betaxanthins (predominantly, vulgaxanthin-I), which are yellow. The major betalain in red beet is betanin, which is betanidin-5-*O*-beta-glucoside, containing phenolic and cyclic amine groups, acting as antioxidants [6]. Betanin, the major betalain in red beetroot, showed poor bioavailability [7]. Commonly betalains are used as food colorants. The five examined *Beta vulgaris* cultivars from Hungary showed no significant differences in the content of red-violet pigments [8]. However, studying commercial beetroot products and beetroot juice prepared from seven red beet varieties grown in Upper Austria, it was found, that total betalain content is variety-specific [9]. In comparison to other vegetables, the antioxidant capacity of beets is very high. A highly significant correlation was demonstrated between antioxidant capacity and the contents of red pigments, whereas a remarkably less tangible relationship was found between antioxidant capacity and content of yellow pigments [10]. Betalain's other biological effects are uncertain.

Betaine (trimethylglycine) is found naturally in most living organisms and rich dietary sources include seafood, especially marine invertebrates (≈1%), wheat germ or bran (≈1%) and spinach (≈0.75%). The total content of betaine in red beet juice is 0.3% - 0.4% [11]. The principal physiological role of betaine is an osmolyte and methyl donor (transmethylation). As an osmolyte, betaine protects cells, proteins, and enzymes from environmental stress (dehydration, extreme temperature etc.). Inadequate dietary intake of betaine (the donor of methyl groups) leads to hypo-methylation in many important pathways, including disturbed hepatic protein (methionine) metabolism as determined by elevated blood homocysteine and inadequate hepatic fat metabolism, which leads to steatosis and plasma dyslipidemia. These alterations may contribute to various diseases, predominantly cardiovascular ones [12]. Betaine has the principal role in lowering the blood level of homocysteine, which is the key element in cascading development of atherosclerosis.

The history of the study of biological activity of ***nitrates*** in the context of red beet health effects represents an excellent example of how radically our understanding of food utility can be changed. It was long considered that nitrates are a harmful substance contaminating vegetables. Nitrates can be converted in to nitrosamines which could lead to endocrinological diseases, defects in human fetuses, as well as cancerogenesis etc. [13]. However, at present time the red beet nitrates are considered as one of the most important nutrients (about it see below).

Speaking of chemical composition of *Beta vulgaris* one of the compounds, which content in beet root is high and it can cause side effect, should be mentioned. It is oxalic acid. Red beet belongs to oxalate-accumulating plants [14]. Therefore, regular consumption of red beet is contraindicated for people with urolithiasis.

3. Red Beetroot Processing and Product Formulation

Various processing methods applied to food materials may have significant effects on their antioxidant potential and bio-accessibility of included phytochemicals. There are huge numbers of red beetroot-based dietary supplements and functional food on the market: juice and juice mixtures (predominantly, with lemon juice), gels, fermented and fractionated juice, dried powder (tablets, capsules, micro-capsulated formulations, crunchy beetroot slices) [15] and beetroot enriched bread [16] (**Figure 1**). The variety of red beetroot product formulations presented at markets is determined not only by manufacturers' wishes to satisfy customers' gastronomical preferences and culinary traditions, but also by the necessity to keep and increase functionality of the products.

Guldiken *et al.* [17] analyzed and compared the total phenolic (TP), total flavonoid (TF) contents, total antioxidant capacities (TAC) of boiled, oven-dried,

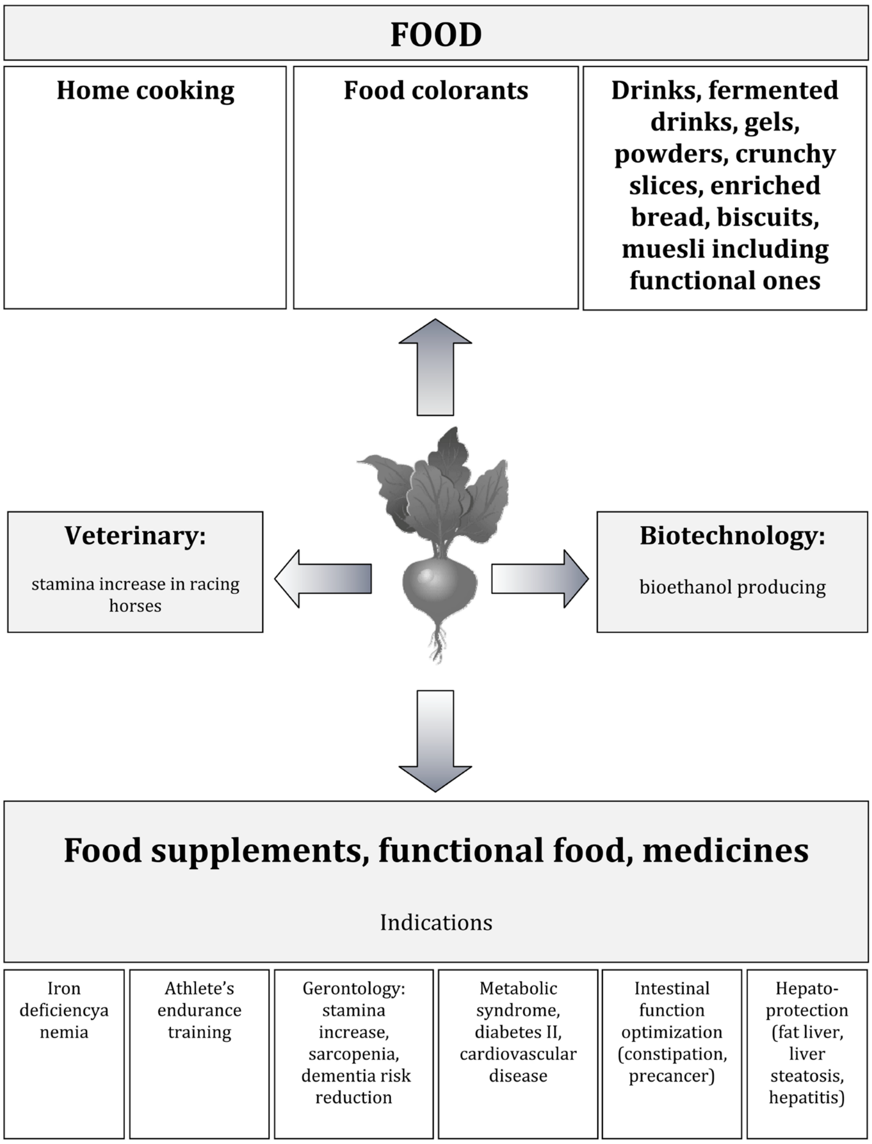

Figure 1. Red beetroot processing and product's health effects.

pickled, pureed, juice-processed and jam-processed red beetroot. Dried, pureed, and fresh red beetroot samples had the highest TP, TF and TAC. The *in vitro* digestion method revealed the highest recovery for TP and TAC in jam.

The effect of raw beet juice and cooked beets on blood pressure of hypertensive subjects also has been tested [18]. Although both formulations of beetroot were effective in improving blood pressure, endothelial function and systemic inflammation, the raw beetroot juice had a greater antihypertensive effect. Nevertheless red beetroot boiling caused the highest loss of the total antioxidant activity [19]. Red beet peels and pulp exhibits high antioxidant activity after thermal processing (10 min, 80˚C) [20]. The highest betalain content was found in pressed juice obtained after microwave pretreatment [21]. Drying conditions of red beetroot affect betalain variance, and polyphenol microstructure changes. A strong thermal shock, provided by convection, followed by microwave wattage, leads to a better preservation of bioactive compound content [22].

Violet betacyanins are 3 times more stable when heated than yellow betaxanthin. To keep red beetroot quality, the use of new preservation techniques, high hydrostatic pressure, significantly reduces the number of sporage microorganisms with a slight degradation of pigments [23].

Of note is the paradox in terms of manufacturers' and consumers' wishes to reduce nitrate content in red beetroot juice-based products. In one part of society nitrates are positioned as a food pollutant. Therefore, the methods of red beetroot juice purification from nitrates have been developed. The use of membrane technology (reverse osmosis) allows removal of 96% of salts, 95% of nitrates, while retaining a majority of the pigment [24]. On the other hand, red beetroot juice, purified by nitrates, loses an essential part of its functionality, due to its potential effect on improving cardiovascular health and exercise performance. Beetroot-based nutritional formulations with a high content of bio-accessible nitrates, antioxidants and potassium [25] appeared on the market during the last decade. It was supposed that higher polyphenol content diminishes nitroso species synthesis following oral ingestion of nitrate containing red beet juice. It seems the solution of the problem of red beetroot juice "contamination" with nitrates will be achieved via development and manufacturing of specialized red beetroot juice drinks for different consumer target groups.

Fermentation is a quite promising direction in red beetroot juice processing. This method allows reduction of sugar content in red beetroot juice and modification of phytochemical pharmacokinetics. The profile and content of betalains in plasma and urine of volunteers after long-term exposure to fermented red beet juice has been studied [26]. During juice consumption, the contribution of betalain metabolites was higher than that of native betalains. Boiling, microbial activity and softening of the matrix of red beetroot due to spontaneous fermentation reduced the content of betanidin and vulgaxanthin-I by 51% - 61% and 61% - 88% respectively [27] in the juice.

We used red beetroot fermentation with bread yeast followed by juice fractionation by ultrafiltration. Due to fermentation, the total sugar content in red beetroot juice decreased from 5.20% to 0.57% without essential loss of the pigments. The obtained product was used for subsequent fractionation by ultrafiltration to isolate the fraction, with the capacity to stimulate iron intestinal absorption [28].

Currently the development of new dietary supplements as well as functional food predominantly takes place within the framework of identification and isolation of pure phytochemicals. However, consumption of highly purified plant compounds cannot be called "physiological", because naturally, isolated phytochemicals are not consumed. In addition, taking into account the complex interaction between separate substances (including synergy and antagonism), it becomes virtually impossible to forecast the vector of new product biological effects. It is rational to focus not only on chemical composition of the products, but on their functionality. This approach sometimes allows the discovery of unexpected effects of natural compound compositions.

4. Antioxidant Effects and Chemoprevention of Cancer

Beta vulgaris has been ranked among the most potent antioxidant vegetables. The results of the study of antioxidant activity of apple peel, carrot pulp, as well as light and red grapes, red beetroot peel and pulp showed that the *Beta vulgaris* specific effect was less than that of grapes at maximal activity [29].

As it is known antioxidant nutrients in fruits and vegetables are important to maintain human health and neutralize a negative effect of oxidative stress. Oxidative stress is a form of oxidative process that represents an imbalance between the production and manifestation of reactive oxygen species and a biological system's ability to readily detoxify the reactive intermediates or to repair the resulting damage. In humans, oxidative stress is involved in many diseases—atherosclerosis, neurodegenerative diseases, myocardial infarction, cancer, as well as ageing [30].

Many plant pigments are antioxidants. The major secondary plant metabolites—pigments of red beets are different from those of most fruits and vegetables. The health-benefit properties of natural pigments have been focused on in many works, especially those of carotenoids and anthocyanins, whose antioxidant properties have been extensively studied. Red beet pigments betalains have not been much explored as bioactive compounds, but a lot of studies have indicated their potential as antioxidants [31]. It was found that at pH > 4 betanin is about 1.5 - 2.0-fold more active than some anthocyanins considered very good free radical scavengers [32]. Crude aqueous and ethanolic extracts of root tissue of red and high pigment beet strains exhibited antioxidant and phase II enzyme-inducing activities (*i.e.* xenobiotics elimination), and these extracts were fractionated using Sephadex LH-20 chromatography. Red and yellow pigments were found in active fractions, but other components remained unidentified [33].

Free-radical scavenging, reducing, and phase II enzyme-inducing activities of aqueous extracts of four beet (*Beta vulgaris*) strains—red, white, orange and high-pigment red were determined. The extracts of red and high-pigment red phenotypes were most capable of inhibiting oxidation of beta-carotene [34].

The administration of betalains from red beets provided a radio-protective effect in mice irradiated by ^{60}Co *in vivo* [35]. Beetroot extract ingestion in mice after 10 days of beta-ray irradiation minimized DNA damage of splenocytes, boosted differentiation of hematopoietic stem cells into burst-forming units-erythroid, enhanced hematocrit and blood hemoglobin, and improved the survival rate of lethally exposed mice [36].

Red beetroot juice provides antidote effect on heavy metal toxicity. In our study [37] has shown that chronic cadmium (Cd) intoxication causes increase of Cd concentration in blood, liver and kidney which provoked the rise of oxidative processes in organs, suppressive on immune response in chickens manifested in alteration of cell and humoral immunity parameters. Oxidative stress markers (hepatic and kidney malondialdehyde amount, liver glutathionperoxidase and blood catalase activity), biochemical and immunological indices in Cd-exposed chickens were almost back to initial values fractionated by ultrafiltration red beetroot juice *per os* for 10 days. Ingestion of fractionated red beetroot juice by Cd-treated chickens prevented the oxidative impact of this heavy metal and provided an immune-modulating effect.

Besides considerable antioxidant and anti-inflammatory activity, *Beta vulgaris* phytochemicals provide an anti-proliferative effect in breast, liver, colon and bladder cancer cell lines, through the induction of both intrinsic and extrinsic apoptotic pathways. A significant body of evidence also points to the role of these phytochemicals in the down regulation of the pro-survival genes, baculoviral inhibitor of apoptosis repeat-containing 5 and catenin beta-1, as well as the genes controlling angiogenesis, hypoxia inducible factor 1A and vascular endothelial growth factor A [38]. As free-radical-scavenging reducing agents and phase II enzyme-inducing activators, red beet varieties with higher red pigment content [34] are more effective. Lee *et al.* [39] reported about betanin and betain anti-proliferative effects against HepG2 cancer cell lines *in vitro.* An interesting observation is that a liver cancer chemo-preventive effect was exhibited at a very low dose of red beetroot extract used in the study [40], thus indicating that beetroot warrants more attention for possible applications in the control of malignancy.

The cytotoxic effect of the beetroot extract is comparable to doxorubicin (Adriamycin) in the human prostate and breast cancer cell lines. The mentioned red colored anticancer antibiotic's chemical structure with a planar configuration of an aromatic chromophore attached to a sugar molecule is remarkably similar to that of betanin [41]. It has shown an *in vivo* anti-tumor promoting activity evaluation against mice skin, and lung bioassays also revealed a significant tumor inhibitory effect [42]. Drinking water with red beetroot color antagonizes esophageal carcinogenesis in N-nitrosomethylbenzylamine treated rats [43].

5. Impact on the Gastrointestinal System

Red beet product consumption provides a significant effect on nearly all organs of the digestive tract: pancreas, liver, colon. Red beetroot is well known as an "internal cleansing" substance and provides a mild laxative effect. Because of the extensive amount of literature on studies which have examined the physiological and nutritional effects of *Beta vulgaris* on both humans and animals, it is largely accepted that intestinal peristaltic improvement is related to dietary fiber. There are no differences between red beetroot and sugar beetroot effects. Beet fiber contains three main fractions: pectin, cellulose and arabinose polymers with a potential weight loss effect [44]. It should be noted that laxative effects are provided not only by fiber rich red beet products, but also by fiber free *Beta vulgaris* juice.

Red beetroot juice also diminishes blood cholesterol level. Extract of pomace of red beets containing polyphenols and dietary fiber stimulates intestinal excretion of cholesterol and cholesterol metabolites [45]. This mechanism is probably responsible for the hypocholesterolemic effect of beet products. The presence of both higher cellulose content and red beet fiber in the diet significantly reduced the incidence of precancerous lesions-aberrant crypt foci-in the colon [46].

Recently, the effect of red beet on carbohydrate metabolism, in particular, the dynamics of glycemia, both in normal conditions and in diabetes, is being actively studied. According to the morphological and biochemical results obtained in the experiment in streptozotocin-diabetic rats, the extract of *Beta vulgaris cicla*, when administered by gavage, reduces blood glucose levels by regeneration of the pancreatic beta-cells [47]. Consumption of soluble dietary fiber is correlated with decreased postprandial glucose and insulin responses and hence has beneficial effects on metabolic syndrome. Swiss chard (*Beta vulgaris cicla*) extracts exhibit hypo-glycaemic activity [48]. In an Australian study [49] sixteen healthy individuals were recruited to consume the test meals in a controlled single-blind cross-over design. Results revealed a significant decrease of the postprandial insulin response in the early phase (0 - 60 min) and a significantly lower glucose response in the 0 - 30 min phase ($P < 0.05$) after red beetroot juice consumption.

Red beetroot juice provides a hepato-protective effect. First of all, it was demonstrated on the toxic hepatitis experimental models. The aim of the cited study [50] was to examine the effect of long term feeding (28 days) with beetroot juice on phase I and phase II enzymes, DNA damage and liver injury induced by hepato-carcinogenic N-nitrosodiethyamine (NDEA) in rats. Long term feeding with beetroot juice showed the protective effect of beetroot juice against oxidative liver damage. In another study [51] two toxicants were tested: NDEA and carbon tetrachloride. All of the investigated antioxidant enzymes were inhibited by the administration of either toxicant alone or by 26% - 77% as compared to the control. Pretreatment with juice caused a partial recovery of the activity of glutathione peroxidase and glutathione reductase by 35% and 66%, respectively. Similarly, DNA damage in blood leukocytes caused by either toxicant was slightly diminished, by 20%, in the rats treated with juice before NDEA administration.

Liver-protecting properties of bioactive substances of table beets were also demonstrated in a model of an ischemia-reperfusion injury of the rat [52]. Hepatic ischemia was maintained for 45 min, followed by 15 min reperfusion. The treated group was fed red beetroot lyophilized powder mixed into a raw chow. As a result of feeding, global parameters and enzymatic antioxidants of the liver were found to increase significantly, which indicated a positive effect on its redox state.

Non-alcoholic fatty liver disease (as civilization's disease!) has a prevalence of 25% - 30% in unselected populations and has become the main reason for referrals to hepatology services [53]. In the experiments in rats with food-induced fatty liver it was shown that peroral ingestion of fractionated by ultrafiltration (with cut-off-point 150 KDa) red beetroot juice brakes obese body weight gain, visceral fat mass, improves the blood cholesterol fraction proportion as well causes hypo-lipidemic effect and provides histologically proved hepatoprotection [54]. It was reported, that *B. vulgaris* could be used for the treatment and prevention of alcoholic liver disease [55].

To check how red beetroot juice impacts cell fat metabolism, we used rat bone marrow stromal mesenchymal multipotent cells (BMSMMC) as a model, *i.e.* stem cell cultures [56]. It is known, that BMSMMC differentiate into a variety of cell types, including osteoblasts (bone cell), chondrocytes (cartilage cell) and adipocytes (fat cell). The direction of BMSMMC differentiation may be modulated by adding a lot of substances, including phytochemicals [57], to the cultivation medium. Both native red beetroot juice and that fractionated by ultrafiltration were tested regarding their influence on the mentioned cells differentiation *in vitro*. It was found that, unlike the native red beetroot juice, the fractionated one significantly suppressed stem cell adipogenic differentiation [56]. It is worth noting that fractionated red beetroot juice ingestion in combination with allogeneic BMSMMC intravenous transplantation resulted in better bone reparation and significant hematopoiesis stimulation in rats with experimental polytrauma [58].

6. Effect on the Cardiovascular System and Endurance Exercise Performance

It has been over 30 years since the publication about red beetroot juice capacity to reduce blood pressure and positively influence physiological response to exercise [59]. For a long time, this interesting fact has been forgotten by researchers and doctors. Only in 2008, after the appearance of the article in the journal *Hypertension* [60], which confirmed this effect, did the intensive study of red beetroot impact on human's cardiovascular system and stamina begin.

Red beet juice hypotensive effects are associated with nitrates, which are found in high concentration also in spinach, lettuce, radishes and celery. Thanks to the *B. vulgaris*, a kind of "rehabilitation" of nitrates in public and medical opinion has happened. In general, nitrates provide ergogenic and cardio-protective properties.

What is the mechanism of nitrate-induced vasodilatation? Following oral consumption nitrates (NO^{3-}) are absorbed by the intestine. Following uptake from the blood, nitrates are concentrated in saliva via an active transport system. Once secreted in the oral cavity, commensal bacterial anaerobes, located predominantly in the crypt of the tongue, bioactivate nitrates and reduce them to nitrites (NO^{2-}) in saliva. Once swallowed, salivary nitrites are converted to nitric oxide (NO) in the stomach acid, but some of the nitrites are absorbed to increase circulating plasma NO^{2-} concentrations. *Beta vulgaris* nitrates, being bioconverted to nitrite and nitric oxide, are responsible for lowering blood pressure and vasoprotection (60). Beetroot juice lowers blood pressure to a greater extent than sodium nitrate [61]. Now nitrate is an important ingredient of sport food.

Nitric oxide plays numerous biological roles, functioning and affecting neurotransmission, healing wounds, tumours, asthma, blood flow, host defense, penile erection etc. [62]. NO is primarily of interest due to its role in relaxing human vasculature—an effect that may result in improved blood flow during rest and exercise. This effect is mediated by a modulation of endothelial function [63]. In randomized, crossover, double-blind study has been shown that the consumption of the single dose (140 ml) of red beetroot juice improved macrovascular endothelial function, but not muscle oxygen saturation parameters in pregnant women [64].

A single dose of beetroot juice enhances cycling performance in stimulated altitudes. One week of daily dosing with beetroot juice improves submaximal endurance and blood pressure in older patients with heart failure and preserved ejection fraction [65]. Promising results have been obtained in patients with peripheral arterial diseases (PAD) and intermittent claudication during consumption of concentrated beetroot juice. It was found that increasing plasma nitrite prior to training exercise may allow PAD subjects to train with less pain, at higher workloads for longer durations at each training session, thereby maximizing the beneficial peripheral vascular and skeletal muscle adaptations [66]. Acute beetroot juice ingestion can decrease central sympathetic outflow at rest and during exercises [67]. Dietary (red beetroot) nitrate supplementation reduces the O_2 cost of low-intensity exercise and enhances tolerance to high-intensity exercise in humans [68]. Red beet juice is in use for improvement of stamina in race horses, especially in Arab countries.

In spite of the discovery of nitrate's role in red beetroot juice induced vasodilatation, we are far from a complete understanding of the mechanism of red beetroot product impact on the cardiovascular system. Bahadoran *et al.* [69] made a systematic review and meta-analysis results demonstrate the blood pressure-lowering effects of red beetroot juice and highlight its potential nitrate-independent effects. Of all nitrate rich vegetables, precisely red beetroot provides the most significant microcirculation stimulation. It seems *Beta vulgaris* cardiovascular effects are the result of a complex impact of a few biologically active substances.

7. Effects on Iron Metabolism

Most of the scientific publications about red beet are devoted to their antioxidative effect in human body. However, the different effect of beet root also can take place. First of all, the influence of red beet on iron metabolism should be mentioned.

Iron is found in almost all foods, so dietary iron intake is related to energy intake. However, its availability for absorption is quite variable, and poor bioavailability is a major reason for the high prevalence of nutritional iron deficiency anemia (IDA). The body's need for iron depends on the physiological status (pregnancy, old age, regular exercise stress) of the organism. Nutritional iron deficiency arises when physiological requirements cannot be met by iron absorption from the diet. Some pathological conditions cause secondary iron deficiency. There are also a lot of genetic forms of iron-related anemia.

Iron deficiency is one of the leading risk factors for disability and death worldwide, and IDA prevalence varies widely: from 7.2% - 14.0 % in developed EU countries to 60% in females of reproductive age in Asian countries.

Targeted iron supplementation with pharmaceuticals is widely used, but peroral iron salt ingestion often causes side effects—nausea, vomiting, abdominal pain. Oral iron supplementation leads to an improved blood hemoglobin level, but at the cost of increased oxidative stress [36].

Many attempts have been made to improve food iron bioavailability by diet enrichment with fruits and vegetables. One of most important plant compounds which enhance iron absorption is ascorbic as well as other organic acids. Nevertheless, increased fruit and vegetable consumption is not a panacea. Plants specific effects do not always target an iron bioavailability increase.

The impact on iron metabolism is the least studied aspect of red beetroot health effects. In folk medicine red beets are associated with good health (red blood). Traditional medicine in all European countries suggests using red beet juice as a source of iron for anaemia treatment. Beets are recognized in some folk medical traditions as treatment for blood loss, or for "weak" blood conditions. However, iron concentration in beet juice is too low (0.1 - 0.8 mg/100ml) [28] to provide a significant anti-anaemic effect. Only one scientific publication with strong proof of red beetroot impact on iron metabolism has been found. In 2018 on 8 volunteers was shown "… obvious increase serum level mild increase in hemoglobin and ferritin after taking 8 g of beetroot for 20 days and thus it can be stated that beetroot might have some therapeutic properties for iron deficiency" [70].

There is some indirect corroboration of the connection between beets and blood. First of all, it should be noted that extreme consumption of *Beta vulgaris var. rubra* can cause metal (iron included) in the liver [71]. The authors found significant accumulation of Cu, Fe, Mg, Mn, Zn and P in the liver in healthy rats, which were treated with lyophilized powder of table beet root (2 g/kg b.w.) added into rat chow for 10 days. This phenomenon was described by high mineral content in red beetroot. This opinion is difficult to accept because iron content in dried beetroot is about 170 mg/kg [72], and in the cited research rats received 68 μg of iron daily, which is too small to be the source of iron overload. The most likely explanation may lie in the influence of impact of other red beetroot compounds on iron assimilation.

The second indirect confirmation of a relationship of red beetroot consumption and iron metabolism is the phenomenon called beturia. Beturia, the passage of pink or red urine after the ingestion of beetroot, is said to occur in 10% - 14% of the population and is more common in iron deficiency and malabsorption. Beturia does not arise from deficiency in hepatic metabolism or renal excretion of betacyanins [73], but the reasons of the appearing of the pigments in urine are not clear. Beturia is harmless, although it may scare the red beet consumer, its importance being solely in differential diagnosis, for example, from haemoglobinuria [74]. Perhaps, beturia is somehow linked to the iron metabolism.

Can phytonutrients directly impact iron active intestinal transport? We studied the effect of buffered vegetables' native juice on the iron absorption in chicken intestines using modeling system *in vitro*. Zucchini, carrot, cucumber, pumpkin, beetroot, sugar beet and mangold were tested. It was shown that red beetroot juice causes the most marked effect at 36% - 40% and it does not depend on juice pH nor ascorbic acid concentration [28].

Red beetroot compounds can stimulate intestinal iron absorption through several mechanisms. Ascorbic and other organic acids significantly enhance iron bioavailability and intestinal transport. The beetroot is rich in ascorbic and citric acids. There are some facts which allow us to conclude that betalains can be related to iron ion transport in intestinal mucosa. The incubation of rat everted gut sac in buffer containing $FeSO_4$ in the absence or presence of aqueous extract of *Grewia tenax* (betalains containing plant) showed that the pigment significantly enhances transmucosal transport of iron ions *in vitro*. [75]. But not only betalains can stimulate iron absorption in intestinal mucosa. The addition of 1 g sugar-beet fibre to 3 g semi-synthetic diet resulted in a 54% increase in iron absorption in rats. The same amount of wheat bran had no effect on Fe absorption [76].

With the aim to increase red beetroot juice specific activity we used ultrafiltration. The fraction with high capacity to stimulate (dose dependent) iron duodenal absorption in chicken *in vivo* exceeded native juice by 3 times has been isolated by ultrafiltration [28]. This study demonstrated, that red beetroot juice contains compound or compounds complex with the ability stimulate duodenal iron absorption. The effect is dose dependent. The study of the chemical composition of fractionated red beetroot juice now is in progress.

8. Conclusion

In conclusion, consumption of red beetroot products, including native juice and its fractions had several beneficial nutritional effects in mammals. The juice from beets seems to be most effective as an anti-anaemic, anti-ischemic, anti-inflammatory, antioxidant and anticancerogenic product. The use of red beet root products might also be advantageous for intestinal peristaltic as well as lipid metabolism optimization. We suppose, fractionated red beetroot juice is prospective for senile sarcopenia as well as senile cognitive decline and Alzheimer's disease prevention.

Acknowledgements

The authors extend sincerely thanks to all Institute of Innovative Biomedical Technology as well as Institute of Biology of the University of Latvia who participated in more than ten years red beetroot research.

Source of Funding

The Project is executed in accordance with the contract 1.2.1.1/16/A/004 between "Competence Centre for Food in Latvia" Ltd. and the Central Finance and Contracting Agency, with support from the European Regional Development Fund.

Conflicts of Interest

The authors declare no competing interests.

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