EXTRACTION AND PROFILING OF FUNCTIONAL COLOURANT FROM BEETROOTS: A REVIEW

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Abstract

Given the importance of colour in the acceptance or rejection of a product, the use of colorants is a wide spread practice within the food industry. At the same time, with the increasing consumers' awareness of the health effects that some artificial colorants can exert, there is a growing tendency to prioritize foodstuffs containing natural additives. *Beta vulgaris* known as Beetroot is a member of a family of *Chenopodiacea*e and is widely used as a natural food colorant. Its distinctive color is due to nitrogen-containing water-soluble pigments called betalains. Some non-conventional technologies (cryogenic freezing, aqueous two-phase extraction, gamma irradiation, pulsed electric field, ultrasound-assisted extraction, microwave-assisted extraction and membrane processing) have the potential to improve extraction rate. Beetroot is an exquisite cradle of nutrients, including proteins, sucrose, carbohydrates, vitamins, minerals, fiber. They also contain an appreciable amount of phenolic compounds and antioxidants such as, carotenoids and flavonoids. Recent studies evidenced that beetroot consumption had favorable physiological benefits, leading to the treatment of cardiovascular diseases, diabetes, cancer, artheritis, liver damage and intestinal inflammation.

Keywords: Beetroot, Betalain, Bioactive compound, Extraction, Colourants.

1.0. Introduction

One of the first perceptions of food is its hue, a characteristic that highly influences consumers' choice, since it leads to the creation of an idea of the flavour, odour, and composition of the food product. Therefore, food colorant is one of the most used additives, applied to restore the original colour of foodstuff when it is lost. With the recent food industry interest in replacement of artificial colorants by natural counterparts, an increasing number of research studies have been focusing the exploitation of natural resources to meet this challenge (Vege *et al.*, 2021). For being natural, non-toxic, and water-soluble, betalain extract have been widely studied as alternatives to the widely used synthetic food colorants.

The successful application of natural colourants in food and beverage products requires understanding their techno-functional properties and chemical composition. By utilizing these unique properties, formulators can meet consumer demand for natural and healthy ingredients by creating visually appealing and nutritionally enhanced products.

Beetroot (*Beta vulgaris* L.) is botanically classified as a biennial herb of the *Chenopodiaceae* family; it originated from Eastern and Southern Europe, and Northern Africa (De Oliveira *et al.*, 2020). Beetroot is grown in many countries worldwide, and the main producers are France, Germany, the United States, Turkey, Ukraine, Poland, Egypt, the United Kingdom, and China (Liu *et al.*, 2024).

Red beetroot pigments are usually extracted by physical pressing of the sliced red beetroots or centrifugation of ground roots followed by blanching. Aqueous extraction of shredded beetroots has also been used. The addition of ethanol or methanol to water is generally necessary to thoroughly extract the pigments in the presence of acidification or heat treatment, especially for the improved extraction yield (Yu *et al.*, 2020).

Profiling studies such as the yield, water absorption, foaming capacity, bulk density, water absorption capacity, colour quality, pH, phenolic acid, flavoniod, etc. play a crucial role in understanding the physicochemical, functional and bioactive constituent of beetroot colourant. These properties impact the sensory attributes, and processing requirements of food products. By profiling these properties, researchers can enhance the use of the colourant in the preparation of various food products, such as baked goods, snacks, beverages, meat products etc. Moreover, the utilization of beetroot colourant can address the increasing demand for natural colourant. Synthetic dyes affect a significant portion of the population, thus, requiring the development of safe and health-promoting natural colourant. In addition, the development of value-added products from beetroot colourant can helps to create economic opportunities for farmers, food processors, and entrepreneurs, contributing to the overall economic growth of agricultural communities. Therefore, the main objective of this review is to provide information within the last few decades on the modification of the extraction method and profiling of beetroot for food applications.

2.0 Materials

This review paper is written using secondary data electronically sourced from Web of Science, Research Gate, Science Direct published in different journals, research gate, and annual reports studied by various researcher, institution and organization.

2.1 Chemical composition and nutritional profile

Beet root is a leading root vegetable with an exquisite cradle of nutrients, including proteins, sucrose, carbohydrates, vitamins (B-complex and vitamin C), minerals, fiber (Table 1). They contain an appreciable amount of phenolic compounds, betalains, and antioxidants such as coumarins, carotenoids, sesquiterpenoids, triterpenes, flavonoids (astragalin, tiliroside, rhamnocitrin, kaempferol, rhamnetin) with acclaimed multitudinal health privileges. Some other known bioactive compounds reported in beetroot are alkaloids (ipomine, calystegine B_1, calystegine B_2, calystegine B_3, calystegine C_1), tannins, and essential and non-essential amino acids, namely methionine, leucine, isoleucine, cysteine, histidine, arginine, and others as mentioned in Table 1 (Babarykin *et al.* 2019; Lechner and Stoner 2019).

Table1: Nutritional value of beetroot.

	g per 100 g
Nutrients	180
Energy (KJ)	1.61
Protein	0.17
Total lipid	1.08
Ash	9.56
Carbohydrate (by difference)	6.76
Sucrose	2.8
Total fiber	
Fatty acids	0.27
Total Saturated Fatty Acids (SFA)	0.026
Palmitic acid (SFA 16:0)	0.001
Stearic acid (SFA 18:0)	0.032
Total monounsaturated fatty acids (MUFA)	
Phenolic acids and flavonoids	89. 06 ± 4.62
Polyphenol	

Flavonoid	
Catechin	79.22 ± 2.04
Betacyanins	0.715 ± 0.018
Betaxanthins	0.30 ± 0.01
Vitamin C (as total ascorbic acid) (mg)	80.06 ± 2.06
Thiamine (mg)	4.9
	0.031

(USDAARS, 2019; Saponjac *et al.*, 2016; Barger *et al.*, 2022).

2.2 Betalains in red beetroot

Red beetroot contains a number of bioactive compounds that can exhibit health-promoting effects, including betalains, ascorbic acid, flavonoids and polyphenols betacyanins. Beetroots have approximately 75–95% betacyanins and 5–25% betaxanthins. More than 80% pigments from red beetroot consist of betacyanins, namely, betanin and isobetanin, an isomer of betanin. The content of these pigments present on the surface of vegetables is high, but it steadily decreases to the interior of the beet (purple and crown). A previous study investigated the content of betalains in the processed beetroot juice and reported that betanin served as the most abundant component (300–600 mg/kg), followed by vulgaxanthin and isobetanin (Yu *et al.*, 2020). Betalains possess a uniform structural characteristic that is derived from betalamic acid, together with a radical R1 or R2, where the substituents can be a hydrogen or radical. The variation in the substituent groups originates from diverse origins of pigments and influences their stability and hue. According to their chemical structure, it is relatively simple to extract betalains. Two predominat forms include yellow betaxanthins and redviolet.

The renowned betacyanin is betanin due to its typical red color from red beetroot. Structurally, betanin is betanidin 5-O-β-glucoside with a cyclic amine group and a phenolic group, acting as extremely excellent electron donors. The yellow-orange betaxanthins originate from the condensation reaction of amino acids or biogenic amines with betalamic acid (Slavov, 2013). The betalain remains stable at the pH range of 3–7. Some reported investigations have indicated that betacyanins and betaxanthins can absorb visible light, while the difference in structure among these compounds reflects on the light-absorbing ability (Yu *et al.* 2020). Furthermore, betalains are quite unstable and liable to degradation when oxygen and light are present at high temperatures.

2.3 Extraction of red beetroot pigments

The conventional extraction approaches like maceration and Soxhlet employ some organic solvents with or without heat treatment. Red beetroot pigments are usually extracted by physical pressing of the sliced red beetroots or centrifugation of ground roots followed by blanching. Aqueous extraction of shredded beetroots has also been used. The addition of ethanol or methanol to water is generally necessary to thoroughly extract the pigments in the presence or absence of acidification or heat treatment, especially for the improved extraction yield. A recent study evaluated the optimal extraction conditions (ethanol concentration and time) to recover betalains in red beetroot (*Beta vulgaris* L.). According to Iahtisham (2020), it was suggested that aqueous ethanol medium is appropriate for maximal recovery of beetroot betalains instead of ethanol or water as a single solvent. However, the main shortcomings of this conventional technique include long extraction time, degradation of betalains, and employment of toxic organic solvents as well as solvent contamination. Generally, maceration is a simple and economical method. However, this method is characterized by low yields, employment of organic solvents, and high extraction time. Similarly, Soxhlet is a common method, but it needs energy consumption and use of organic solvents (Yu *et al.*, 2020).

Currently, some nonconventional techniques that have been used for extraction of red beetroot pigments and the pretreatments have been proposed to improve extraction rate of betalains, these including cryogenic freezing, aqueous two-phase extraction, gamma irradiation, pulsed electric field, ultrasound-assisted extraction, microwave-assisted extraction and membrane processing. These extraction processes have advantages as alternative environmentally friendly procedures for extraction of betalains over conventional procedures, because they can decrease extraction time, post-treatment wastewater, and solvent-energy consumption (Yu *et al.*, 2020; Kosa and Zaheer, 2019).

2.4 Use of beetroot colourants in food products

Red beetroot serves as a frequently consumed vegetable in many western countries. It can be consumed either in raw, cooked, or mixed types. Meanwhile, red beetroot has the advantage of bright color, crisp, and tender flesh, which can be used for carving and color mixing in western cuisine. Application of betalains from red beetroot has been investigated because of their prevailing effect on flavor, color, and nutrition. Due to the synthetic red colorants' adverse effects on human health as a food additive, there is an increased interest in searching for natural pigments, e.g., betalains. Beetroot, as a food pigment, is used for coloring some dairy food products, such as yogurts, candies, jellies, chicken frankfurters, sausages, and ice cream. Also, beetroot as a dietary supplement or food additive could enhance sensory attributes, nutrition values, and bioactivities (Kohajdova *et al.*, 2018). Currently, betalains are widely employed in the food industry as an additive or a natural dye, and they exhibit in vitro and in vivo antioxidant ability mainly due to the presence of betacyanins. In addition, betalains can be applied in the packaging of food with natural polymers. A recent study has shown that betanin-fortified rice as a raw dietary supplement can be employed as a functional grain to improve health (Tian *et al.*, 2020).The present Brazilian legislation has indicated that the employment of natural red dye acquired from beetroots is permissible in beverages and foods. However, the limit for daily intake of betalains in healthy adults remains to be established for the moment.

2.5 Health promotion of betalains in beetroot

It has been reported that betalains exhibit anticancer, antiviral, anti-inflammatory, and antioxidant activities. Due to the potent antioxidant ability to scavenge free radicals, betalains and betalain-rich diets could be utilized for the potential treatment of various diseases, such as cardiovascular diseases, asthma, cancer, arthritis, intestinal inflammation, and diabetes (Yu *et al*,. 2020).

3.0 Conclusion

Betalains as important bioactive compounds are promising to be used in the food industry. The available scientific literature demonstrates that the methods used for the extraction and processing of betalains from red beetroot determine the stability and quality of the target products. However, some non-conventional technologies (cryogenic freezing, aqueous two-phase extraction, gamma irradiation, pulsed electric field, ultrasound-assisted extraction, microwave-assisted extraction and membrane processing) have the potential to improve the extraction rate of betalain. Furthermore, the present review can provide a theoretical basis to utilize red beetroot betalains as colorants and bio-functional ingredients in the food and medical industries.

4.0 Recommendations

Further research on modification approaches by optimizing various processing on structure and function in betalains, food safety and shelf life studies are crucial to fully exploit the potential of the colourant at both domestic and industrial level so as to boost the acceptance of the product.

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