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Estimation of betalain content in beetroot peel powder

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PAPER

Abstract

This study explores the economic benefits of utilizing beetroot peels as a source of natural color extraction, with a focus on reduction of waste. It was determined through rigorous experimentation that sun-drying at a controlled temperature of 22°C emerged as the optimal and most cost-effective method for preserving betalain content in peels. Furthermore, water was identified as the preferred solvent for extraction of betalain, exhibiting both higher yield and lower cost, compared to ethanol. The resulting beetroot powder demonstrated a stable pH range of 6.1–6.6, rendering it well suited for a diverse range of food applications. These findings emphasize the potential of beetroot peels as a valuable and sustainable source of natural colorants, with significant implications for the food and related industries.

Keywords: beetroot peels; natural color; reduction of waste; sun-drying; betalain content beetroot powder.

Introduction

According to the Food and Agriculture Organization (FAO), one-third of the produced food is wasted, which amounts to approximately 1.3 billion tons per year. This has significant economic, social and environmental impacts. Among the agro-food wastes, fruits, vegetables, roots, tubers and cereals have the highest rate of wastage. The minimally processed food industry generates plant-based food waste; however, recent research has shown that these food wastes might be useful because of their high content of bioactive compounds that can be recovered and used in the production of food additives, functional foods, supplements and nutraceuticals. The main bioactive compounds isolated from this waste include polyphenols, such as tannins, flavonoids, and anthocyanins, vitamins (A and E), essential minerals, fatty acids, volatile compounds and pigments (Vilas-Boas *et al.,* 2021). For example, natural pigments can replace synthetic colorants. Nowadays, natural colorants from various sources, particularly from waste plant material, have received particular attention and popularity because of the health awareness of consumers (Lu *et al.,* 2021; Sharma *et al.,* 2021). Beetroot (*Beta vulgaris* L.) plant from the *Amaranthaceae* family is a good source of antioxidants for phenolic compounds and betalains. Betalains are water-soluble nitrogenous compounds present in vacuoles of beetroot cells, and are divided into two subclasses: betacyanins (red pigments) and betaxanthins (yellow-orange pigments) (Figure 1).

According to Delgado-Vargas *et al.* (2000), betacyanins make up approximately 75–95% of beetroot pigments, with the remaining 5–25% comprising betaxanthins. In 2018, the global production of beetroot was estimated to be approximately 275 million metric tons, and the concentration of betalains in red beetroots is 200–2,100 mg/kg fresh weight. Red beetroot is used for

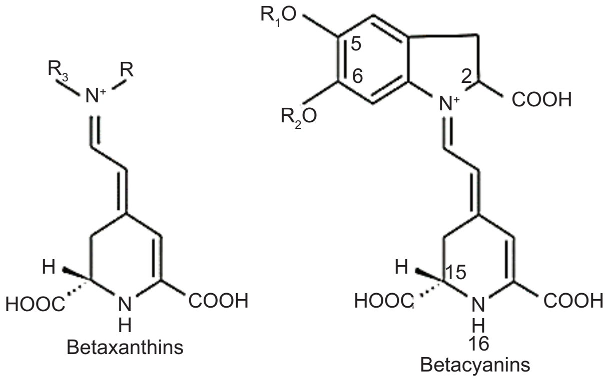

Figure 1. Main subclasses of betalains (Miguel, 2018).

human nutrition in both fresh and dried forms, such as chips, tea and powder for bakery, but it is also widely used as red food colorants, for instance, to improve the color of tomato paste, sauces, desserts, jams and jellies, ice creams, sweets, and cereals (Chhikara *et al.,* 2019; Clifford *et al.,* 2015; Kaur and Singh, 2014).

Drying is an alternative to the consumption of fresh fruits and vegetables and allows their use during the off-seasons. Dried beetroot powder has an extended shelf life and can be used as a value-added ingredient in a variety of food products for providing a strong red color (Bunkar *et al.*, 2020). The European Union has authorized the use of betalains in foods, with food code E162; this additive consists of several betacyanins obtained by the purification of mechanically processed beet juice (Nirmal *et al.*, 2021).

During the industrial process, the beetroots are peeled, and the peeled skin is discarded. The chemical composition of the beetroot peel is as follows: moisture (86.3%), ash (1.48%), total lipids (0.2%), crude fiber (2.6%), protein (1.02%) and total sugars (8.4%) (Shuaibu *et al.*, 2021). Beetroot peels possess numerous biological activities, such as antimicrobial, antioxidant, antihypertensive, anti-inflammatory, anti-anxiety, anticancer and antidiabetic properties (Aykın-Dinçer *et al.,* 2022; Deshmukh and Gaikwad, 2022; Nirmal *et al.,* 2021). The aim of this study was to investigate methods for reducing waste in beetroots by reusing beetroot peels and evaluating and comparing two different drying methods for beetroot peels as well as assessing the efficiency of two different solvents for extracting betalain content.

Materials and Methods

The study was carried out in 2022 at the Department of Food Science and Quality Control, College of Agricultural Engineering Sciences, University of Sulaimani, Sulaymaniyah-Kurdistan region-Iraq.

Sample preparation

Fresh beetroots (*Beta vulgaris* L.) were purchased from a local market in Sulaimani, and 4 kg beets were washed with tap water to remove adhered material, dirt and other surface impurities. The cleaned beetroots were peeled manually with a sharp knife at a thickness 2.25 ± 0.70 mm, measured by a digital Vernier caliper.

Drying method and yield calculation

The beetroot peels were dried by two different methods: sun drying and air (tray) drying. In sun drying method, the peels were spread and dried under the sun. The study was conducted in the autumn season, and the day temperature was between 22°C and 24°C. In tray drying, the fresh beetroot peels were placed on a stainless steel plate and dried in a lab dryer (XMT dryer-02200124/Japan) set to 40°C until the peels turned crispy. Beetroot peels dried by both methods were crunched into powder using an electrical grinding machine (Lexical LBL-1509- Germany). The weight obtained after the drying process is shown in Table 2, and the yield was calculated using the following equation as described by Zia *et al.* (2021):

$$\text{Yield}\% = \frac{W}{W_0} \times 100,$$

where

W is the weight of the dried extract and W_0 is the original weight of the sample.

Extraction of total betalain

In this study, ethanol:water (50:50) (solvent 1) and 100% deionized water (solvent 2) were the two solvents used to extract betalains from beetroot peel powder.

For extraction, 0.1 g of dried peel powder was dissolved in 10 mL of solvent and agitated for 1 min; the contents were centrifuged for 10 min at 3,600 g, and the supernatant was collected and analyzed by using the method described by Ravichandran *et al.* (2013).

Spectrophotometry analysis

The total betalain content of beet peels extract was determined using a spectrophotometer (UV-2602 Labomed spectrophotometer, USA). The absorbance was measured at two different wavelengths, 480 nm and 538 nm for betaxanthins and betacyanins, respectively. The betalain content was calculated using the following equation (Aztatzi-Rugerio *et al.*, 2019; Ravichandran *et al.*, 2013):

$$\text{Betalain content}\left(\frac{\text{mg}}{\text{L}}\right)=\left[\frac{\text{A}\times\text{MW}\times\text{DF}\times1000}{\varepsilon\times\text{L}}\right]$$

where

A is the absorbance; *MW* is the molecular weight; *DF* is the dilution factor; ε is the molar extinction coefficient, and *L* is the path length of the cuvette (1 cm). For quantification of betaxanthin and betacyanin, molar extinction coefficients in water and molecular weights were applied as ε = 48,000 L/mol×cm and MW = 308 g/mol; ε = 60,000 L/mol×cm, and MW = 550 g/mol, respectively.

Results and Discussion

Calculation of losses in beetroots

Table 1 shows the fresh peel and loss ratio for 2.3 kg of beetroot. The fresh peel ratio was recorded as 309 g, with 2.25-mm thickness of peels. Additionally, the heads and tails were eliminated and accounted for an additional 4.3% loss. Based on this calculation, 1 ton of beetroot, and fresh peels and losses consist of 134.3 kg and 43.4 kg, respectively, with a total of 177.7 kg of waste remaining per ton. This range was not acceptable economically as well as environmentally.

Drying temperature and powder yield (%)

In this study, two methods of drying, sun drying and tray drying, were used. Sun drying is one of the oldest and simplest methods of food preservation and is widely acceptable due to its low capital and operating costs as well as the little expertise required. On the other hand, tray or cabinet drying using hot air is a laboratory-based and industrial method of food dehydration that involves transferring heat to the surface of the foodstuff exposed to hot air to evaporate moisture from the food surface. We converted the final product into powder, as powder has a longer shelf life and greater solubility than the flesh form. The two different methods used for drying determined how temperature affects the stability and extractability of betalain. The results are shown in Table 2. The final yields of sun-drying and tray-drying methods were 17.4% and 17.8%, respectively, showing no significant differences ($p < 0.05$) between both drying methods. However, calculating the drying time showed that tray drying took only 8 h, compared to sun drying, which took a longer time of 120 h. As reported in the Material and Methods section, the average atmosphere temperature during the study was between 22°C and 24°C, which explained the higher drying period under these conditions. The drying time is an important parameter to consider because it not only affects production costs but also modifies the chemical characteristics of the product, increasing the time of exposure to the air and therefore the risk of oxidation.

Estimation of total betalain content extracted by different solvents

Table 3 shows the total betalain content in peel powder extracted using water and ethanol 50%. The maximum total betalain content of 418 mg/L was recorded in sun-drying method and water for extraction, while the lowest total betalain content of 172 mg/L was obtained in hot air-drying (tray) method and ethanol 50% for extraction.

The amount of betacyanin in the water extract was higher due to its hydrophilic nature and stability over a high pH range, while the amount of betacyanin in the ethanol 50% extract was lower because the presence of organic solvents, such as ethanol, increases the susceptibility of betacyanins to deacylation, resulting in decreased betacyanin and betalain contents (Herbach *et al.*, 2006). Indeed, some studies reported that water gives the maximum solubility of betalain, compared to the solvents, such as ethanol and acetone (Gokhale and Lele, 2014; Udonkang *et al.*, 2018). In addition, Deng *et al.* (2015) reported that betalain compounds could be easily extracted by using pure water, and noted that the type of solvent used affected the final yield of extraction and stability of pigments.

Considering the drying method used, Table 3 shows that the total betalain content obtained with both extraction

Table 1. Calculation of beetroot peel waste and remaining components.

Weight of beetroots (kg)	Fresh peels (kg)	Loss (kg)	Flesh (kg)
2.33 ± 1.5	0.309 ± 0.20	0.1 ± 0.06	1.924 ± 1.260

Table 2. Drying conditions, powder weight and yield (%).

Drying method	Temperature	Powder weight (g)	Yield (%)	Drying time (h)
Sun drying	22–24°C	46.5 ± 0.5	17.4	120
Tray drying	40°C	47.5 ± 0.55	17.8	8

Table 3. Total betalain (betacyanin and betaxanthin) content extracted by using different solvents. Different letters indicate statistically significant differences between average values ($p < 0.05$).

Drying method	Solvent extraction	Betacyanin (538 nm) (mg/L)	Betaxanthin (480 nm) (mg/L)	Total betalain (mg/L)	pH
Tray drying, 40°C	Water	130.9 ± 8.1[b,c]	87.6 ± 6.4[c,d]	219	6.2 ± 0.03
	Ethanol 50%	98.7 ± 6.21[c,d]	72.9 ± 3.8[d]	172	6.6 ± 0.06
Sun drying, 22–24°C	Water	253.0 ± 37.1[a]	165.2 ± 23.0[b]	418	6.1 ± 0.05
	Ethanol 50%	130.8 ± 11.5[b,c]	94.8 ± 6.2[c,d]	226	6.5 ± 0.01

solvents (water and ethanol 50%) were higher in sun-drying method (418 and 226 mg/L) than in tray-drying method (219 and 172 mg/L). This could be attributed to the lower temperature used in sun drying, compared to tray drying. This was accorded by various studies (Bunkar *et al.*, 2020; Gokhale and Lele, 2014; Ravichandran *et al.*, 2013) that reported temperature as an important factor affecting stability of betalains. The degradation of betalains increases with an increase in temperature, and the past studies have shown that betacyanin is more temperature-sensitive than betaxanthin.

The pH range of the beetroot extracts prepared from powder obtained by different drying methods and with different solvents was 6.1–6.6. This result was consistent with the study conducted by Bunkar *et al.* (2020), which reported pH of beetroot powder extract in the range of 5.9–6.8. As reported by Liliana and Oana-Viorela (2020), betalains are stable at a pH range of 3–7; hence, slightly different pH values observed in the extracts cannot be considered responsible for different yields of betalains.

Unexpectedly, the longer period of exposure to air in sun-dried powder appears to not affect stability of betalains, or if a higher oxidation occurs in the sun-drying method, compared to tray-drying, this effect is much lower compared to the effect of temperature.

Conclusions

The purpose of drying beetroot peels and converting into powder is to recover waste of the beetroot production industry and extend its shelf life as a natural colorant for subsequent use. The study findings highlighted the potential benefits of utilizing beetroot peels for natural color extraction. Between the two drying methods explored in the study, sun-drying method at a temperature of 22–24°C emerged as the most effective and cost-efficient approach for maintaining betalain content within beetroot peels. Moreover, the investigation revealed that water, as a solvent for betalain extraction, not only yielded higher quantities but also proved more cost-effective, compared to ethanol. An additional significant observation was the pH of 6.1–6.6 of resultant beetroot powder. This pH stability is crucial for its suitability in diverse food applications. These comprehensive findings strongly support the viability of beetroot peels as a valuable reservoir of natural colorants, demonstrating their potential utility across multiple industries, notably the food industry.

Author Contributions

BKS conceived and designed the study. BKS conducted the research. SV performed the statistical analysis. BKS and SV wrote the original draft of the manuscript. Both authors read and contribute to the review and editing of the final manuscript.

Conflict of interest

The authors declared no conflict of interest.

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