Green extraction of betacyanin from beetroot peel using microwave and ultrasound technology

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The extraction of phytochemicals from waste food sources and other byproducts has emerged a major step towards sustainable technology. Beetroot is the widely preferred source for commercial extraction of betacyanin. Water was used as a green solvent for the extraction. Microwave and ultrasound technology were used to extract betacyanin from dried and powdered beetroot peel. The recovery was observed to greater at higher temperature for low extraction time. The betacyanin content for microwave extraction and ultrasound extraction was 58.16 mg/g and 55.36 mg/g, respectively. The microwave technology was proved to be better in comparison to ultrasound technology for extraction of betacyanin content.

Keywords: Green extraction, microwave, ultrasound, betacyanin.

Introduction

Phytochemicals are produced by plants for different auxiliary functions like defense, repair etc. They possess several pharmaceutical and health benefits such as anti-inflammatory, antibacterial, antioxidant, etc. They are also used as additives and colorants in a variety of food products. The efficient recovery of phytochemicals has always been a challenging task. Raw fruits and vegetables are primarily used in the daily diet, cuisines and food production at industrial scale. But the processing of fruits and vegetables leads to generation of agricultural and food processing waste. There are no specific guidelines for the disposal of such waste which can contribute to billion tons of waste. These agricultural and food processing waste, and their by-products still contain several valuable phytochemicals[1]. The sustainability of agro and food processing units can be improved by recovering the phytochemicals from such waste[2]. The extraction of phytochemicals is done by using organic solvents like ethanol, methanol, acetone, diethyl ether etc.[3]. These organic solvents are often toxic in nature and generate pollutants and wastewater. Water can be used as a green solvent for the extraction of phytochemicals. Water is non-flammable, non-toxic, eco-friendly, cheap and is available is abundance. Since, water is a polar solvent, polar compounds have better solubility in it[4].

Betacyanin are naturally occurring hydrophilic compounds found in plants beetroot, bougainvillea, dragon fruit, cactus pear and amaranth[5]. The structural conformation of betacyanin consist of betanidin, a glycone having acyl group and sugar branches[6]. These red-violet pigments have become popular because of their stability in the pH range between 3–7. They possess natural coloring properties and have potent antioxidant activity[7]. They are also reported to have health benefits due to their anti-inflammatory, antidiabetic and antitumor properties. They are also used in processing of meat, confectionary products, beverages etc.[8]. Conventional extraction of betacyanin from Amaranth species, colored quinoa, dragon fruit etc. is reported[9–11]. However, the conventional techniques had several limitations such as long extraction time, decomposition of compounds, low stability, low yields and usage of toxic organic solvents[12–15]. These limitations have led to application of non-conventional technologies for the extraction of phytochemicals. The non-conventional technologies include ultrasound assisted extraction, microwave assisted extraction, pulse electric field extraction etc. Ultrasound technology involves the use of ultrasounds to produce a cavitation effect. This effect leads to the breakdown of cell walls of plant matrix, facilitating solvent diffusion and increasing mass transfer[8]. In microwave technology, the molecules are heated by the influence of conduction and dipole moment. The heating causes the disin-

tegration of cell wall causing the liberation of compounds into the solvent[16]. The efficiency of extraction in both the techniques is affected by process parameters such as extraction temperature, extraction time, choice of solvent, etc. Microwave and ultrasound have been used for the extraction of phytochemicals from different plant sources[17–20].

Peel of fruits and vegetables are considered as waste and contains a wide variety of phytochemicals. The extraction of phytochemicals from peel of fruits and vegetable has been also reported[21–23]. The peel of beetroot is a waste of beetroot processing. The main aim of this research was to use water for recovery of betacyanin using microwave and ultrasound technology. Extraction time (3 min, 5 min and 8 min) and temperature (40°C, 70°C and 95°C) were considered as process parameters.

Experimental

The beetroot peels were collected from the local fruit juice shops. The peels were washed and then sorted to remove damaged peels. It was subject to oven drying at 40°C for 24 h. The powder of dried peels was made by grinding it in a domestic grinder[24].

The extraction experiments were carried out in a Microwave-ultrasound reactor (Model: NutWav Pro provided by Nutech Analytical Technologies Pvt. Ltd., India). Preliminary experiments were done to determine the optimum ratio of sample and solvent (1:4). 4 g of dried powdered beetroot peel was taken in 80 mL of distilled water for the extraction of betacyanin. After extraction, the samples were filtered by Whatman filter paper No. 1 and extracts were stored in amber bottles. The absorbance for betacyanin content was measured 536 nm and 650 nm. The betacyanin content of the extracts were calculated by eq. (1) given by Wruss et al.[25]:

$$\text{Betacyanin content (mg/g)} = \frac{(A \times DF \times MW \times 1000)}{(\varepsilon \times i)} \quad (1)$$

where molecular weight of betacyanin (MW) = 550 g/mol, A = $A_{536nm} - A_{650nm}$, ε (molar extinction coefficient in L×mol^{-1}× cm^{-1}) = 60,000. DF = dilution factor, i = path length of cuvette in cm.

The optimization of extraction was done by conducting nine experiments for both microwave and ultrasound technology. The combination of extraction time and temperature

was same for both technologies. All the experiments were performed in triplicate. One-way ANOVA was used for the statistical analysis of the experimental data.

Results and discussion

The moisture content of samples was determined by oven drying method. Drying of samples was done at 40°C for 24 h. Initial moisture content of beetroot peel was 87.5% and the moisture content of oven dried sample was 5.13%.

Effect of microwave technology on betacyanin content:

The betacyanin content obtained from the microwave extraction is depicted in Table 1. The highest yield (55.91 mg/g) of betacyanin content was obtained at 95°C of temperature for 3 min of extraction time. The lowest yield (39.86 mg/g) was obtained at the same temperature for 8 min of extraction. The betacyanin content was significantly affected by both the process parameters. The loss in extraction yield of betacyanin can be due to thermal treatment at higher temperature ranges[16]. It was reported when extraction is carried for longer duration at higher temperature the betacyanin are decomposed. It was also reported that yellow product viz. cyclo-dopa-5-O-glucoside and betalamic acid are produced due to decomposition of betacyanin[4]. The betacyanin content from beetroot peel using microwave technology was higher than *Gomphrena globosa* as reported[15].

Table 1. Betacyanin content of beetroot peel

Experiment No.	Process parameters		Betacyanin content (mg/g dry weight of powdered sample)	
	Time (min)	Temp. (°C)	MAE	UAE
1	3	40	42.38±0.12^a	40.25±0.28^a
2	5	70	44.83±0.39^a	41.56±0.70^a
3	8	95	39.86±0.04^a	36.85±0.37^a
4	3	70	43.50±0.91^b	42.05±0.58^b
5	3	95	55.91±0.55^a	53.74±0.97^b
6	5	40	41.35±0.73^a	42.73±0.86^a
7	5	95	53.82±0.29^b	50.11±0.07^a
8	8	40	58.16±0.45^a	55.36±0.22^a
9	8	70	46.27±0.33^a	43.95±0.10^b

The data was significant when p > 0.05 denoted by superscript '*a*' and the it was non-significant when p < 0.05 denoted by superscript '*b*'.

Effect of ultrasound technology on betacyanin content:

Table 1 shows the betacyanin content of beetroot peel. The ultrasound extraction carried out at 40°C for 8 min yielded
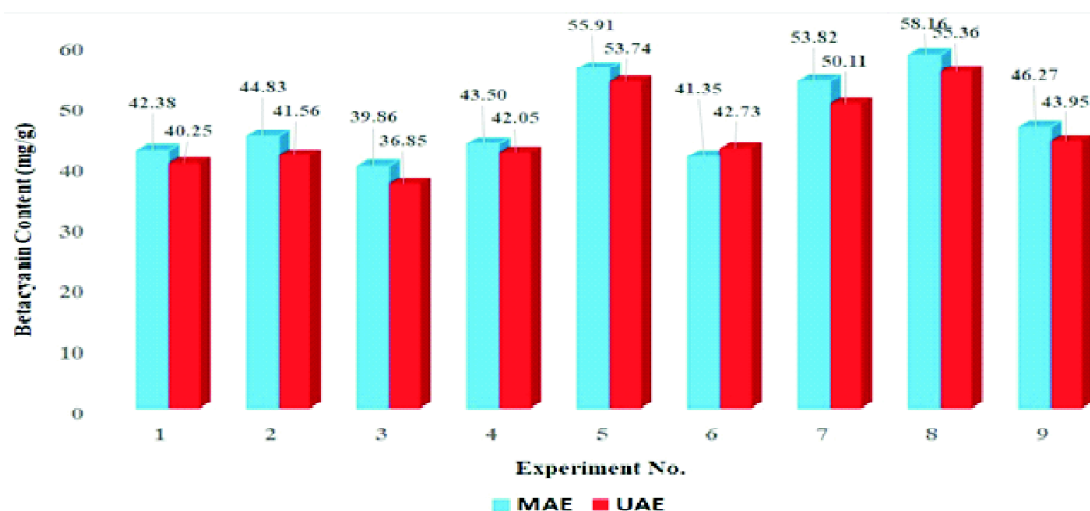
Fig. 1. Bar graph representation of betacyanin content (mg/g) obtained by microwave assisted extraction (MAE) and ultrasound assisted extraction (UAE).

the highest betacyanin content (55.36 mg/g). The betacyanin content was reduced to the lowest value (36.85 mg/g) at 95ºC for the same extraction time. The cavitation effect created by the virtue of ultrasounds causes the enlargement of pores and swelling of plant matrix. This influenced the diffusion of betacyanin into the solvent and increased the extraction efficiency. It was also reported that increase in temperature decreases the viscosity and surface tension of the solvent which affects the mass transfer[26]. The swelling of plant matrix took a longer time during initial stage of extraction. This betacyanin content is increased because micro-bubbles tend to collapse at the contact surface due to the cavitation effect[27]. The betacyanin content of beetroot peel obtained by ultrasound extraction was greater in comparison to *Basella rubra* betacyanin content[28].

Comparison between microwave and ultrasound technology for betacyanin content:

The comparison between microwave and ultrasound technology is shown in Fig. 1. It can be observed from the bar graph that the recovery of betacyanin was higher for microwave extraction than ultrasound extraction. The superiority of microwave technology to ultrasound technology in terms of phytochemical recovery has also been reported[29,30].

Conclusion

The beetroot peel has been found as a good source of betacyanin. It can be easily used for the extraction using both microwave and ultrasound technology. Distilled water proves to be better and green solvent for betacyanin recovery.

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