Innovative Food Science and Emerging Technologies 32 (2015) 136–145

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

journal homepage: www.elsevier.com/locate/ifset

Evaluation of ultrasonic nozzle with spray-drying as a novel method for the microencapsulation of blueberry's bioactive compounds

Feyza Tatar Turan [a], Alime Cengiz [a], Talip Kahyaoglu [a,b,*]

[a] Department of Food Engineering, Engineering Faculty, Ondokuz Mayıs University, 55139 Samsun, Turkey
[b] Department of Food Engineering, Chemistry-Metallurgical Faculty, Yıldız Technical University, 34210Istanbul, Turkey

ARTICLE INFO

Article history:
Received 21 July 2015
Received in revised form 9 September 2015
Accepted 19 September 2015
Available online 8 October 2015

Keywords:
Ultrasonic nozzle
Conventional nozzle
Spray-drying
Freeze-drying
Blueberry
Bioactive compounds

ABSTRACT

In this study, using an ultrasonic nozzle in the production of blueberry microspheres was investigated as a new technology by comparing with a conventional nozzle. In addition to this, ultrasonic and conventional nozzles were compared with freeze-drying method. In the first part of the study, the physicochemical properties of microspheres were examined and compared with each other. There were no significant differences ($p > 0.05$) in the total phenolic content and antioxidant activity of blueberry extract microspheres produced by ultrasonic nozzle and freeze-drying. Moreover, with regard to morphological characteristics, microspheres produced by ultrasonic nozzle were observed to be more uniform in terms of size and shape. Secondly, the microspheres were evaluated for their impact on the quality of ice creams and cakes. In ice cream, the ultrasonic nozzle microspheres showed phenolics content retention ($p > 0.05$) similar to freeze-dried microspheres. After baking, the ultrasonic nozzle microspheres of extract-enriched cake had the highest anthocyanin retention (79.35%). As a result, it was observed that the ultrasonic nozzle used in this study provided more protection for blueberry's bioactive compounds compared with a conventional nozzle.

Industrial Relevance: The ultrasonic nozzle technology is a new atomization technology for food applications. The ultrasonic nozzle technology used in this study could lead to application in the food industry improving the stability of blueberry phenolics and other bioactive compounds.

1. Introduction

Blueberry fruits are a rich source of bioactive compounds such as anthocyanins and proanthocyanidins and other flavonoids. However, the short shelf life of blueberry fruits has remained a huge challenge that agri-food industries have to face. Thus, different methods have been investigated to enhance their stability and to protect the bioactive compounds against the effects such as temperature, light, oxygen, and pH. Microencapsulation is a process that has been widely used to protect food ingredients from adverse environmental conditions. Bioactive compounds have been incorporated in microcapsules to stabilize them, to convert them into powders, to alleviate unpleasant tastes or flavors, as well as to improve their bioavailability. In the literature, microencapsulation of blueberry was studied in terms of color and chemical stability (Jiménez-Aguilar et al., 2011), antioxidant capacity and anthocyanin content (Lim, Ma, & Dolan, 2011), physical and storage properties (Flores, Singh, & Kong, 2014) and in vitro release properties of blueberry with different wall materials (Flores, Singh, Kerr, Phillips, & Kong, 2015).

Among the available microencapsulation methods, spray-drying offers several advantages, it is a continuous process, which is a potentially economical technologythat requires short residence times. The spray-dryer is usually generated by pressure, rotary or two fluid nozzles that have some drawbacks such as poor control of the mean droplet size, broad droplet size distributions and risk of clogging in case of suspensions (Dalmoro, Barba, Lamberti, & d'Amore, 2012). In addition, these nozzles' operating energy (pressure, centrifugal or kinetic energy) is transferred to the kinetic energy of the particles, which causes a partial separation of the compounds in mixture or defects on the microcapsules' surfaces. These disadvantages can be reduced or overcome using an alternative nozzle type like ultrasonic nozzles. Ultrasonic nozzle technology employs ultrasound vibrational energy as a means to atomize fluids (Klaypradit & Huang, 2008). The vibration energy applied to the atomizing surface spreads to the surface, forming a liquid film and then when the liquid film absorbs vibrational energy, it generates capillary waves. The capillary waves causea collapse; ejecting small drops of the liquid (Fig. 1). One advantage of using an ultrasonic nozzle is that the mechanical stress caused by the ultrasonic vibration is relatively minor so that it does not damage bioactive compounds

* Corresponding author at: Food Engineering Department, Chemistry-Metallurgical Faculty, Yıldız Technical University, 34210Istanbul, Turkey. Tel.: +900 0212 383 45 77.
E-mail address: talipk@yildiz.edu.tr (T. Kahyaoglu).

http://dx.doi.org/10.1016/j.ifset.2015.09.011
1466-8564/

(Park & Yeo, 2004). Another advantage of this nozzle is that the probe and exit orifice are relatively large, and practically uncloggable, which can be accurately controlled for more uniform size distribution, sphericity of droplets and required low energy (Berger, Mowbray, Copeman, & Russell, 2010). Also, the ultrasonic nozzle shows success in accurately processing low flow rates.

There are limited studies in the literature regarding the application of ultrasonic nozzles in microencapsulation (Bittner & Kissel, 1999; Freitas, Merkle, & Gander, 2004; Klaypradit & Huang, 2008; Legako & Dunford, 2010; Yeo & Park, 2004). Klaypradit and Huang (2008) investigated the feasibility of chitosan based on encapsulation of fish oil by the ultrasonic spray drier. Also, Legako and Dunford (2010) produced fish oil microcapsules by using 2- and 3-fluid pressure and ultrasonic nozzles and evaluated the physical and chemical properties of the microcapsules.

Another common microencapsulation method is freeze-drying, which is based on the removal of water by sublimation of the frozen product (Horszwald, Julien, & Andlauer, 2013). The freeze-drying method can minimize damage to the product (structure, texture, appearance and flavor changes, etc.), which can occur as a consequence of the high drying temperature used in spray-drying (Anwar & Kunz, 2011). However, there are some disadvantages to this process, such as the long drying time and higher energy consumption. In addition, an industry-scale comparison showed that the freeze-drying process is 4–5 times more expensive than the spray-drying technique (Hammami & René, 1997).

To the best of our knowledge, there is lack of studies examining the physicochemical properties of blueberry microspheres prepared by using an ultrasonic nozzle and the application of such microspheres in food production. Therefore, the objectives of this study were: (1) to produce blueberry (*Vaccinium corymbosum* L.) microspheres by different methods (spray-drying and freeze-drying methods), (2) to compare the physicochemical properties of microspheres, and (3) to evaluate the functional properties of ice cream and cake enriched with microspheres. The study aimed to improve the physicochemical properties of microspheres by ultrasonic nozzle and lay the foundation for food production and application of blueberry microspheres.

2. Materials and method

2.1. Materials

Cultivated early season ripening blueberries (Highbush blueberry, *V. corymbosum* L.) were purchased from Gifimey Ltd. Şti. (Giresun, Turkey). The fruits were stored at −18°C until used. Maltodextrin (Sigma Chemical, St. Louis, USA) of 4–7 dextrose equivalents (DE) were used as a wall material with gum arabic (Merck, Darmstadt, Germany). All the other reagents used for analyses were of analytical grade.

2.2. Blueberry juice and extract preparation

The fruits were destemmed, washed and crushed into juice using a blender (Warring Products Division, Dynamics Corporation of America, New Hartford, CT). The fruit juice was centrifuged at 21,111 *g* for 5 min, filtered through filter paper using a Buchner funnel with vacuum, and then used for experiments. The blueberry juice had a total solids content of 8.5 ± 0.5°Brix.

For the extraction of the bioactive compounds of blueberry fruits, they were washed and crushed and then 0.1 kg of blueberries were extracted with 97% (v/v) ethanol until a volume of 200 mL was reached. Extraction was performed at room temperature (22°C) using an Ultra-Turrax (IKA T25 digital, Germany) operating at 21,111 *g* for 30 min. The extraction flask was covered with aluminum foil to protect against photodegradation. The resulting extracts were filtered with a vacuum filter and evaporated in vacuum for 2 h (Buchi Rotavapor R-3, Switzerland), at 40°C and a vacuum pressure of 23 mmHg.

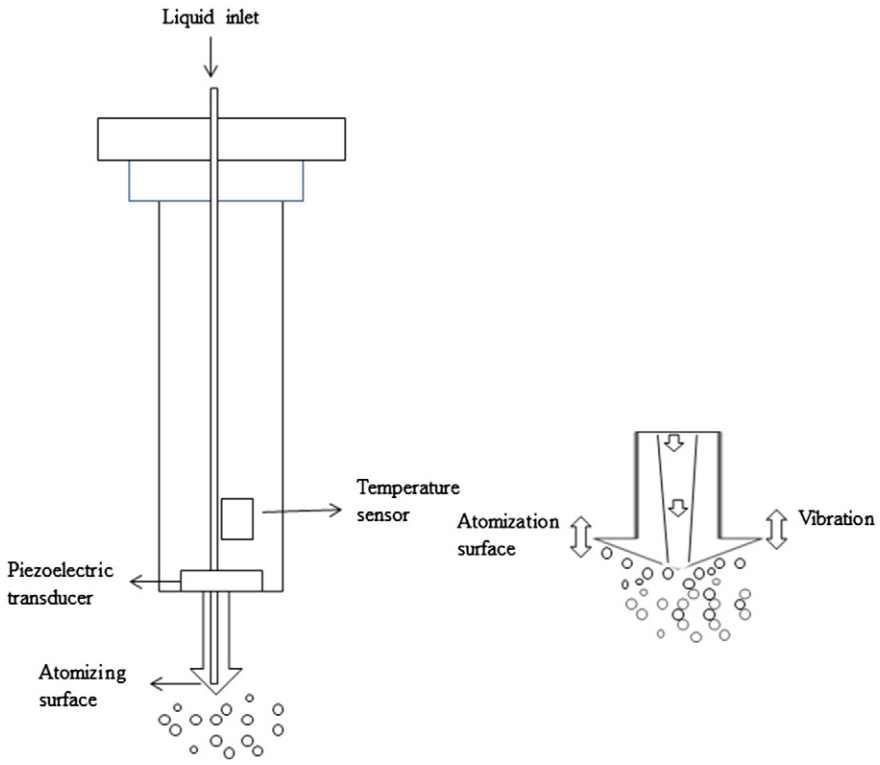

Fig. 1. Schematic representation and working principle of the ultrasonic nozzle.