Journal of Food Engineering 194 (2017) 67–78

Contents lists available at ScienceDirect

Journal of Food Engineering

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

Spray drying of inulin component extracted from Jerusalem artichoke tuber powder using conventional and ohmic-ultrasonic heating for extraction process

Krittiya Khuenpet [a], Mika Fukuoka [b], Weerachet Jittanit [a,*], Sarote Sirisansaneeyakul [c]

[a] Department of Food Science and Technology, Faculty of Agro-Industry, Kasetsart University, 50 Ngam Wong Wan Road, Chatuchak, Bangkok, 10900, Thailand

[b] Department of Food Science and Technology, Tokyo University of Marine Science and Technology, 4-5-7 Konan, Minato-ku, Tokyo, Japan

[c] Department of Biotechnology, Faculty of Agro-Industry, Kasetsart University, 50 Ngam Wong Wan Road, Chatuchak, Bangkok, 10900, Thailand

ARTICLE INFO

Article history:
Received 7 October 2015
Received in revised form
2 September 2016
Accepted 5 September 2016
Available online 8 September 2016

Keywords:
Electrical conductivity
Extraction
Inulin
Jerusalem artichoke
Ohmic heating

ABSTRACT

In this study, various ohmic heating conditions and conventional heating were applied in the inulin extraction process from Jerusalem artichoke tuber (JAT) powder. The inulin extracts were evaporated to be around 30 °Brix and then spray-dried to be inulin powder. The main objectives were (1) to compare the quality of inulin extracts obtained from different extraction conditions and (2) to evaluate the yield of inulin powder production from JAT powder and the inulin powder quality. The results showed that the electrical conductivities of JAT powder solutions ranged between 0.0677 and 0.2057 S/m. The application of ohmic heating method at electrical frequency of 20 kHz and electrical field strengths of 15 and 20 V/cm could not raise the inulin extraction yield when comparing with the conventional heating. The addition of ultrasonic treatment step into the ohmic heating process could not escalate the extraction yield. The sugar and inulin contents in the extracts obtained from various ohmic heating treatments and conventional heating were not much different. The inulin contents of all extract samples were roughly in range between 75 and 80 g/100 $g_{dry\ mass}$. The production yields of inulin powder from JAT powder were 14.53–17.29% which was rather low due to the loss of solids occurring in the extraction and spray drying processes. The scanning electron micrographs illustrated that the particle sizes of inulin powders produced in this study were much smaller than those of commercial inulin powders.

1. Introduction

Jerusalem artichoke (*Helianthus tuberosus* L.) is a native species of sunflower originally found from Canada and then cultivated widely in Europe, North America and Asia (Seljasen and Slimestad, 2007). Many varieties of Jerusalem artichoke (JA) were bred, developed and successfully grown in Thailand especially in the northeastern region (Vorasoot and Jogloy, 2006; Tanjor et al., 2012). Jerusalem artichoke tubers (JAT) accumulates inulin instead of starch as a carbohydrate reserve (Marx et al., 1997; Takeuchi and Nagashima, 2011).

Inulin is a linear polymer of fructose unit joined by β-(2 → 1) D-fructosyl-fructose bonds and terminated with/without a glucose unit by α-D-glucopyranosoyl bond (Blecker et al., 2002; Ronkart et al., 2007). The chain lengths of these fructans or degrees of polymerization (DP) of inulin range between 2 and 60 units (Van Loo et al., 1995; Judprasong et al., 2011) depending on species, harvesting maturity, storage time and production conditions (Saengthongpinit and Sajjaanantakul, 2005; Stanley and Nottingham, 2007). Small molecules with DP < 10 are called fructo-oligosaccharides (FOS) (Sirisansaneeyakul et al., 2007). Inulin is a non-digestible carbohydrate commonly used by the food industry as a soluble dietary fiber, prebiotic and fat or sugar replacement (Barclay et al., 2010; Gunnarsson et al., 2014).

The extraction is a key step for the inulin production from JAT. It is similar to the extraction of sucrose from sugar beets because inulin is water soluble especially in hot water. One of the most common methods for isolation of inulin from plants is hot water extraction (Srinameb et al., 2015). The raw materials for inulin extraction in industrial practice could be either dried or fresh JAT. If

* Corresponding author.
E-mail address: fagiwcj@ku.ac.th (W. Jittanit).

http://dx.doi.org/10.1016/j.jfoodeng.2016.09.009

the factory does not have sufficient facilities to handle all the fresh JAT in its harvesting season, the JAT should be dried and stored to be raw material for inulin powder production along the rest of the year. In case of applying dried raw material, the freshly harvested JAT would be washed, sliced, blanched, dried and then grounded to be powder (Khuenpet et al., 2015a,b). The dried JAT is milled to be powder prior to extraction step in order to raise its specific surface area, facilitate the mass transfer from inside the particle to the solvent and subsequently improve the inulin extraction efficiency. For the inulin extraction by applying the fresh JAT, it seems like the production steps consume less energy than that of dried JAT because the drying process is not required; however, the fresh JAT must be processed within a few days due to its short storage life under atmospheric condition. In Thailand, JAT can be harvested after 100–140 days planting, and crop yields of JAT are regularly 13–19 ton per hectare (Tiengtam et al., 2015). It would be difficult and costly for the inulin production factory to process all the freshly harvested JAT to be inulin powder within the limited time during harvesting season. Although cold storage might be used for extending its shelf life, the investment, energy and maintenance costs are normally not cheap and even more expensive than drying JAT and then storage under room temperature. Moreover, it was proved that the chemical compositions in JAT especially inulin content changed along the storage period in coldroom. Saengthongpinit and Sajjaanantakul (2005) reported that after 4–6 weeks of cold storage JAT at 2 and 5 °C, sucrose and FOS (DP 3–10) increased and DP > 10 fractions decreased. Drying JAT before extraction is often essential in order to reduce the degradation and chemical changes during storage (Marur and Sodex, 1995). Moreover, drying JAT for long term storage enabling factories to efficiently manage their raw material procurement, inventory and production.

So far, most published researches applied conventional heating method for the hot water extraction of inulin from JAT. In general, they used high temperatures between 70 and 100 °C and long duration for their experiments leading to cell tissue alteration and impurities release into the inulin extract (Franck, 2006; Toneli et al., 2008; Zhu et al., 2014). Main important factors influencing on the yield of inulin extraction include temperature, extraction time and ratio of solvent and solid (Paseephol et al., 2007; Toneli et al., 2008; Abou-Arab et al., 2011; Saengkanuk et al., 2011; Apolinário et al., 2014). The increase of extraction temperature, time and solvent proportion normally results in the inulin extraction yield escalation; however, the energy and time consumption together with the solvent cost must be considered in order to determine the optimum condition. Saengthongpinit and Sajjaanantakul (2005) applied hot deionized water at 80 °C for 1 h in inulin extraction from JAT and coagulated inulin by alcohol precipitation prior to drying. Precipitation of inulin is related to the polarity of solvent. High concentration of ethanol had lower polarity than water resulting in inulin precipitation (Saengthongpinit, 2005). Luque-Garcia and Luque de Castro (2003) pointed out that precipitation by alcohol is efficient and widely used in laboratory; however, it was deemed uneconomical and unsuitable for industrial-scale inulin production due to the price of alcohol and its recovery cost. Recently, Srinameb et al. (2015) studied inulin extraction from JAT powder by accelerated solvent extractor (ASE) using water as the extraction solvent. The highest extraction efficiency was obtained when the extraction temperature of 80 °C for 20 min was used.

Thus far, there have been some researchers applying the innovative methods such as pulsed electric field, ohmic heating and ultrasonic in their extraction processes with the expectation to raise the extraction efficiency when comparing with the conventional method (Milani et al., 2011; Wanpen et al., 2013; Jovanovic-Malinovska et al., 2015; Loypimai et al., 2015). The pulsed electric fields were applied by using alternating electric field at 200 V and frequency of 50 Hz on extraction of fruit juices from prunes, apples and grapes; as a result, an increase of juice yield up to 10% was found (Flaumenbaum, 1949). Zagorulko (1957) and Vorobiev et al. (2005) described that the increase in extraction yield after applying pulsed electric field occurred due to the electrical breakage of cellular membranes, namely electroplasmolysis phenomena. Wang and Sastry (2002) and Lebovka et al. (2005a,b) claimed that ohmic heating could induce electropermeabilization of the cell membranes. Vorobiev and Lebovka (2008) described that when the electrical current flows through the biological tissue, it causes both temperature rise and also membrane damage resulting in the diffusion of solutes inside the cellular structure. Ohmic heating was successfully applied to increase the efficiency of sucrose extraction from sugar beet, extraction yield of soy milk form soy beans and beet dye diffusion (Halden et al., 1990; Kim and Pyun, 1995; Lima et al., 2001). Some studies such as Lakkakula et al. (2004) found that ohmic heating could increase the extraction yield of rice bran oil from rice bran that is fine particle; however, no investigation has been conducted on the use of ohmic heating to extract inulin from fine JAT powder. The applications of ohmic heating at high frequency have been interested by some researchers due to its fast heating rate. Park et al. (1995), Imai et al. (1996) and Wu et al. (1998) stated that the heating rate of food materials depended on the frequency of alternating current during ohmic heating. Imai et al. (1995) found that heating rate of egg albumin solution slightly increased as frequency increased. The heating rate at 10 kHz is 7.5 times greater than that of 50 Hz for fish protein gel (Park et al., 1995). Another potential technique for enhancing the extraction yield in food industry is ultrasonic (Mason et al., 1996). Jovanovic-Malinovska et al. (2015) applied the ultrasonic to assist inulin extraction from JAT powder. They reported that ultrasound assisted extraction by using ethanol concentration 63% v/v, extraction temperature of 40 °C and sonication time of 10 min could increase the concentration of extracted inulin from JAT powder about 4-fold compared with the conventional extraction that applied ethanol concentration 85% v/v at 50 °C for 60 min. Moreover, Wanpen et al. (2013) investigated the effect of ultrasonic pretreatment on inulin extraction from JAT and found that the ultrasonic pretreatment caused higher mono- and di-saccharides ratio in inulin extract indicating that ultrasound pretreatment promoted depolymerization of inulin chain.

Although there have been a number of researches applying innovative methods for raising the efficiency of extraction process, the published articles related to the inulin extraction from JAT powder by ohmic heating and ultrasonic are remarkably limited. Hence, the objectives of this research were (1) to compare the quality of inulin extracts obtained from different extraction conditions and (2) to evaluate the yield of inulin powder production from JAT powder and the inulin powder quality.

2. Materials and methods

2.1. JAT powder preparation

Fresh JAT variety JA 102 was supplied by Petchaboon Research Station, Faculty of Agriculture, Kasetsart University, Thailand. The fresh JAT was processed to be JAT powder by applying the method of Khuenpet et al. (2015a,b). The JAT samples were washed and sliced into 2 mm thickness. The slices were immediately immersed in 0.5% w/v citric acid solution for 5 min and blanched in boiling water for 2 min. Then, the slices were dried in a tray dryer at temperature of 65 °C until reaching moisture content equal or less than 8% dry basis (d.b.). Dried JAT chips were ground into JAT powder by two milling steps applying a Fitz mill model M5 (The