Spray-drying for Inulin Powder Production from Jerusalem Artichoke Tuber Extract and Product Qualities

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บทคัดย่อ

อินูลินเป็นพอลิแซ็กคาไรด์ซึ่งมีคุณสมบัติเชิงหน้าที่เป็นพรีไบโอติกในการศึกษานี้ อินูลินถูกสกัดจากหัวแก่นตะวันแล้วถูกทำแห้งแบบพ่นฝอยเพื่อแปรรูปเป็นผลิตภัณฑ์ผง วัตถุประสงค์หลักของการศึกษานี้คือ เพื่อหาสภาวะการทำแห้งแบบพ่นฝอยที่เหมาะสมและคุณภาพของอินูลินผง สารสกัดอินูลินที่มีความเข้มข้น10, 20 และ 30° บริกซ์ถูกนำมาทำแห้งแบบพ่นฝอย โดยใช้อุณหภูมิลมร้อนขาเข้าและขาออกที่150 และ 90 องศาเซลเซียส ตามลำดับ ผลการทดลองแสดงให้เห็นว่า การใช้สารสกัดที่มีความเข้มข้น 30°บริกซ์ ให้ผลิตภัณฑ์อินูลินผงที่มีลักษณะดี ได้ปริมาณผลผลิตสูงและผงที่ได้มีความชื้นต่ำ หลังจากนั้นได้ทดลองทำแห้งโดยใช้อุณหภูมิลมร้อนขาเข้าที่150, 170 และ 190 องศาเซลเซียส ในขณะที่อุณหภูมิลมร้อนขาออกและความเข้มข้นของสารสกัดจากแก่นตะวันถูกกำหนดที่ 90 องศาเซลเซียสและ 30°บริกซ์ตามลำดับ ผลปรากฏว่า อุณหภูมิลมร้อนขาเข้าที่ระดับ 190 องศาเซลเซียส มีความเหมาะสมมากกว่า 150 และ 170 องศาเซลเซียส เพราะให้ปริมาณผลผลิตสูงกว่า ผลิตภัณฑ์ผงมีความชื้นต่ำกว่า มีความสามารถในการละลายและค่าการดูดซับดีกว่า และมีความคงตัวมากกว่า ภาพจาก กล้องจุลทรรศน์อิเล็กตรอนแบบส่องกราด (SEM)แสดงให้เห็นว่าผงอินูลินที่ผลิตโดยการทำแห้งแบบพ่นฝอยที่อุณหภูมิลมขาเข้า150 และ 170 องศาเซลเซียส มีรูปทรงที่กลมมากกว่า และมีการเกาะติดกันของอนุภาคมากกว่ากรณีที่ใช้อุณหภูมิลมขาเข้าที่ 190 องศาเซลเซียส

คำสำคัญ: อินูลิน แก่นตะวัน พรีไบโอติก การทำแห้งแบบพ่นฝอย

Abstract

Inulin is a polysaccharide that has functional properties as a prebiotic. In this study, inulin was extracted from Jerusalem artichoke (JA) tubers and then spray-dried to become a powder form. The key aims of this study were to determine the suitable spray-drying conditions and the inulin powder qualities. The inulin extracts at concentrations of 10, 20, and 30 ºBrix were spray-dried using the inlet/outlet drying temperatures at 150/90ºC. As a result, the feed material at 30 ºBrix provided good characteristics of inulin powder with high powder recovery and low moisture content. Then the drying experiments were conducted at inlet air temperatures of 150, 170, and 190ºC whereas the outlet air temperature and the JA extract concentration were fixed at 90ºC and 30 ºBrix. It appeared that the drying temperature of 190°C was more appropriate than 150°C and170°C because it provided higher powder recovery, lower moisture content, better solubility and absorptivity, and more stability of powder. The SEM micrographs showed that the inulin powders produced by the spray-drying temperatures at 150 and 170°C had more sphere-shaped and had attached particles than those at 190°C.

Keywords: Inulin: Jerusalem artichoke: Prebiotic: Spray-drying

Introduction

Jerusalem artichoke tuber (JAT) is an agricultural product rich in inulin [1]. Inulin is a polysaccharide consisting of a chain of fructose molecules with a terminal glucose molecule. It has many functional properties such as a fat substitute, prebiotics, and dietary fibers depending on its degree of polymerization (DP). It was observed that inulin could increase viscosity, give 'body', optimize the texture of low calorie beverages, and provide spread-ability to low fat and no fat products, yogurts, salad dressings, mousses, and chocolates [2]. Some studies revealed that soluble non-starch polysaccharide such as inulin had a positive effect on cholesterol metabolism in rats [3].

During the last few decades, it appears that Jerusalem artichoke (JA) can be successfully grown in Thailand, especially in the Northeastern region. At present, JAT is deemed as a popular herbal food among Thai people due to its neutraceutical properties especially for diabetics. However, the knowledge and technique about the production of inulin powder from JAT is still limited. This study extracted inulin from JAT and it was then spray-dried into a powder form. The key aims of this study were to determine the suitable spray-drying conditions and the inulin powder qualities.

Materials and Methods

JAT powder preparation

The fresh JAT variety JA 102 was supplied by the Agro-Ecological System Research and Development Institute, Kasetsart University (Petchaboon Research Station), Thailand. Raw JAT samples were washed to eliminate soil and other impurities, sliced to a 2 mm thickness, blanched in hot water for 2 min, and then dried at 65°C until reaching the moisture content below 8% db. Dried JAT was ground to be JAT powder using a Fitz mill model M5 (The Fitzpatrick Company, USA) and then an Alpine Augsburg pin mill type 160Z (Alpine American Corporation, Natick, MA). The JAT powder was screened by 60 and 80 mesh sieves after the 1st stage milling by a Fitz mill and the 2nd stage milling by a pin mill. The JAT powder was used as a raw material for inulin powder production by applying extraction, evaporation, and spray-drying procedures.

Preparation of inulin extract

Inulin was extracted from the JAT powder using hot water at 85°C for 30 minutes with the ratio of powder to water of 1:35 (w/w). After that, the sediment was separated from the extract using a basket centrifuge at 1,500 rpm with a filtering bag. The inulin extract was used as the raw material for the inulin powder production.

Determination of suitable concentration of inulin extract for spray-drying

Inulin extract was evaporated to the concentrations of 10, 20, and 30 °Brix by boiling it on a "FISHER" hot plate stirrer model 210T (Fisher Scientific (M) SdnBhd, Selangor Darul Ehsan, Malaysia) using a magnetic bar for stirring at speed level 3. The concentrated solution was processed to be powder by a "NIRO" small-scale spray dryer model "Mobile Minor 2000" (GEA Process Engineering Inc., USA) using the inlet and outlet drying at 150°C and 90°C respectively. The powder recovery percentage of each spray-drying experiment was calculated applying the equation (1) whereas the qualities of inulin powder collected from each spray-drying run were determined in aspects of color and moisture content. The results were used for determining the suitable concentration of inulin extract for spray drying.

$$\%\ \text{product recovery} = \frac{\text{Solid weight of powder after spray drying}}{\text{Total soild weight in feed material before spray drying}} \times 100$$

Determination of suitable spray-drying temperature for inulin powder production

The inulin extract samples at the suitable concentration determined from the previous step were spray-dried applying the inlet drying air temperatures at 150, 170, and 190°C whereas the outlet air temperature was maintained at 90ºC by controlling the feed flow rate. The powder recovery percentage was calculated while the qualities of inulin powder were determined in aspects of moisture content, water absorption index (WAI), water solubility index (WSI), bulk density, and microstructure.

Color measurement

The colors of samples were measured in triplicate by a Hunter Laboratory Mini Scan XE colorimeter (Hunter Associates, Reston, VA) in the L*, a*, b* scale. L* represents lightness ($0 \leq L \leq 100$), while a*(+), a*(-), b*(+) and b*(-) represent redness, greenness, yellowness, and blueness respectively. The colorimeter was calibrated with a standard white tile using illuminant D65 and the10° standard observer.

Moisture content determination

The moisture contents were determined in triplicate by the oven method using 2 g of sample and 105°C drying air temperature until constant weight was obtained [4].

Determinations of WAI and WSI

The WAI and WSI were determined in triplicate by application of a modified method [5]. The 2.5 g of powder sample was suspended in 30 ml of water at 30°C in a 50-ml centrifuge tube, left for 30 min, and then centrifuged at 5,000 g for 10 min. The supernatant was separated out whereas the remaining sediment was weighed. The WAI was calculated by dividing the sediment weight by the dry weight of the initial powder sample. The WSI was calculated by dividing the amount of dry solid in the separated supernatant by the dry weight of the initial powder sample and expressed as a percent.

Bulk density

Bulk density was determined in triplicate by adding 20 g of inulin powder to a 50 ml graduated cylinder and holding the cylinder on a vibrator for 1 min. The bulk density was calculated by dividing the mass of the powders by the volume occupied in the cylinder.

Microstructure

The microstructures of inulin powders were observed by scanning electron microscopy (SEM). Powder samples were sprinkled onto double-sided tape on an SEM stubs and then sputtered with gold (SCD 040, Balzer Union, Switzerland) prior to the microstructure observation by the “JEOL” scanning electron microscope model JSM-6610LV (Seal Laboratories, USA). Magnification of 1,000 times and accelerating voltage of 15 kV were applied using the signals of secondary and backscattered electrons.

Table 1 Powder recovery percentages, moisture contents, and color values of powder samples produced from inulin extracts at various concentrations by spray-drying at inlet/outlet temperatures of 150/90^{o}C

Attribute	Concentration of inulin extract (°Brix)		
	10	20	30
Powder recovery (%)	67.78^{a}±0.80	82.24^{b}±1.11	88.13^{c}±0.41
Moisture content (%wb)	7.48^{c}±0.12	6.78^{b}±0.05	6.56^{a}±0.14
L*	89.61^{c}±0.51	80.91^{b}±1.12	77.29^{a} ±0.32
a*	-0.60^{a}±0.12	-1.10^{b}±0.29	-1.32^{c}±0.22
b*	9.10^{a}±0.17	11.14^{b}±0.20	12.46^{c}±0.15
Whiteness index	76.03	72.41	68.93

Note: Means with different letters in the same row are significantly different at *P<0.05

Statistical analysis

The software package of SPSS version 16.0 was used for the analysis of variance in the statistical analysis.

Results and Discussion

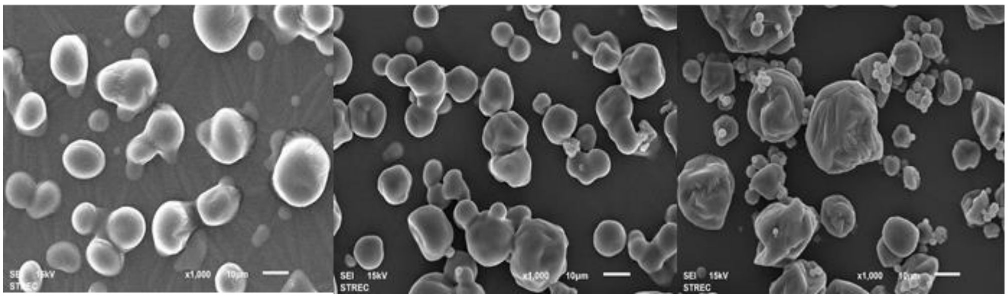
The results of the spray-drying experiments using various concentrations of inulin extract are illustrated in Table 1. It appeared that the concentration of inulin extract at 30 ^{O}Brix provided a significantly higher powder recovery percentage than those of 10 and 20 ^{O}Brix. Furthermore, the moisture content of the powder sample produced from 30 ^{O}Brix inulin extract was significantly lower than those of 10 and 20 ^{O}Brix. This may be due to the fact that the increase in solid contents of feed material led to the reduction of water proportion in the feed. As a consequence, when applying the same drying temperature, the moisture content of inulin powder was less than those of 10 and 20 ^{O}Brix counterparts. Although the concentration of inulin extract at 30 ^{O}Brix provided the higher product recovery with preferred moisture content level, the color of its powder was more intense than those of 10 and 20 ^{O}Brix. This intense color was caused by more heat exposure of the sample during spray-drying. This heat exposure together with the reducing sugars and amino acids in the specimens resulted in a browning reaction, namely Maillard reaction. According to the experimental results, it can be stated that the suitable inulin extract concentration for spray-drying was 30 ^{O}Brix due to its high powder recovery percentage and low moisture content of the powder, whereas the more intense color of the powder was not a serious problem because, in general, only a small amount of inulin powder is applied when adding to food.

The results of the spray-drying experiments using various drying air temperatures for 30 ^{O}Brix inulin extracts are presented in Table 2. It appeared that the drying temperature of 190°C provided the higher product recovery than those of 150°C and 170°C. This may be due to the lower moisture content of the spray-dried inulin powder under this drying condition resulting in higher glass transition temperature and subsequently less hygroscopicity and stickiness of product. The less hygroscopicity and stickiness of the product causes a less amount of solid attachment on the surface of the spray-drying chamber and other compartments of the spray-drying system [6]. In regard to the WAI and WSI values, it was found that the higher drying temperature at 190°C resulted in a better solubility and absorptivity of the powder. This was because the higher drying temperature caused a higher drying rate leading to a more porous structure of the inulin powder [7]. The result of the bulk density determination indicated that the higher drying temperature at 190°C provided the higher bulk density of powder. This may be due to the increased shrinkage of the inulin powder as a result of the application of a higher temperature.

Table 2 Powder recovery percentages, moisture contents, WAI, WSI, and bulk densities of powder samples produced from 30 ^{O}Brix inulin extracts using various drying air temperatures

Inlet/outlet temperature(°C)	**Powder recovery (%)**	**Moisture content (%wb)**	**WAI (g/g)**	**WSI (%)**	**Bulk density (g/ml)**
150/90	88.13^{a}±0.41	6.43^{ab}±0.13	1.21^{b}±0.06	45.38^{a}±4.80	0.58^{a}±0.24
170/90	87.23^{a}±0.47	6.77^{b}±0.63	0.80^{a}±0.16	71.64^{b}±4.97	0.62^{a}±0.37
190/90	90.59^{b}±0.94	6.07^{a} ±0.14	1.09^{b}±0.18	77.35^{b}±5.20	0.74^{b}±0.18

Note: Means with different letters in a column are significantly different at *P<0.05



(a) **(b)** **(c)**

Figure1 Scanning Electron Microscopy (SEM) micrographs of spray dried inulin powder using various drying air temperatures: (a) 150°C; (b) 170°C; (c) 190°C

The powder microstructures in the cases of the application of the drying temperatures at 150, 170 and 190°C were investigated using SEM, as shown in Figure 1. It appeared that the inulin powders produced by the spray-drying temperatures at 150 and 170°C had more sphere-shaped and attached particles than those at 190°C. This should be the consequence of the lower glass transition temperature and subsequently higher hygroscopicity and stickiness of the product dried at lower temperatures which had higher moisture content levels. In general, the powder that had the higher moisture content level had lower glass transition temperature [8].

Conclusion

The most appropriate inulin extract concentration for spray-drying was 30 °Brix, while the drying temperature of 190°C was more appropriate for inulin production than 150°C and170°C because it provided a higher powder recovery, lower moisture content, better solubility and absorptivity, and more stability of powder.

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