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FULL PAPER

Effect of temperature and foam mat drying method on the physical and chemical properties of white sweet potato (*Ipomoea batatas* L.) inulin

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Abstract

White sweet potatoes have functional compounds that are good for the body in the form of inulin. Inulin is a soluble fiber that is very useful for digestion and body health. Several factors can affect the physical and chemical characteristics of inulin produced such as temperature and drying method. The study was conducted to determine the yield, physical, and chemical characteristics of white sweet potato inulin. The experimental design in the study used a Completely Randomized Design (CRD) with two factors. The extraction process is carried out by grinding sweet potatoes, mixing them with distilled water, filtering and evaporation. A variation of temperature in extraction is 40°C, 60°C, and 80°C while the foaming agent in the foam mat drying process uses 2% and 10%. The physical and chemical characteristics that were analyzed are the water absorption, solubility, availability, and moisture content of inulin. The result is that with a higher temperature and concentration of foaming agent, the yield and moisture content are getting lower while water absorption and solubility are getting higher. Whereas the analysis of availability shows that the result of all formulations is inulin even though it is assumed to have a different amount. The higher the temperature in the extraction process and the higher the concentration of foaming agent used in inulin the lower the yield.

1. Introduction

Inulin is a fructose unit polymer with a glucose terminal group that is very useful for digestion and body health (Sardesai, 2003). The fructose unit in inulin is linked by β-(2à1)-glycosidic bonds in a straight chain (Ma'aruf, 2011). The use of inulin is very widespread in the food industry. Inulin's needs in Indonesia have increased from year to year, but all of them are still imported from other countries. Inulin is a fructan homopolymer that was first isolated from Inula helenium. Inulin can also be found in chicory, dandelion, and artichoke (Roberfroid, 2000). According to Tungland (2000), inulin can be obtained from red onion, scallion, garlic, banana, asparagus, wheat, and barley. In addition, inulin can also be extracted from dahlia tubers (Zahranti, 2005) and from local tubers such as cassava (*Manihot esculenta*), uwi (*Dioscorea* spp.), sweet potato (*Ipomoea batatas* L.), and gembili (*Dioscorea esculenta* L.) (Louise *et al*., 2017).

The utilization of sweet potatoes is increasingly being calculated as an alternative food ingredient in food diversification in Indonesia. Based on the Direktorat Kacang-Kacangan dan Umbi-Umbian (Directorate of Beans and Tubers Republic of Indonesia, 2002) the starch content in white sweet potatoes was 28.79% with a reduced sugar content of 0.32%. This causes the difference in total sugar and reducing sugar to be greater, and then the availability of inulin is also getting bigger (Siregar, 2014). In addition, as a basic nutrient, namely, a source of carbohydrates other than rice, white sweet potatoes have functional compounds that are beneficial for the health of the human body (Wahyono *et al*., 2015). One of the functional compounds in white sweet potatoes is inulin (Arfiani, 2016).

The inulin drying process by oven produces low concentrations of inulin because the fructan units are hydrolyzed during the drying process (Gupta *et al*., 2003) and the results are sticky, lack crumbs, and have poor physical appearance (Wilujeng, 2010). The drying process using a cabinet will produce semi-crystalline inulin which has a hard texture and has a little difficulty interacting with other foods in the mixing process, but the costs are cheap (Toneli *et al*., 2006). Spray drying will produce amorphous inulin that is easily soluble in water, but has expensive costs (Toneli *et al*., 2008). Therefore, alternative drying is needed which requires a

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lower cost but does not change the properties of the original material. One of the drying methods that will be applied is a foam mat.

Foam mat drying is a method of drying liquid material that is used as foam first by adding a foaming agent by shaking it then drying, the result is a crumb structure, easy to absorb water, and easily soluble in water (Kumalaningsih *et al*., 2004). The addition of a foaming agent and filler on drying will likely affect the inulin. In the previous study, inulin extraction from White Sweet Potato obtained a 7.72% yield (Yudhistira *et al*., 2019) and yellow sweet potato obtained an 8.80% yield (Yudhistira, Siswanti and Anindita *et al*., 2020). In addition, the blanching and foam mat drying methods for inulin extraction using albumin obtained a yield of 22.53% (Yudhisthira *et al*., 2020). The results of the treatment have been applied and have improved the characteristics of the marshmallow product (Yudhistira *et al*., 2021) and bread (Yudhistira *et al*., 2022). In this study, the physical and chemical properties of inulin from white sweet potatoes were tested which were obtained from temperature variations in the extraction process and the foam mat drying method in the isolation process.

2. Materials and methods

2.1 Preparation of samples

Fresh white sweet potato variety from Korea, sourced from Matesih, Karanganyar, Central Java, was used in the extraction, isolation, and characterization stages of inulin. White sweet potato is carried out by washing, stripping the skin, washing again, molding with a thickness of 1 mm, drying, and sifting with an 80-mesh sieve (Kosasih *et al*., 2015). Inulin Standard (Fibruline Instant Ex Cosucra from Chicory) for comparison analysis.

2.2 Inulin extraction

White sweet potato flour was mixed with distilled water (1:5) and soaked for 1 hr, then heated in a water bath (40°C, 60°C, and 80°C) with stirring for 30 min, filtered with a two-layer filter cloth, and evaporated using a vacuum rotary evaporator (73°C; 60 rpm; 2.5 hrs). The extraction process is carried out as much as twice by repeating the residue from the first stage of extraction (Kosasih *et al*., 2015).

2.3 Isolation of inulin

The inulin extract produced was regulated by % Brix to 30%, soaking the inulin extract in 95% ethanol (1:2) for 12 hrs, separating the solvent and extract using a centrifuge (15 mins, 5000 rpm) (Kosasih *et al*., 2015). The foam mat (FM) method is used to dry inulin by mixing the inulin extract with a foaming agent (egg white) and filler (maltodextrin) using a mixer until foamy for 5 mins, then the foam is dried in a drying cabinet at 60°C for 3 hrs. Dry inulin extract is ground to obtain inulin powder (Winarti *et al*., 2013). All treatments follow code, F0: 80^{o}C without FM drying; F1: 40^{o}C, egg white 2%; F2: 40^{o}C, egg white 10%; F3: 60^{o}C, egg white 2%; F4: 60^{o}C, egg white 10%; F5: 80^{o}C, egg white 2%; and F6: 80^{o}C, egg white 10%.

2.4 Physical analysis

2.4.1 Water absorption

Samples were prepared to 1–1.5 g, then wrapped in filter paper and tied tightly. Then, the sample was hung in a jar containing distilled water at a distance of half the height of the jar, and the jar was closed tightly. Sample weighing was carried out after 5 hrs of treatment (Yuwono and Susanto, 2001).

$$\text{Water Absorption (\%)} = \frac{(W_2 - W_1)}{W_1} \times 100\%$$

Where W_1: sample initial weight and W_2: sample final weight

2.4.2 Solubility

A Whatman 41 filter paper was placed in the oven at 105°C for 10 min, then cooled in a desiccator, and weighed to a constant weight. Then 3.5 g of sample is put into 150 mL of distilled water at a temperature of 25°C and filtered with filter paper with known weight. The filter paper is reheated at 105°C for 3 hrs, cooled in a desiccator and weighed to a constant weight.

$$\text{Solubility (\%)} = \frac{(W_1 - W_2)}{W_1} \times 100\%$$

Where W_1: sample initial weight and W_2: sample final weight

2.5 Chemical analysis

2.5.1 Total sugar and reducing sugar

Preparation of DNS reagent was prepared by dissolving 10.6 g of 3,5-dinitrosalicylic acid and 19.8 NaOH in 1416 mL of water. After that, 306 g of Na-K Tartrate, 7.6 g of phenol melted at 50^{o}C and 8.3 g of Na-metabisulphite were added. This solution was stirred thoroughly, and then 3 mL of this solution was titrated with 0.1 N HCl with a phenolphthalein indicator. The standard curve was constructed by measuring the value of reducing sugar in glucose in the range of 0.2–0.5 mg/L. Then, the value of reducing sugar was searched using the DNS method. The results obtained were plotted in a linear graph. The total reducing sugars were determined using the DNS standard curve. Approximately 1 mL of sample was put into a test tube, and then 3 mL of DNS

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reagent was added. The solution was placed in boiling water bath for 5 mins and then allowed to cool to room temperature. The wavelength absorbance was measured at 550 nm (Miller, 1959).

2.5.2 Liquid Chromatography-Mass spectrometry

The sample was dissolved in distilled water at a temperature of 100°C. Then, the sample was injected, with methanol containing 0.3% acetic acid and water containing 0.3% acetic acid (9:1) and 10% water as the mobile phase uses methanol at a flow rate of 1 mL/min and an injection volume of 20 µL (Susilowati *et al.,* 2015).

2.5.3 Water content

Water content analysis was carried out by preparing an empty bottle. Next, the bottle was placed in the oven for 1 hr and weighed before adding the sample. A sample of 1-2 g was placed in it, then heated for 4 hrs at 105 °C. During heating, weighing is carried out to reach a constant weight (AOAC, 2002).

$$\text{Water Content (\%)} = \frac{(W_1 - W_2)}{(W_1 - W_0)} \times 100\%$$

Where W_0 : weight of the bottle, W_1 : sample initial weight and W_2 : sample final weight

2.6 Data analysis

The study used a completely randomized design (CRD) with two treatment factors. The data obtained were analyzed by SPSS version 16.0 using One Way ANOVA if there were significant differences between treatments followed by the DMRT test (Duncan Multiple Range Test) with a significance level of <0.05.

3. Results and discussion

3.1 Characteristics of white sweet potato flour

Based on Table 1, the difference between total sugar and reducing sugar is 10.44±0.04%. This means that there is a possibility of the availability of inulin compounds in white sweet potatoes (Siregar, 2014); therefore, it can be continued from the extraction process to the isolation of inulin to obtain the compound.

Table 1. Characteristics of white sweet potato flour

Analysis	Content (%)
Reducing sugar	4.62±0.02
Total sugar	15.06±0.07

3.2 Inulin powder yield

Table 2 shows that the highest value of yield is F1. In this study, the yield ranged from 4.22 to 6.93% (d/w). This result was lower than the previous study related to the effect of foam mat drying on the extraction of white sweet potatoes, which only ranged from 6.66-22.53% (d/w) (Yudhistira *et al*., 2020). It can be seen that the higher the temperature, the lower the water content; furthermore, the resulting yield is also lower because the substances that evaporate cause the material to decrease in weight (Syafrida *et al*., 2018). Likewise, the concentration of the foaming agent (egg white). The higher the concentration of egg white, the more air is trapped; hence, the water easily evaporates during the drying process. The inulin rendering is inversely proportional to the increasing temperature and concentration of the foaming agent (Harmayani *et al*., 2011).

3.3 Water absorption

Based on Table 2, the largest value of water absorption is F6. This indicates that the higher the temperature used, the higher the absorption of water due to the increased ability to absorb water. Agustina (2008) reported that the size of water absorption is influenced by water content, so the lower the water content, the higher the ability to absorb water. According to Harmayani *et al*. (2011), the use of foaming agents in the form of egg white affects the absorption of water from the produced inulin. Water absorption will increase with the increasing concentration of protein in the material. The presence of fiber in materials is also affected because of the nature of fibers that easily absorb water (Richana, 2004). Harmayani *et al*. (2011) stated that egg white contains a number of OH that can bind to water

Table 2. Characteristic white sweet potatoes inulin by foam mat drying method

Formulation	Yield (%) (d/b)	Water Absorption (%)	Solubility (%)	Water Content (%)
F0	5.00^{d}	$8.09±0.09^{a}$	$3.97±0.08^{d}$	$1.14±0.37^{b}$
F1	6.93^{g}	$8.06±0.14^{a}$	$3.74±0.05^{a}$	$1.46±0.84^{c}$
F2	6.22^{f}	$8.07±0.10^{a}$	$3.75±0.02^{a}$	$1.19±0.10^{b}$
F3	5.29^{e}	$8.13±0.08^{a}$	$3.76±0.06^{b}$	$1.07±0.29^{a}$
F4	4.84^{c}	$8.18±0.04^{a}$	$3.77±0.08^{b}$	$1.06±0.29^{a}$
F5	4.40^{b}	$8.34±0.03^{b}$	$3.81±0.03^{c}$	$1.05±0.30^{a}$
F6	4.22^{a}	$8.57±0.07^{c}$	$3.82±0.01^{c}$	$1.03±0.15^{a}$

Values are presented as mean±SD. Values with different superscripts within the same column are statistically significantly different at α = 0.05.

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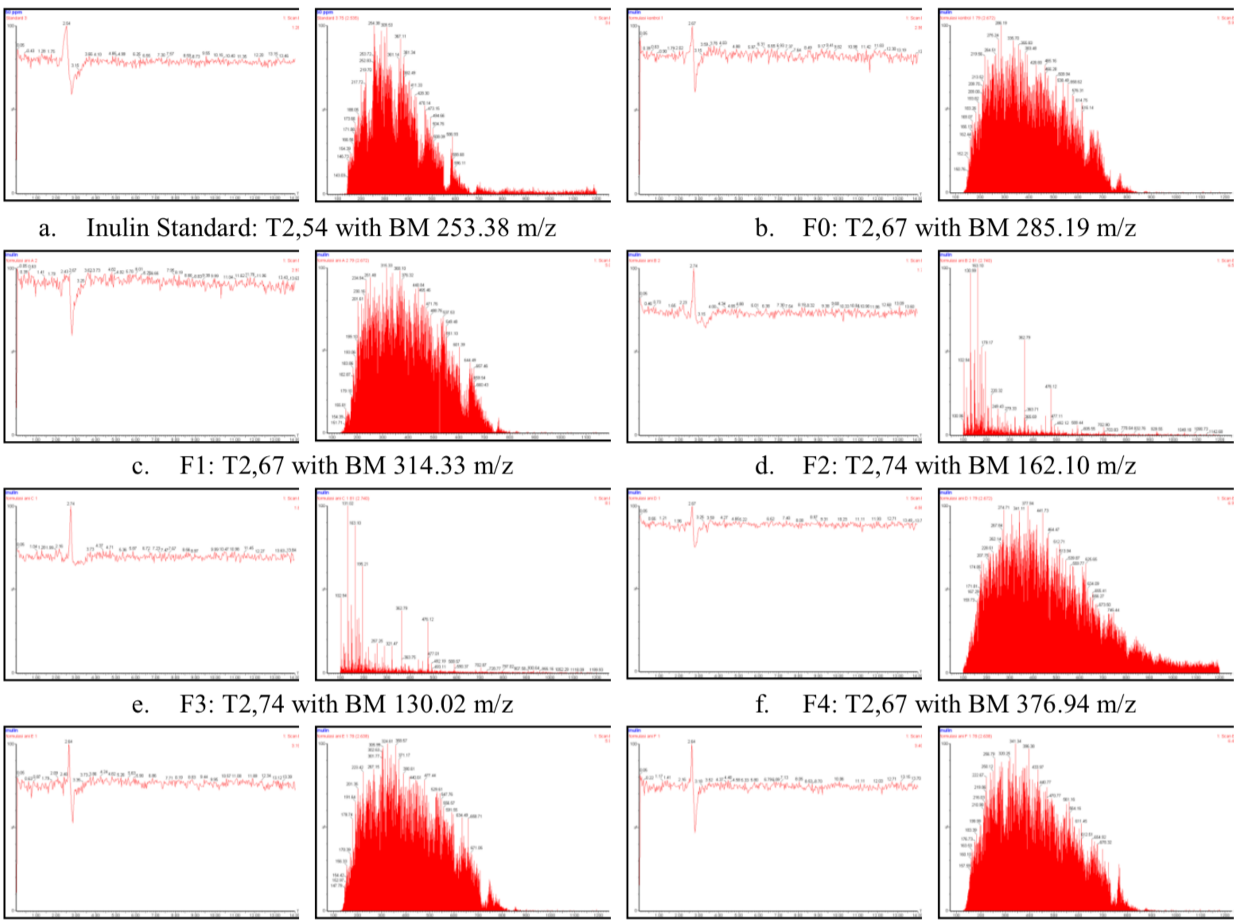
molecules around it. Foaming agents affect the absorption of water, according to Kumalaningsih *et al.* (2004) the material dried by this method will be easier to absorb water. The density of inulin produced from the foam mat drying method is low. Furthermore, it is easy to bind moisture (Kumalaningsih *et al.*, 2004). Water absorption properties are related to the rehydration of a material as well, and this is associated with the structure of inulin. Where materials with high porosity also have a high level of rehydration (Punthi *et al.*, 2022), this property is important for determining the processing stage or application of this inulin.

3.4 Solubility

Based on Table 2, the greatest solubility is F6. In this study, the water content ranged from 3.74-3.97% (d/w), this result was lower than in previous studies related to the effect of foam mat drying on the extraction of white sweet potatoes, which only ranged from 3.68-4.72% (d/w) (Yudhisthira *et al.*, 2020). The solubility of inulin is influenced by OH groups, which cause inulin to be polar; hence, it dissolves easily in water. The increase in solubility of inulin is also caused by the presence of air trapped during foam formation. Inulin is produced which is more axle. The nature of this shaft makes it easier to penetrate the water when dissolved (Winarti *et al.*, 2013). The easier the water enters, the greater the tendency to form OH bonds (Dewi *et al.*, 2012). The higher the temperature during the evaporation process, the more evaporated substances are released from the material, and the weight of the material produced decreases (Desrosier, 1988). The higher the concentration of egg white used, the higher the solubility because egg white contains a number of OH which can bind water molecules around it (Harmayani *et al.*, 2011).

3.5 Inulin availability

The F1–F6 sample as shown in Figure 1 has 3 samples that are thought to have low inulin content, this is because the use of temperature in the three formulations tends to be low, thus inhibiting the absorption of inulin. However, in the last 3 formulations, F4, F5, and F6 were close to the retention time of standard inulin at T2, 54. According to Kelly (2008), the molecular weight of inulin will be directly proportional to the length of the chain link. The shorter the bond, the more soluble the compound can be used as a substitute for sugar in its application. But on the contrary, if the bond gets longer then it will be difficult to dissolve and it can be used for fat substitution in the application. If seen from the whole picture of the inulin spectrum at F0, F1, F4, F5, and F6 which has a high molecular weight (greater than the standard BM inulin of 253.38 m/z), it can be used for fat substitution because it can replace the



a. Inulin Standard: T2,54 with BM 253.38 m/z
b. F0: T2,67 with BM 285.19 m/z
c. F1: T2,67 with BM 314.33 m/z
d. F2: T2,74 with BM 162.10 m/z
e. F3: T2,74 with BM 130.02 m/z
f. F4: T2,67 with BM 376.94 m/z
g. F5: T2,64 with BM 323.61 m/z
h. F6: T2,64 with BM 340.34 m/z

Figure 1. Chromatogram and mass spectrum inulin

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fat function as in nonfat milk products, yoghurt, vla, cheese, meat, sauces, soups, and sausages. However, F2 and F3, which have a low molecular weight (smaller than the standard BM inulin of 253.38 m/z), can be used for sugar substitutions such as chocolate and vla to replace the sweet function of sucrose (Shoaib *et al*., 2016) and as a substitute for fat (Yudhistira *et al*., 2020).

3.6 Water content

Based on Table 2, the biggest water content is F1. The higher the temperature and foaming agent used, the lower the water content. In this study, the water content ranged from 1.03–1.46% (d/w). This result was lower than the previous study related to the effect of foam mat drying on the extraction of white sweet potatoes, which only ranged from 8.24–11.35% (d/w) (Yudhisthira *et al*., 2020). The ability of the material to release substances from the surface also increases with increasing temperature. If the water content of the material reaches its equilibrium point, the drying process will take place faster (Wiyono, 2006). The water content of the material decreases due to the rate of water diffusion in the material to the surface being smaller than the evaporation of water to the surface (Prabawa *et al*., 2023). The higher concentration of egg white used can increase the surface and porosity of the product, which results in maintaining an open structure during the drying process. Furthermore, the amount of air trapped is higher, and water easily evaporates during the drying process (Harmayani *et al*., 2011).

4. Conclusion

The higher the temperature in the extraction process and the higher the concentration of foaming agent used, the lower the inulin water content. While the absorption of water and solubility of inulin will be even greater, Analysis of the availability of inulin from the whole formulation showed that inulin was produced although it was thought that the molecular weight of inulin from the six formulations was stated to be different due to the low -temperature treatment, hence the inulin absorption was poor. The higher the temperature in the extraction process and the higher the concentration of foaming agent used in inulin, the lower the yield.

Conflict of interest

The authors declare no conflict of interest.

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