JBAT X (X) (20XX) XX-XX

Jurnal Bahan Alam Terbarukan

http://journal.unnes.ac.id/nju/index.php/jbat

The Performance of Extraction Equipment Modification toward Size Particle of Tuber and Yield of Inulin of Dahlia Flower Tuber

Elmi Sundari[✉,1], **Erti Praputri**[1], **Wenny Marthiana**[2)]

DOI 10.15294/jbat.v6i2.XXXX

[1]Chemical Engineering, Faculty of Industrial Technology, Bung Hatta University
[2]Mechanical Engineering, Faculty of Industrial Technology, Bung Hatta University

Article Info

Article history:
Received
April 2017
Accepted
October 2017
Published
December 2017

Keywords :
Extractor;
Inulin;
Starch;
Size reduction

Abstract

Isolation of inulin from starch generally is done by extraction method. The size of the material to be extracted will affect the extraction process performance. In laboratory scale, the size reduction was done with a knife and the separation of starch from tubers was done by juicer. Temperature fluctuations during the extraction process would affect the yield of inulin, hence juicers and waterbath were found ineffective for larger scale. This research was aimed to design an extractor equipped with agitator blades for size reduction and a temperature controller. Extractor performance was investigated by evaluating agitation time (60-150 minutes), distance between agitator blades on the shaft (5 and 7 cm), number of the agitators, (1, 2, and 3 blades) against the fineness of cut material, starch and inulin content. The results showed that the highest fineness of the samples was achieved at a distance of agitator blade of 7 cm, with 3 agitator blades and agitating time of 150 minutes. The highest yield of starch was 11.7% at size reduction time of 120 and 150 minutes using 3-blades agitator and the distance of 7 cm. The content of crude inulin obtained were by using the extractor was 2.206% and 2.213% by using the water bath. The difference of inulin content was 0.007% so it suggests that the extractor designed in this study can be used on inulin production in larger scale. The efficiency of the extractor was 85%.

INTRODUCTION

Inulin is a substance in food material which cannot be digested by digesting enzymes that reach the colon without changing the structure and can select the growth of stimulation and beneficial activity of bacteria in the digesting system (Zubaidah et al., 2013). Inulin is widely used as a supplementary (functional food gradient) in foods and beverages, as well as a dietary supplement. Prebiotic inulin types include oligofructose and fructooligosaccharide (FOS) (Greg, 2008). Inulin is currently used by some industries in Indonesia comes from chicory and artichoke tubers (Gaafar, 2010). Both species are not exist in Indonesia, but dahlia tubers have characteristics similar to imported tuberss. Inulin from the dahlia tubers has better quality than chicory and artichoke because it contains 72% inulin (At Tachriirotul, 2011). The inulin of dahlia tubers has been studied by several previous researchers such as, Kosasih et al. (2015) who did extraction by using ethanol solvent. The results show that the best ratio of tubers dahlia and ethanol is 1: 2. The inulin content of fresh dahlia tubers is 6.0-9.5% (w/w). Melanie et al. (2015) also utilized red dahlia tubers as samples in the study found that at 80 °C, with a 30 minute extraction time and pH 5-10 on affect the changes in inulin structure. The development of inulin removal process from tuber of dahlia plant was also studied by Budiwati (2010) which got the yield of 6.87% for shelled tubers and 4.9% for unpeeled tubers using

✉Corresponding author:
Chemical Engineering, Faculty of Industrial Technology,
Bung Hatta University
E-mail: elmisundari@yahoo.com

ISSN 2303-0623
e-ISSN 2407-2370

90% ethanol solvent. Sundari et al. (2014) also discussed the ratio of starch and solvent(water), time of extraction, temperature of extraction, and settling time. The results showed that at a ratio of 1:2, 15 minutes of contact time, temperature of 70 °C, and 48 hours of sedimentation time gave a rough inulin as 45 grams.

Generally, the inulin separation from starch is done by extraction. Factors affecting the extraction process are the particle size of the material to be extracted and the temperature stability during the extraction process takes place. The particle size will affect the area of contact between solids and solvents as well as the rate of the extraction process (Megawati et al., 2016). On a laboratory scale, the size reduction is done by a knife, and the separation of the starch from the tubers is carried out using a juicer. The extraction process is carried out in a erlenmeyer, and to maintain the temperature during the extraction process, a waterbath is used. On a larger scale, Sari et al. (2010) create an extractor for oleoresin removal from cinnamon peels with a capacity of 5 kg of material. This extractor consists of a cylindrical vessel equipped with a stirrer and a heating coil. The stirrer used is in the form of a propeller, has a function to distribute to the entire material surface. The heat source is generated from the hot vapor produced by the boiler fed into the heating coil in the extractor. Material size reduction is done outside the tool, so for the process of extraction process required 3 units of tool those are material size reducer, boiler, and oleoresin separator. The weakness of these tools is that the temperature inside the extractor is unstable because the steam produced depends on the heat supplied to the boiler. The product is also unstable.

Meanwhile, enumeration using a stirrer blade is one way of reducing the size of the material to increase the contact surface area with the solvent to increase inulin. In this research it was used blade type turbine blade stirrer with intercellular distance of 5 cm and 7 cm. The use of more than one current stirrer blades is widely practiced in the industry to provide a better distribution of energy dissipation (Wang, 2010). There is not much literature that has published the choice of impeller type as a stirrer blade or performance test of the device. Loose, different types of impeller will produce different material flow patterns so that contact between the material and the stirring knife can occur (Thangaraj et al., 2006). In addition, the number of mixer blades used will also produce different flow patterns (Driss et al., 2012). The turbine stirrer will produce axial and radial flow patterns at once. Around the turbine will form strong turbulence, strong flow and shear between materials in the process of down sizing (Shastri et al., 2015). This research fits perfectly with the controller for sizing and temperature control. Factors in this extractor process are the size reduction and the extraction process can be done in one equipment.

RESEARCH METHODOLOGY

The designed extractor was a modification of the extractor designed by Sari et al. (2010). The modifications were heating coils, stirrers, and materials separator. All material used to make the extractor was stainless steel because the processed material is food. The dahlia tubers used for the research comes from the plantation located in Biaro and Matur of West Sumatra (Nevi, 2013). Water was used as a solvent to extract starch and inulin. Inulin level analysis was done quantitatively using HPLC method (Maaruf, 2011) and qualitatively using recorsinol reagent (Yurmizar, 1989). The design of this extractor did not take into account the effect of the wind because it is placed indoors. The diameter of the extractor is calculated using the equation 1- 5 (Wallas, 1990).

Extractor volume calculation, V_s

$$V_s = \frac{\pi}{4} \times D_D^2 \times H_s \quad (1)$$

Ellipsoidal top volume calculation, V_e

$$V_e = \frac{\pi}{6} \times D_D^2 \times H_e \quad (2)$$

Conical bottom volume calculation, V_c

$$V_c = \frac{\pi}{6} \times D_D^2 \times H_c \quad (3)$$

$$H_c = \frac{1}{2} D_D tan\ 30° \quad (4)$$

Extractor diameter calculation, D_D

$$D_D = \sqrt[3]{\frac{V_t}{0.339\pi}} \quad (5)$$

Wall thickness, t_s of extractor was calculated by using equation 6-8 (Walas, 1990).

$$t_s = \frac{PR}{SE - 0.6P} + C \quad (6)$$

Figure 1. Extractor and its equipment (a) Extractor; (b) chopper and top; (c) outer filter; (d) inner filter

Ellipsoidal top thickness, t_e

$$t_e = \frac{PD_D}{2SE - 0.2P} + C \quad (7)$$

Conical base wall thickness, t_c

$$t_c = \frac{PD_D}{2(SE - 0.6P)cos\ 30°} + C \quad (8)$$

The dimension of impeller was calculated by using equation 9-12 (Mc.Cabe,1985).

Impeller diameter calculation, d

$$d = \frac{D_D}{3} \quad (9)$$

Blade length calculation, L

$$L = \frac{d}{4} \quad (10)$$

Blade width calculation, W

$$W = \frac{d}{5} \quad (11)$$

Impeller height from the bottom of the extractor calculation, E

$$E = \frac{D_D}{3} \quad (12)$$

Impeller radial speed, N

$$\frac{N \times d}{\left(\frac{\sigma g_c}{\rho}\right)^{0.25}} = 1.22 + 1.25\left(\frac{D_D}{d}\right) \quad (13)$$

Blade motor power, P

$$N_{Re} = \frac{\rho \times N \times d}{\mu} \quad (14)$$

$$P = \frac{K_T N^3 d^5 \rho}{g_c} \quad (15)$$

Heat calculation

$Q = M\ Cp\ \Delta T$, watt = Q/time (16)

$$Mass\ of\ finenes\ tuber\ = tuber\ mass - mass\ of\ rough\ tuber \quad (17)$$

$$level\ of\ fineness\ (\%) = \frac{mass\ of\ finenes\ tuber}{tuber\ mass}\ x\ 100\% \quad (18)$$

$$mass\ of\ dry\ tuber = starch\ content\ x\ mass\ of\ wet\ tuber \quad (19)$$

$$yield\ of\ starch\ \ (\%) = \frac{mass\ of\ dry\ tuber}{tuber\ mass}\ x\ 100\% \quad (20)$$

The calculation results obtained prototype extractor equipped by a cylinder that has a diameter of 40 cm and total height (top and bottom cover) 1 m. The inner cylinder with a diameter of 25.5 cm and a height of 60 cm, the stirring axes are attached to the top lof the extractor. A stirrer that serves a tuber counter is installed on the shaft of the stirrer. Between the outer and inner cylinders is 6.5 m. The space between the cylinders is called the annulus that functions as a water bath.

The source of heat used comes from electrical energy that flows through 2 units of heating elements mounted on the inside wall of the extractor. Size reduction was done by turning the stirrer into a chopping knife. The chopping knife not only serves to distribute the solvent to the entire surface of the material but also minimizes the size of the material. For containers of reduced size materials, it was designed a cylindrical tube with a diameter of 25.5 cm and a height of 60 cm. To keep the temperature stable, a distance between the inner wall of the extractor and the outer wall of the tube (annular) was filled with water. Annulus was expected to be a substitute for water bath. The prototype extractor design results can be seen in Figure 1.

Extractor Operating Principles

Extractors can handle extraction processes including size reduction operations (tubers dahlia), stirring, water bath (retaining temperature) of extracted material. The process of inulin removal from the dahlia tubers was done in 3 stages of sample preparation (dahlia tubers), starch extraction, and inulin extraction. dahlia Tubers was cleaned, separated skin and flesh, then halved.

Starch Extraction

Starch extraction of dahlia tubers was done without heating. The dahlia tubers were loaded into a cylinder located on the inside of the extractor with a specific tuber and water ratio. The cylinder lid was installed and the bolts on the cylinder cover are tied. The stirring player button is activated and enumerated until a certain level of fineness is reached. Substance samples were calculated using equations 17 and 18.

The main parameter for extraction is the time of enumeration of the fineness of the material. If all samples were chopped, then the stirrer was stopped. The sample was then removed from the extractor and separated between the solid and the solution. Solids (fiber-shaped) can be used as raw material for making other products such as lactic acid and bio-ethanol. The subsequent solution was introduced into the refrigerator so the starch can be precipitated. The amount of precipitated starch was calculated by using equations 19 and 20.

Inulin extraction

Inulin extraction is generally carried out at constant temperature. On a laboratory scale the waterbath can handle it. The required temperature at this extractor is sourced from the heating element attached to the inner wall of the outer cylinder. Between the inner wall of the outer cylinder and the outer wall of the inner cylinder there is an annulus (empty space) that serves as a water bath.

To start the extraction process, the annulus was filled with water until it reaches the heating element. Then activate the heater until it reaches the specified temperature. After that the cylinder was closed and the bolt is tied. The stirrer button is activated and the extraction was set aside for the specified time. The agitation speed of the stirrer in the extraction process is not the same as the process of starch extraction. The yield of inulin was observed by solvent (water) contact time for 15, 30, 45, and 60 min and the stirring speed of 350 rpm (lowest speed limit), 700 rpm, and 1410 rpm (highest speed limit). In the starch-making process, the main function of the agitating blade is as a size reduction tool, whereas in the inulin extraction process, the agitator serves to homogenize the solution. The inulin extraction procedure is subsequently the same as the starch extraction procedure, but the sample and water ratio is 1: 2.

RESULTS AND DISCUSSION

Extractor Performance Evaluation

The performance of the extractor is evaluated by the influence of stirring time (60-150 min), the distance of bladesw on the shaft (5 and 7 cm), the number of stirrer in the agitating shaft (1, 2, and 3 stirrers) to the fineness level (%) of the ingredients and the yield of starch and inulin. The distance and number of the stirrer blade can be seen in Figures 2 and 3.

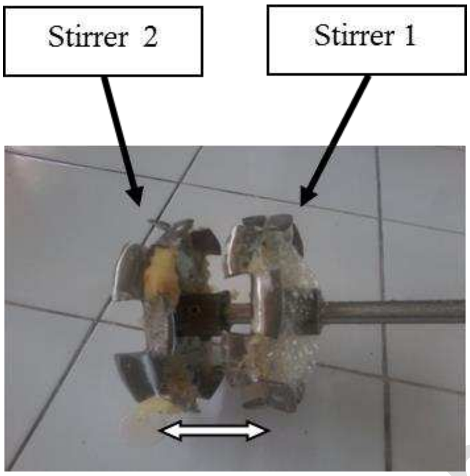

Figure 2. The blade space of 5 cm

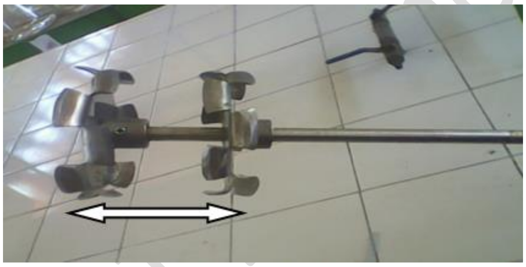

Figure 3. The blade space of 7 cm

The Effect of Chopping Time toward the Material Fineness

The results of the evaluation indicate that to chop dahlia tubers water with the ratio of volume 1: 0,7 (m/v) must be added. This is related to the rotational motion caused by the stirrer. Without the addition of water the rotational motion does not occur so that the tuber chopping to obtain starch does not take place as shown in Figure 4.

The performance of the agitation blades toward the fineness level can be seen in Figure 5. The degree of fineness of the material is observed through the number of rough tubers that are still exist. Tubers are considered rough if it is sized > ½ cm, while <½ cm is considered fine. Considered from the time, the fineness of the tubers increased as the chopping time. Within 60 minutes, the fineness of the tubers reaches 80% while at the chopping time of 150 minutes, tuber fineness reach 94.2% (increase of tuber refinement 14,2%).

Dregs Solution

Figure 4. Solution and dregs of extraction

The effect of the number of stirrer blades attached to the agitating shaft also affects the time to achieve fineness. In Figure. 5, it is also seen that at the same stirrer blade distance of 7 cm and 60 minutes of contact time, it is seen that 2 stirrer blades provide a finishing rate of 81.8%, while 3 stirrers provide a fineness of 79.8%. However, at 150 minutes and the distance of the stirrer blades 7 cm, the fineness of tubers for 2 stirrer blades reached 92.2%, and 3 stirrer blades reached 95.2% fineness. In the chopping using 3 stirrer blade (distance 5 cm) and time 150 minutes, fineness of dahlia tubers reached 92.2%. The finest sample fineness was achieved at a stirring interval distance of 7 cm, the number of stirrer blades 3, and a stirring time of 150 minutes.

Starch Extraction

The Starch yield was observed by adjusting the number of stirring blades on the shaft (1, 2, and 3 stirrer blades) and chopping time (60-150 min). The results showed that the starch content increased with increasing chopping time as seen in Figure 6. This happens for all amount of stirrer blades and stirrer spacing. The highest starch content was 11.7%, it was obtained at the chopping time of 120 and 150 minutes with the number of stirrer blades 3 and the distance of stirrer 7 cm. This is because the stirrer blade has been working maximally at 120 minutes so that all the starch in the tubers dahlia has been extracted optimally. This is in accordance with the statement of Djafar (2010) which states that the large particle size will cause the surface area of contact between the material and the solvent to be small where the diffusion process that occurs in the

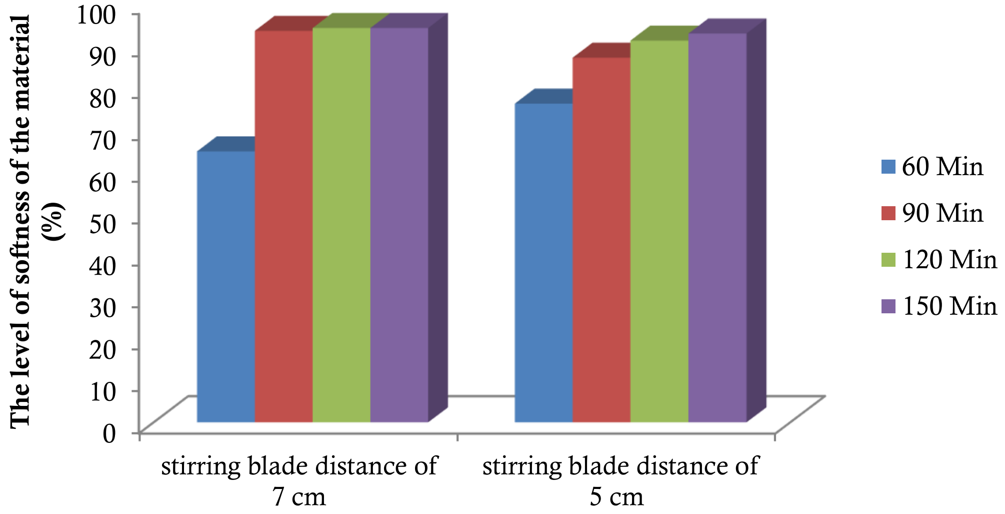

Figure 5. The correlation of distance of the stirrer blade and material fineness

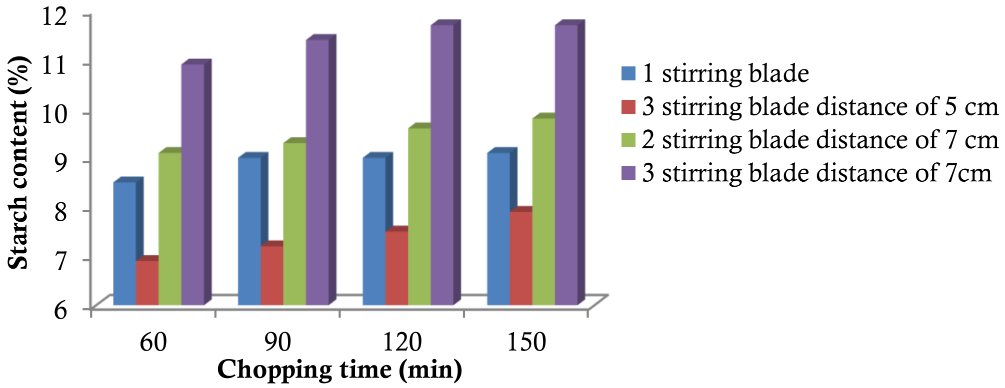

Figure 6. The correlation of chopping time toward starch content

extraction process will take place so slow that the number of extracted substances will also be smaller.

The Effect of Contact Time and Stirrer Speed toward Rough Inulin Yield

Inulin extraction was carried out at 70 °C for 150 minutes (2.5 hours). Figure 7 shows that the longer the time of contact, the greater the amount of inulin would be. This is in accordance with the statement of Goddess (2010) that the time of contact effect on the inulin yied. The longer the time the higher inulin would be obtain. The highest rough inulin content was 11.2%, it was obtained at contact time of 60 minutes and 350 rpm stirrer rotation speed. The lowest rough inulin level was 3.02%, it was obtained at the contact time of 30 minutes and 1410 rpm agitation speed.In terms of agitation speed of the agitator it is seen that the higher the stirring speed the lower the inulin percentage would be obtained. This is not in accordance with the statement of Hartanto & Subagja (2008), the acquisition of crude inulin will increase with the increase of the stirrer cycle. This was due to the high speed of the stirrer causing the contact between the material and the solvent to be short so that the extracted material becomes less. This is in accordance with Dewi (2010) who states that the increase of the agitation speed will decrease the weight of the extraction result. Results of laboratory analysis of inulin levels in rough inulin were 8.523 - 8.917%. This inulin level is still relevant to the levels of inulin studied by Kosasih et al. (2015) which obtained inulin levels of 6.0-9.5% (w / w).

The high level of starch extract successfully extracted from tubers dahlia is not only determined by the performance of extractor but also influenced by the characteristic (moisture content) of dahlia tubers. Dahlias tubers that have low moisture content will provide higher inulin yield, and higher water content will decrease inulin yield

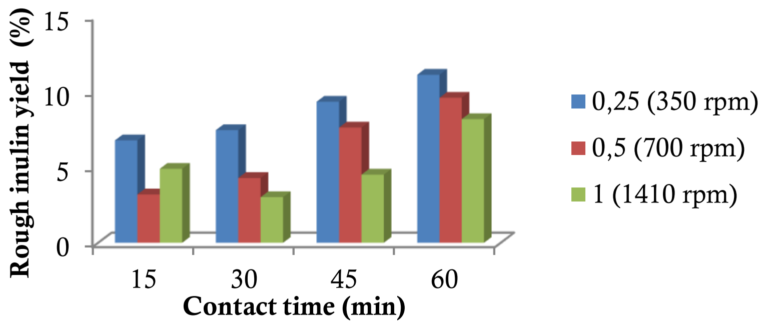

Figure 7. Effect of contact time on rough inulin yield

(Retnaningtyas et al., 2015). The rough inulin content obtained by using extractor was 2,206% and by using water bath 2,213%. The difference of both was 0.007%. Therefore it can be concluded that the extractor design in this study, feasible to be used to produce inulin on a larger scale.

CONCLUSION

The extractor is designed to handle the process of reducing the size of the material (chopping), mixing, extraction, and can replace the water bath function to maintain the temperature. The extractor was capable of chop 8 kg of dahlias Tubers in 150 minutes with the fineness level of 92.2%, and using 3 blades stirrer at a distance of 7 cm. Extractor efficiency reaches 85% so it can be concluded that the extractor design in this study is feasible to be used to produce inulin on a larger scale.

NOMENCLATURES

C	:	Corotion factor
Cp	:	Heat capacity
D	:	Stirrer Blade diameter
DD	:	Extratctor Inner Diameter
E	:	Height of stirrer blade from the base of extractor
E	:	*Joint Efficiency*
Gc	:	Gravitational acceleration
Hc	:	Height of cone
He	:	Height of Ellipsoidal top
Hs	:	Height extractor
L	:	Length of blade
M	:	Material mass
N	:	Agitation speed of stirrer blade
P	:	Stirrer blade power
P	:	Pressure
Q	:	Heat
R	:	Spoke
S	:	*Allowable Stress*
tc	:	Bottom Wall thickness (cones)
te	:	Top Wall thickness (*ellipsoidal*)
ts	:	Extractor Wall thickness
Vb	:	Extracted material volume
Vc	:	bottom Volume (cones)
Ve	:	Top Volume (ellipsoidal*)*
Vs	:	Extractor Volume (cylinder)
Vt	:	Extractor Volume
W	:	Width of blade
Σ	:	*Surface Voltage*
ΔT	:	Temperature difference
ρ	:	Material density

REFERENCES

At Tachriirotul, M. 2011. Inulin: Nutrisi Bakteri Baik dan Musuh Bakteri Patogen, http://attadotcom.wordpress.com, accessed on 27/04/2011.

Budiwati, A.T. 2010. Pengembangan Proses Pembuatan Inulin Dari Umbi Tanaman Dahlia. Laporan Penelitian Program Insentif Riset Peneliti Dan Rekayasa Lembaga Ilmu Pengetahuan Indonesia.

Dewi, K.H. Silsia, D. Susanti, L. Markom, M., Yanti, N.V. 2010. Pengaruh Kecepatan Sentrifugasi Pada Proses Pemisahan Hasil Ekstraksi Teripang (*Holothuria Scabra*) Sebagai Sumber Testosteron pada Berbagai Kecepatan dan Lama Pengadukan. Prosiding Seminar Nasional Teknik Kimia Kejuangan. Yogyakarta.

Djafar, F., Supardan, M.D., Gani, S. 2010. Pengaruh Ukuran Partikel, SF Rasio dan Waktu Proses Terhadap Rendeman Pada Hidrodistilasi Minyak Jahe. Balai Riset dan Standardisasi Industri Banda Aceh.

Driss, Z. Karray, S. Chtourou, W. Kchaou, H. Abid, M.S. 2012. A Study of Mixing Structure in Stirred Tanks Equippped with Multiple Four-Blade Rushton Impellers. The Archive of Mechanical Engineering. 59(1):53-72.

Greg, Kelly, N. D. 2008. Inuin–Type Prebiotic-A Review. Alternative Medicine Reviewer. 13(4):315-329.

Gaafar, A.M. 2010. Extraction Conditions of Inulin from Jerusalem Artichoke Tubers and It's Effect on Blood Glucose and Lipid Profile in Diabetic Rats. Journal of American Science. 6(5):36-43.

Kosasih, W. Pudjiraharti, S. Ratnaningrum Priatni S. 2015. Preparation of Inulin, from Dahlia Tuber. Procedia Chemistry. 16:190-194.

Melani, H. Susilowati, A. Iskandar Y. M. Lotulung, P.D., Andayani, D. G. S. 2015. Characterization of Inulin from Local Red Dahlia (*Dahlia sp.L*) Tuber by Infrared Spectroscopy. Procedia Chemistry. 16:78-64.

Maaruf, Y., Azhar, M., Oktavia, B. 2011. Penentuan Kadar RBB Pada Dye-inulin Secara HPLC Melalui Pembentukan Senyawa dye-inulin. Final Report. FMIPA UNP.

Mc. Cabe, W.L.Smith, J.C., Harrit P. 1985. Unit Operation of Chemical Engineering 4th Ed. Mc. Hill New York.

Megawati, Machsunah E.L. 2016. Ekstraksi Pektin dari Kulit Pisang Kepok (*Musa paradisiaca*) Menggunakan Pelarut HCl sebagai Edible Film. Jurnal Bahan Alam Terbarukan. 5 (1): 14-21.

Nevi. 2013. Sumbar Berpeluang Kembangkan Bunga Dahlia Bernilai Ekonomis. Berita Terkini Sumatera Barat.

Retnaningtyas, Y. Kristiningrum, N. 2015. Determination of Inulin Content in Dahlia variabilis and Dahlia pinnata Tuber Extract by TLC Densitometry Method. e-Jurnal Pustaka Kesehatan. 3(2):284-288.

Sari, E. 2010. Optimasi Kinerja Alat Ekstraksi Dalam Perolehan Oleoresin kulit Kayu Mania Pada Skala Pilot Plant. Jurnal Ilmiah Ekotrans. 10(1).

Shastri, A.P, Borkar, N.B. 2015. A Review on Nomenclature of Agitator. International Journal of Research in Advent Technology. Special Issue on Special Issue 1st International Conference on Advent Trends in Engineering, Science and Technology. 435-439.

Sundari, E. Desfitri, E.R. Martynis, M. Praputri, E., 2014. Identifikasi dan Kondisi Ekstraksi Inulin dari Umbi Dahlia di Sumatera Barat. Prosiding SNSTL Volume I, September. Teknik Lingkungan UNAND.

Thangaraj, K. Joshi, J. B. 2006. Effect of Impeller Design on Flow Pattern and Mixing in Stirred Tanks. Chemical Engineering Journal. 115(3):173-193.

Wallas, S.M. 1990. Chemical Process Equipment, Selection and Design. Department of Chemical and Petroleum Engineering. University of Kansas.

Wang, J. 2010. Suspension of High Concentration Slurry in Agitated Vessels, School of Civil, Environmental and Chemical Engineering. RMIT University, Melbourne.

Yurmizar, 1989, Penandaan Inulin dengan Radionuklida Teknesium-99m dan Biodistribusinya pada Tikus Putih, Skripsi FMIPA, Padang: Universitas Andalas.

Zubaidah, E. dan Akhadiana W. 2013. Comperative Study of Inulin Extracts from Dahlia, Yam, and Gembili Tubers as Prebiotic. Food and Nutrition Sciences. 4:8-12