IOP Conf. Series: Materials Science and Engineering **334** (2018) 012063 doi:10.1088/1757-899X/334/1/012063

Performance evaluation of extractor cutting blade configuration in Inulin extraction process from *Dahlia sp. L* tuber

E Sundari[1,2], E Praputri[1], W Marthiana[1] and M Jaya[1]
[1] Chemical Engineering Department, Bung Hatta University, Jl. Gajah Mada No. 19 Olo Nanggalo Padang, Sumatera Barat, Indonesia

E-mail: elmisundari@yahoo.com

Abstract. Inulin, a polysaccharide plant-based nutrient, can be isolated from dahlia flower tubers by liquid-solid extraction processes and is generally carried out in an extractor tank equipped with an agitator. To accelerate the diffusion rate of solute from the solid phase (bulk phase) to the external surface (boundary layer) in order to increase yield of inulin, the size reduction of material is required. The purpose of this research was to design the cutting blade needed for dahlia tuber size reduction and investigate the effect of blade types, agitator speed (350, 700, 1050, and 1400 rpm), and configuration of cutting blade to material fineness at 90 minutes of contacting time. The results showed that higher cutting blade speed results in higher cut material fineness rate. The best conditions was achieved by the configuration of two four-blade turbine combined with one three-blade turbine with fineness rate more than 90% in 30 minutes of contacting time at every variation of agitator speed. The cutting blade designed in this study can be used for size reduction purpose of tubers other than dahlia tubers.

1. Introduction

The dahlia flower (*Dahlia coccinea Cav.*) is an ornamental plants that have not been widely used in Indonesia. The tubers of dahlia contain about 12.5% of inulin as a storage polysaccharide [1]. Inulin, a plant-based nutrient, is polysaccharide chains that serves as an effective prebiotic additive in beverages, yogurts, biscuits, spreads, and also dietary supplements. Inulin can be isolated from dahlia flower tubers by solid-liquid extraction processes and generally carried out in an extractor tank equipped with an agitator.

The mechanisms of solid-liquid extraction involves three major steps; diffusion of solvent into solid phase, diffusion of solute from the solid phase (bulk phase) to the external surface (boundary layer) and mass transfer of solute from the solid phase to the liquid phase (solvent) [2]. The diffusion rate of solute from the solid phase (bulk phase) to the surface is dependent on molecular size as larger molecules diffuse slower than smaller molecules. The sizes of the particles involved in the diffusion are important because they closely relate to the concepts of heat and energy in the context of diffusion. If there is not sufficient energy to move a larger molecule, it resists the effects of diffusion and is unable to move from one area to the next [3].

[2] To whom any correspondence should be addressed.

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

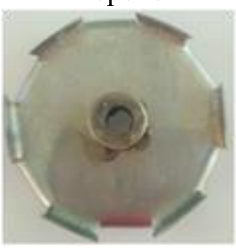
To achieve the fastest and most complete solid-liquid extraction possible, the solvent must be provided with large exchange surfaces. This can be done by reducing the size of solids to be extracted. On a large scale, this can be done by designing an agitator that functions as cutting blade. The blade type was designed to creates enough shear to reduce the size of materials through dispersion process. The process of dispersion is a two possible mechanism. First, the materials will hit the cutting blade and are broken apart. And second, in the turbulence surrounding the cutting blade, the particles will hit one another and hit the cutting blade at high speeds, further reducing the material size [4].

The purpose of this research was to design the cutting blade needed for dahlia tuber size reduction and investigate the effect of blade types, agitator speed (350, 700, 1050, and 1400 rpm), and configuration of cutting blade to material fineness at 90 minutes of contacting time.

2. Materials and Methods

The research was conducted in two steps, designing and evaluating the performance of cutting blade. The material used as cutting blade was 2 mm stainless steel in types of four-blade turbine, three-blade propeller and twelve-blade turbine. The dahlia flower tubers sample was taken from Biaro, West Sumatera. The performance of cutting blade was evaluated against contacting time (15, 30, 45, 60, 75, and 90 minutes), agitator speed (350, 700, 1050, and 1400 rpm), agitator configuration and cut material fineness. Other variables, including samples and solvent ratio, were conducted according to previous study in laboratory scale [5]. The specification of cutting blade designed is described in Table 1.

Table 1. Cutting blade specifications.

Cutting Blade Types	Number of Blades	Diameter (cm)	Weight (gr)
 Turbine	4	19.5	222
 Propeller	3	18	195
 Turbine	12	10.5	250

IOP Conf. Series: Materials Science and Engineering **334** (2018) 012063 doi:10.1088/1757-899X/334/1/012063

3. Results and Discussions

3.1. Effect of agitator speed, types, and configuration of cutting blade on cut materials fineness

This research was conducted to investigate the performance of cutting blade based on mass flow produced by the turbine and propeller types. The results showed that the types, configuration of the blades and agitator speed affected the cut materials fineness. The cut materials fineness is increasing as the contacting time increase as shown in Figure 1. Fineness rate higher than 90% was achieved at 60 minutes of contacting time with an agitator speed of 350 rpm, and a rate of 100% was achieved at 90 minutes. At speeds of 700, 1050 and 1400 rpm, fineness rate higher than 90% were achieved at 45, 30 and 30 minutes of contacting time, respectively. Fineness rate of 100% was achieved at 90 minutes of contacting time. The four-blade turbine has an excellent feature in creating the radial flow and axial flow in the reactor vessel. This will result in the mass flow in every direction that will lead to higher cut material fineness rate [6,7]. The cut material fineness rate is shown in Figure 2.

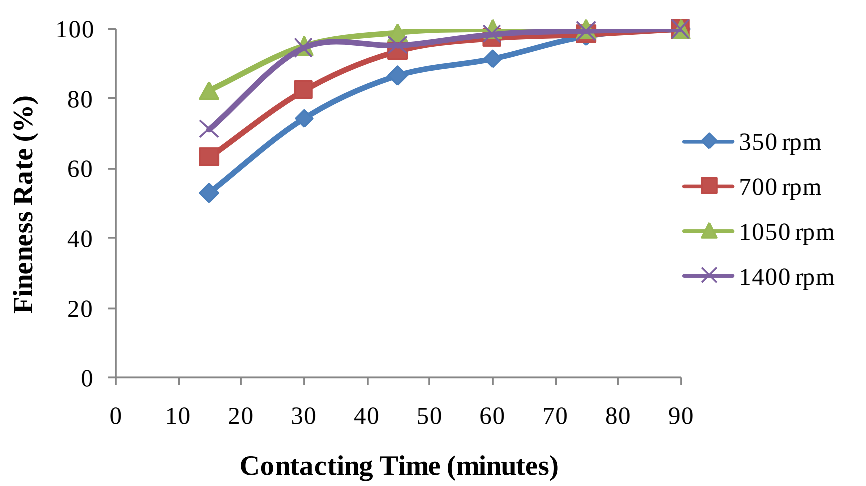


Figure 1. Effect of four-blade turbine configuration on fineness rate at agitator speed variation.

Furthermore, agitator speed showing the positive tendency on the fineness rate. Higher speed results in higher cut material fineness rate. This result was due to the turbulence established by the cutting blade speed that creates enough shear force to reduce the size of materials. However, the fineness rate showing a negative tendency for cutting blade speed of 1400 rpm. At vigorous cutting blade speed a vortex regime appeared, thus reducing the blade performance.

Three-blade propeller gave 94-98% of the fineness rate at 45-90 minutes of contacting time for both agitator speed of 350 and 700 rpm. At agitator speeds of 1050 and 1400 rpm, the cut material fineness rate of 96.5-100% were achieved at 30-90 minutes of contacting time as described in Figure 3. Moreover, the agitator speed also showing the positive tendency on the fineness rate. Higher speed results in higher cut material fineness rate due to turbulence flow established during the process.

Meanwhile, twelve-blade turbine types were only able to achieve maximum of 90% cut material fineness rate at 90 minutes of contacting time as shown in Figure 5. The compact design of blade limits the performance of blade in creating the mass flow, which is only axial flow, that leads to limited cutting performance [8,9].

Likewise, the contacting time also showing positive correlation with the cut materials fineness rate for all types of cutting blade and agitator speed variation. The lengthened time will encouraged the contact between the cutting blade and materials and promoted better size reduction performance [10].

Additionally, variations of four-blade turbine and three-blade propeller types were conducted to evaluate the performance of configuration combination on cut material fineness rate. The best

IOP Conf. Series: Materials Science and Engineering **334** (2018) 012063 doi:10.1088/1757-899X/334/1/012063

configuration was shown by a configuration of two four-blade turbine and one three-blade propeller that gave fineness rate higher than 90% at 30 minutes of contacting time as shown in Figure 7.

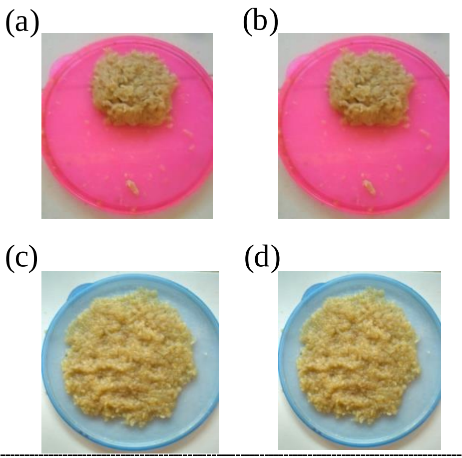


Figure 2. Cut material fineness rate at 90 minutes, four-blade turbine type. (a) 350 rpm (b) 700 rpm (c) 1050 rpm (d) 1400 rpm.

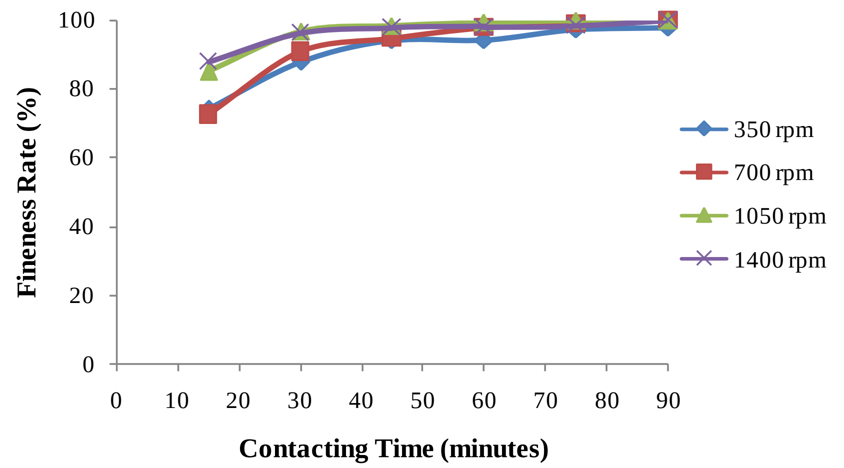


Figure 3. Effect of three-blade propeller configuration on fineness rate at agitator speed variation.

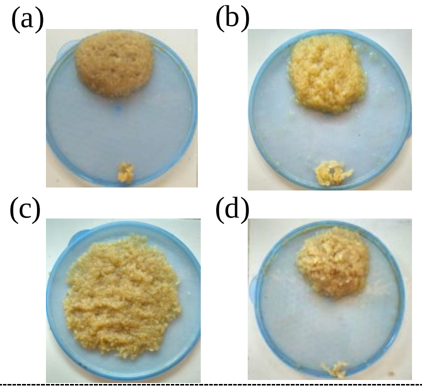


Figure 4. Cut material fineness rate at 90 minutes, three-blade propeller type. (a) 350 rpm (b) 700 rpm (c) 1050 rpm (d) 1400 rpm.

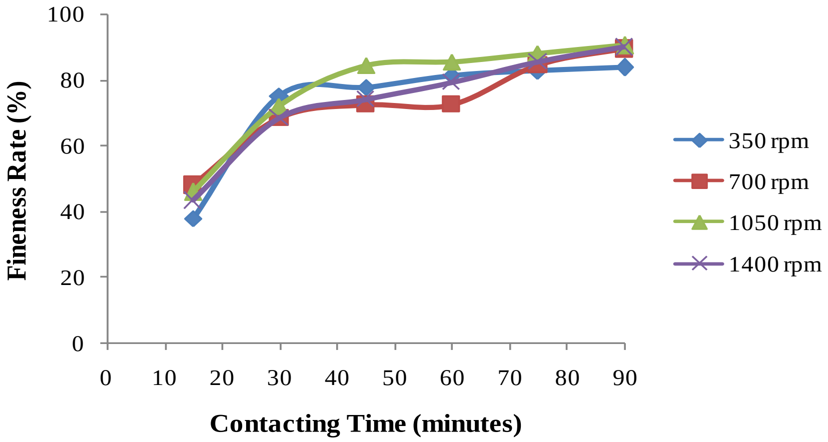


Figure 5. Effect of twelve-blade turbine configuration on fineness rate at agitator speed variation.

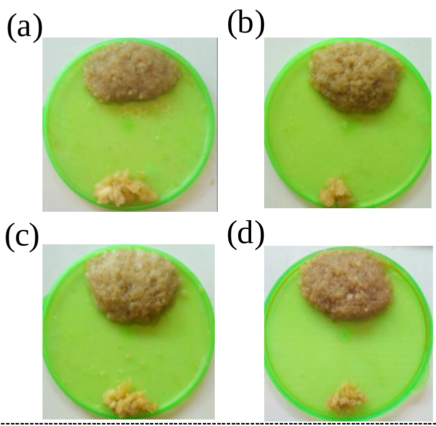


Figure 6. Cut material fineness rate at 90 minutes, twelve-blade turbine type. (a) 350 rpm (b) 700 rpm (c) 1050 rpm (d) 1400 rpm.

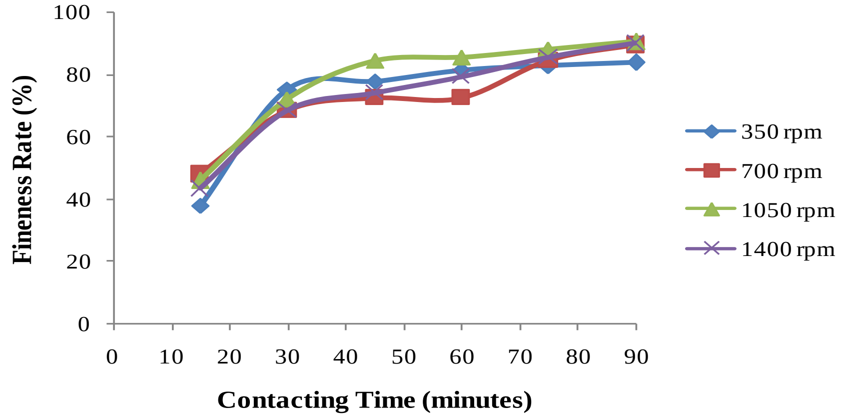


Figure 7. Effect of two four-blade turbine and one three-blade propeller configuration on fineness rate at agitator speed variation.

3.2. Effect of cutting-blade types on electrical power consumption.

Electrical power consumption is equal to the power required for material size reduction process [11,12]. The power needed to rotate cutting blade with drive motor efficiency of 90% and design margin of 1.15 can be calculated using Equation (1). The results are shown in Table 2.

$$P = N_p \rho N^3 D^5 \quad (1)$$

From Table 2, the results showed that, with constant mass of the cut material, every increase of the cutting blade shaft speed by two times led to statistically significant increase in electrical power consumption. The highest energy consumption was demonstrated by four-blade turbine with the cutting blade shaft speed of 1400 rpm. The configuration was found to be inefficient from the energy consumption perspective. The average power consumption per unit volume for industrial reactors ranges from 10 kW m^{-3} for small vessels (approximately 0.1 m^3) to 1-2 kW m-3 for large vessels (approximately 100 m3) [13].

Table 2. Electrical power consumption for variation of agitator speed and cutting blade types.

Cutting Blade Types	Density (kg/m^3)	Agitator Speed (rpm)	Blade Diameter (cm)	Power Number (N_P)	P (kW)
Twelve-blade turbine	0.00104	350	10.5	1.94433E-08	0.1
		700		2.43042E-09	1.8
		1050		7.20124E-10	9.1
		1400		3.03802E-10	28.7
Four-blade turbine		350	19.5	3.03553E-09	2.5
		700		3.79442E-10	39.6
		1050		1.12427E-10	200.3

	1400		4.74302E-11	633.1
Three-blade propeller	350	18	3.85941E-09	1.7
	700		4.82427E-10	26.5
	1050		1.42941E-10	134.3
	1400		6.03033E-11	424.3

4. Conclusion

This research showed that cutting blade configuration, agitator speed and contacting time affected the cut material fineness rate. Agitator speed variations showing positive tendency on the materials fineness rate. Higher agitator speed resulted in higher cut materials fineness rate. The lengthened contacting time also showing positive correlation with the fineness rate. The best operation condition was achieved by the configuration of two four-blade turbine combined with one three-blade turbine with fineness rate more than 90% in 30 minutes of contacting time at every variation of agitator speed (350, 700, 1050 and 1400 rpm). However, the electrical power consumption was found to be high for agitator speed of 1400 rpm and this speed is not favourable. The cutting blade designed in this study can be used for size reduction purpose of tubers other than dahlia tubers.

References

[1] Cruz V A, Belote J G, Belline M Z, Cruz R 1998 *Rev. Microbiol.* **29**, 301-306.
[2] Ahangari H T, Noeparvar P and Moghaddas J Sadegh 2016 *An Indian J* **11 Issue 4** 123-132 ISSN: 0974-7443.
[3] Mardina P, Gunawan A dan Nugraha M I 2012 *Konversi* **1** 1.
[4] McDowell R I 2006 (University of Louisville: Electronic Theses and Dissertations).
[5] Sundari E, Desfitri E R, Martynis M and Praputri E\ 2014 *Prosiding SNSTL* **I** ISSN 2356-4938, OP-022 174-179.
[6] Geankoplis C J 1993 (New Jersey: Prentice Hall).
[7] Driss Z, Karray S, Chturou W, Kchaou H dan Abid M Salah 2012 *The Arch. of Mec. Eng.* **LIX** No.1.
[8] Jirout T and Rieger F 2011 *Chem. Eng. Res. Des.* **89** 7 1144-1151.
[9] Kurniawan R, Juhanda S, Syamsudin R dan Lukman M 2011 (Bandung: Itenas).
[10] Widjanarko S B, Suwasito T S 2014 Jurnal Pangan dan Agroindustri **2** 1 79-85.
[11] Issa H M 2016 *J Eng.* **2016**
[12] John A 1998 (UK: University of Birmingham).
[13] Doran P M 2013 (UK: Elsevier Ltd.)