International Journal on Advanced Science Engineering Information Technology

Vol.9 (2019) No. 6
ISSN: 2088-5334

The Design and Performance of Continuous *Porang* (*Amorphophallus muelleri Blume*) Flour Mills

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***Abstract*—Indonesian *Porang* flour (*Amorphophallus muelleri* Blume) is made into glucomannan flour because of its beneficial health effects. However, the challenge in producing flour is calcium oxalate which must be eliminated, because it can irritate the skin and may cause a kidney stones if the flour is consumed. Over the past 10 years, several batch grinding methods have been used to produce good quality *Porang* flour. However, there has been no research on the continuous method of grinding *Porang* flour using a ball mill. Both the stamp mill and batch type ball mill processes had low production capacities. Therefore, the aim of this work is to design a Continuous Porang Flour Mill (CPFM) machine and test its performance for *Porang* flour production. The CPFM machine consists of a continuous ball mill and a cyclone separator. The experiments were carried out at a ball mill rotation speed of 65 ± 1 rpm, with a capacity of up to 780.67 g / h input of chip material, producing an output of 33.1 - 57.1%. The CPFM meets the low-temperature grinding requirements but is still needed to provide acoustic hearing protection for the operator due to the high level of loudness. CPFM produces *Porang* flour with glucomannan levels ranging from 80.79% to 87.79% and calcium oxalate ranging from 0.12% to 0.29%. The calcium oxalate content overall was under 0.3%, which is better compared when compared to other milling methods.**

***Keywords*— porang powder; glucomannan powder; ball mills grinding; calcium oxalate.**

I. INTRODUCTION

There are two essential components to be considered in the *Porang* flour production. The first is glucomannan, which is a high viscous water-soluble hetero-polysaccharide which consists of β-D-glucose (G) and β-D-mannose (M) with a ratio of G/M from 1 to 1.6 [1]. This has beneficial effects on health including anti-obesity, anti-hyperglycaemic, anti-hyper cholesterol, its use as a prebiotic, and has the potential for use in the food and non-food industry [2]-[4]. It is usually extracted from konjac bulbs (*Amorphophallus konjac*) and konjac glucomannan has a molecular weight of 1.34×10^6 [5]. Over the last ten years in Indonesia, an alternative source of glucomannan has come from *Porang* bulbs (Fig. 1). *Porang* glucomannan has a molecular weight of 1.27×10^6 [6]. Commercial grade glucomannan has an average size particle of 112.83 ± 0.70 µm [7]. The second component of the *Porang* flour production is the small amount of calcium oxalate, which must be eliminated. It is harmful to health, may cause skin irritation, and if it is consumed, may form kidney stone crystals [8], [9]. It is generally shaped like a needle with a length of approximately 2.5 µm [10]. However, over the last five years, more variations of calcium oxalate shapes have been found in various parts of the *Porang* plant. These included raphide or needle-like crystals, styloid, drafts, prisms and a range of small crystals (1 - 15 µm) and larger crystals (20 - 250 µm) [11].

As detailed in the European Commission, Food Chemicals Codex (FCC), and the Chinese Ministry of Agriculture [12]-[14], *Porang* flour is required as a raw material for a standardized glucomannan and konjac flour. Research has been conducted on *Porang* glucomannan flour in order to establish its purity and meet commercial standard requirements. This was conducted using multilevel ethanol leaching and ultrasonic maceration [6], [15], [16]. The ultrasonic maceration process was found to increase the glucomannan purity in the flour from 67.02 % to 84.37 % and reduce the calcium oxalate content from 0.398 to 0.064 % [15]. The standardized purified *Porang* flour has been applied to various food products for their physical property's improvement such as sausage [17] and restructured meat [18].

Fig 1. *Porang* (*Amorphophallus muelleri Blume*)

When design an efficient *Porang* flour mill it is important to consider several factors. These will include production capacity, yield, glucomannan content, and calcium oxalate content. The production of flour from *Porang* chips is usually done using a stamp or a hammer mill [10]. It was reported that a typical stamp mill has a production capacity of 2.34 kg per 15 hours, with 50-60% yield of flour [10], [19], [20] with a glucomannan content of 67.20% and calcium oxalate content of 0.398% [15], [16]. However, a hammer mill had a high calcium oxalate content of 0.800% [10].

Over the last 5 years, there has been an increase in the use of a batch type ball mills with a fixed ball to chip mass ratio, which processed 1.5 kg of *Porang* chips in 4 hours [21]-[23]. The glucomannan content was 71.34% and calcium oxalate content 3.23 % [22]. It should be noted that both the stamp mill and batch type ball mill processes had low production capacities. This study aims to design a Continuous Porang Flour Mill (CPFM) and to test its performance for producing *Porang* flour.

II. Materials and Methods

A. Materials

The raw material properties and chip preparation were carefully considered. The *Porang* bulbs were more than 2 years old and originated from Pajaran Village, Saradan, Madiun, East Java, Indonesia. The diameter of the bulbs was 220 ± 51 mm. These were washed, sliced to a thickness of 5±1 mm, and oven-dried at 70°C for 20 hours. Finally, the properties of the bulb and chip samples were analyzed and the results as shown in Table I.

TABLE I
INPUT MATERIAL PROPERTIES

Input Materials	Water Content (%)	Glucomannan Content (%)	Calcium Oxalate Content (%)
Fresh porang bulb	82.06 ± 0.19	3.70 ± 0.10	-
Porang chip	8.60 ± 1.27	48.65 ± 0.66	10.38 ± 0.67

B. Design of the Porang Continuous Flour Mills (CPFM)

The CPFM consisted of two main units which were the ball mill unit and cyclone separator unit as shown in Fig. 2. The cylindrical body of the ball mill unit was made of stainless steel. The ball mill inner body was 300 mm in length 2 and 65 mm in diameter. This was filled with 17 kg of 3 different types of stainless-steel balls. The diameters of the balls and their ratios are presented in Table II. Three lifters set at an angle of 120° and 1cm in height, were located inside the inner cylinder. The ball mill rotation was driven by an electric motor and regulated using Toshiba inverter VF-S11. The ball mill inlet blower provided fresh air supply for cooling and blew *Porang* chips from the inlet hopper into the milling body. A 500 µm filter was installed in the outlet of the ball mill body. An on-off periodic pressurized air supply was introduced into ball mill outlet at a rate of 1 second on and 5 seconds off to clean the filter and to push the flour into cyclone separator unit. The cyclone separator unit was made of fiberglass and constructed in the form of 1D3D cyclone [24]. The blower was installed in the top part of the barrel of the cyclone separator and the Toshiba inverter VF-S15 regulated the suction velocity. Filtered particles of flour from the ball mill outlet were then separated using a 1D3D type of cyclone separator with D = 20 cm.

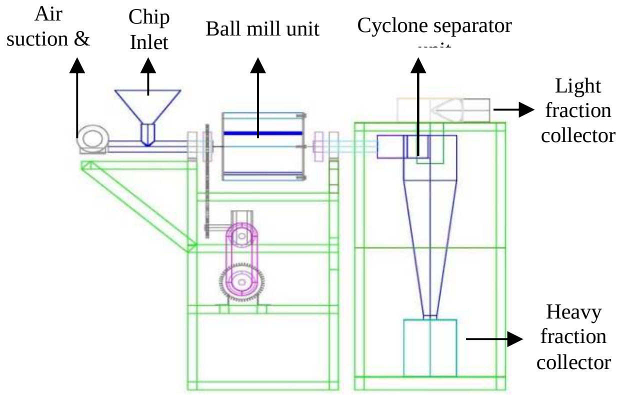

Fig 2. Design of CPFM

TABLE II
DIAMETER AND RATIO OF STAINLESS-STEEL BALL

No	Ball Diameter (mm)	Ratio
1	24.4± 0.4	4
2	36.1± 1.0	2
3	44.7± 0.3	1

C. Experimental Setup

1) Pre-test of the ball mill operation: In order to ensure the optimal milling for the ball mill, a pre-test of the ball mill rotation was conducted. The pre-test was conducted with the balls and *Porang* chips volume of 25% of the total inner body volume, and the ball mill rotational velocity was determined. The determination of optimal rotational velocity was based on a calculation and visualization method. Firstly, a calculation was conducted to obtain the optimal value of rotational velocity for the ball mill, which was set at 65-80% from critical rotational speed [25] or at 70-80% from critical rotational speed [26]. Equation 1 was used for critical rotational speed calculation.

$$N=\frac{42,3}{D^{\frac{1}{2}}} \quad (1)$$

N = Critical rotational velocity (rpm)
D = Cylinder diameter (m)

The visualization method captured the mass trajectory inside the ball mill body by using a 10.1 MP Sony camera DSC-S3000 with and without flour load to record the milling process.

2) The performance of the CPFM: To study the cyclone particle collection characteristic of the flour, the performance of the CPFM was measured at three levels of cyclone suction velocity: 5 ± 0.1 m/s, 7 ± 0.1 m/s, and 10 ± 0.1 m/s. The heavy fraction of flour collected at the bottom part of the cone, while the light fraction collected at the top part of the barrel of the cyclone unit. In addition, important physical and chemical performance parameters were measured. The physical performance parameters consisted of chip compressive strength, temperature distribution, cyclone suction velocity, sound loudness level, particle size, yield, production capacity, particle size, and distribution. The chemical performance parameters included water content, glucomannan, and calcium oxalate content.

There were several instruments used for physical analysis. For example, chip compressive strength was measured using an Imada Digital Force Gauge model ZP-200N. The cyclone suction velocity was measured using a CMM/CFM Thermo-Anemometer VA893. The temperature at the inlet, outlet, and in the environment was measured by a K type thermocouple and recorded in a GRAPHTEC midi logger GL820. The level of sound during the milling process was recorded using an EXTECH sound level meter type 407732. Finally, the light and heavy fractions of the collected *Porang* flour were analyzed for their particle size distribution using a CILAS 1090-dry particle size analyzer. As noted above, three types of chemical analyses were conducted to measure the water content, glucomannan, and calcium oxalate content. Water content was measured using a standard oven analysis [27]. The analysis of glucomannan content was based on [12], and levels of calcium oxalate content used a volumetric analysis method [20]. Leaching of *Porang* flour uses three-level of ethanol concentration [20].

III. Results and Discussion

A. Porang Chip Compressive Strength

Compared to potato or cassava chips, *Porang* chips have approximately four times higher compressive strength with approximately the same water content and thickness level (Table III). Therefore, more energy in the CPFM was required for milling the chips. Unlike potato or cassava chips which consist mainly of starch, the higher compressive strength of *Porang* chips was more predictable due to the glucomannan present. It was confirmed that the *Porang* glucomannan particles were bigger and harder than its impurities which included starch and calcium oxalate. Therefore, the glucomannan granules could not easily be smashed into fine particles in the milling process [6].

TABLE III
Physical Properties of Agricultural Chip Commodities

Agricultural Commodity	Water Content (%wb)	Chip Thickness (mm)	Compressive Strength(MPa)
Porang Chip	11.41 ± 0.12	2.75 ± 0.23	4.16 ± 1.13
	7.32 ± 0.21	2.00 ± 0.12	2.70 ± 1.24
Potato Chip	9.33 ± 0.87	1.62 ± 0.16	0.89 ± 0.36
Cassava Chip	8.47 ± 0.25	2.85 ± 0.05	0.81 ± 0.04

B. Pre-Test of the Ball Mill Operation

The pre-test of the ball mill operation was conducted to determine its optimal rotational velocity using two methods. The first used Equation 1 to calculate the critical speed rotation of a 265 mm ball mill which resulted in 82.2 rpm. This was followed by the calculation of the optimal rotational velocity and was found to be 80% of the calculated critical rotational speed which was 65.7 rpm. The second method used a visualization method of the mass trajectory experiments during the milling process using several rotational velocities with the results presented in Table IV. These show that below optimal rotational velocities (25 and 48 rpm) optimal milling did not occur. At this point, friction forces were more dominant than collision forces. On the other hand, above optimal rotational velocities (83 and 100 rpm), critical rotational velocity occurred with centrifugal forces dominant while collision and friction forces were reduced. In order to achieve optimal milling conditions, both collision and friction forces should be present. It is interesting to note in Table IV that both the calculation and visualization methods confirmed the optimal rotational velocity was 65±1 rpm.

TABLE IV
Captured Milling Balls Trajectories Based on Rotational Velocity

Rotational Velocity (rpm)	Balls Only Loaded	Flours and Balls Loaded
25 ± 1		
48 ± 1		
60 ± 1		
65 ± 1		
83 ± 1		
100 ± 1		

C. The Physical Performance Parameters

The discussion of physical parameters of the CPFM machine (Fig. 3) comprises of temperature distribution, sound loudness level, particle size distribution, yield, and production capacity.

Fig 3. The CPFM

1) Temperature distribution: Milling temperature was monitored at three locations in the ball mill unit: the environment, the inlet, and the outlet (Table V). The temperature differences in the three locations were less than 5^0C and did not exceed 35^0C. Due to the blower's heat produced from its electric coils, the inlet temperature was 3^0C higher than in the outlet. The collision and friction forces acting inside the milling body may have also contributed to the temperature increase. However, as the increase was no more than 3^0C, it suggests that the milling process had an insignificant effect on overall processing temperature. The regulation of the temperature for the milling process is essential as a low-temperature could preserve the glucomannan granules in the flour. According to previous research, decomposition may occur in the glucomannan's constituent molecules. For example, the glucose molecule starts to degrade at 235 ^{0}C [28] or to decompose at 300 ^{0}C [29]. In addition, a caramelization process may occur if the temperature reaches 160^0C. Therefore, it is important for efficient CPFM operation that the temperature parameters are within the range to produce *Porang* flour.

TABLE V
TEMPERATURE PROFILE OF THE CPFM OPERATION

Cyclone Suction Velocity (m/s)	Position	Temperature		
		Average (°C)	Min (°C)	Max (°C)
5.1 ± 0.1	Environment	28.8 ± 0.5	27.5	29.9
	Inlet	33.7 ± 1.7	28.1	35.5
	Outlet	32.9 ± 2.3	28.5	37.1
7.0 ± 0.1	Environment	29.5 ± 0.2	28.6	30.1
	Inlet	33.7 ± 0.8	31.5	35.0
	Outlet	34.3 ± 2.1	30.5	37.5
10.0 ± 0.2	Environment	29.8 ± 0.8	27.4	31.1
	Inlet	34.8 ± 1.6	29.6	37.1
	Outlet	32.7 ± 2.1	28.3	36.4

2) Sound loudness level: The source of the milling sound from CPFM processing originated from friction and balls colliding with each other and the walls of the mill. Its level was considered high with an average level of 97.8 ± 1.5 dB which is a similar sound threshold as a motorcycle or a diesel locomotive [30]. Operator to long-term exposure to high levels of sound may cause long-term health effects such as sensory-neural hearing deficit or hearing loss. However, this can be overcome using acoustic–hearing protectors. Moreover, it is believed that mediation using sound and vibration isolation techniques to the mill and its location, can contribute to a reduction in milling sound levels.

3) Particle size distribution: The mechanism of course and fine particle production was observed in the collision and friction forces. The forces existed among the balls as well as the balls to the mill's wall. The resultant forces from the rotation of the ball mill caused the chips to break into coarse and fine particles. Friction forces also occurred among the flour particles themselves.

The cyclone separation process was based on molecular weight classification and the centrifugal forces acting on the particles inside the cyclone separator unit. During the continuous milling process, *Porang* flour was constantly transferred by air flowing from the electric blower to the milling body through a 500 μm screen filter and then to the 1D3D cyclone separator.

Inside the cyclone separator unit, the separation between glucomannan and calcium oxalate occurred. Calcium oxalate has a lower molecular weight (±126.07 Dalton) than glucomannan (200-2000 kDalton) [21]. Therefore, more *Porang* glucomannan granules were expected in heavy fraction of the flour and calcium oxalate particles and other impurities in a light fraction of the flour. The numerical simulation study by using Fluent 6.1 CFD software showed that the heavy large particles were dominantly found in cyclone walls whereas light small particles were in the central region of the cyclone [31]. The heavy and the light fractions of the *Porang* flour particle size distribution separated by 1D3D cyclone are consecutively shown in Fig. 4 and Fig. 5. The particle size distribution of the heavy and the light fractions for the three levels of cyclone suction velocity is given in Table VI.

The heavy particle collection of the suction velocity of 5 m/s had a higher particle collection rate especially in the range 95 μm to 300 μm compare to the other suction velocities. It means the suction velocity of 5 m/s can collect more heavy particles on that specific range which made the average diameter of the suction velocity of 5 m/s (324.83 μm) is smaller than the 7 m/s and 10 m/s.

The *Porang* flour particles consisted mainly of *Porang* glucomannan granules which their average diameter 324.83 μm to 348.71 μm. It is identified in the previous research that the glucomannan granules have an egg-like shape with a diameter ranging from 250 μm to 750 μm [6], with impurities located in its shell. It was also identified that the *Porang* glucomannan granules were in the range of 283 μm to 500 μm [16].

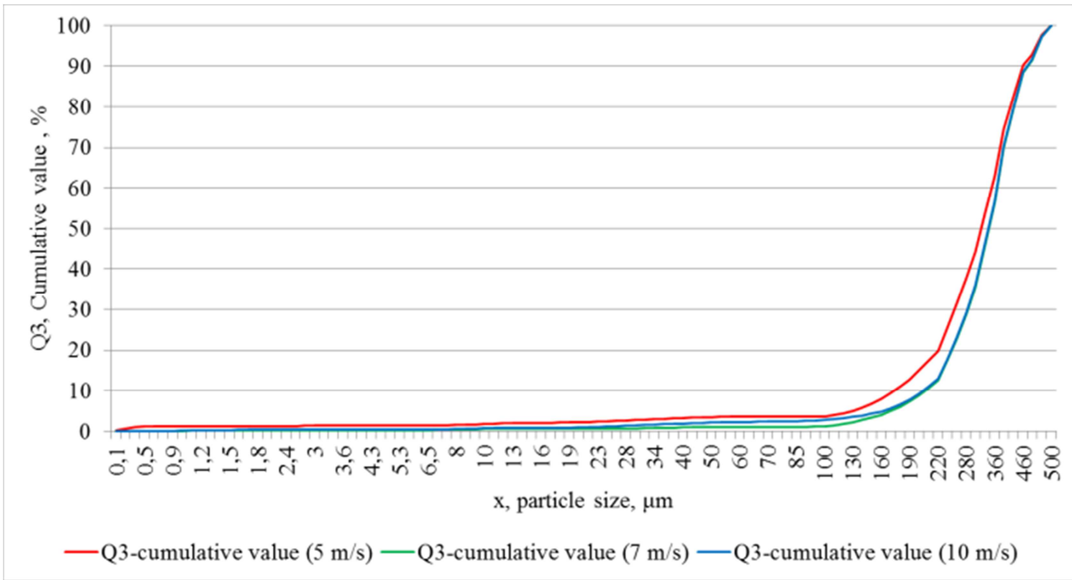

Fig 4. The heavy fraction of *porang* flour particle size distribution

TABLE VI
THE HEAVY AND LIGHT FRACTION OF THE PORANG FLOUR

Cyclone Suction Velocity (m/s)	The Heavy Fraction		The Light Fraction	
	Particle Size Range (µm)	Average Diameter (µm)	Particle Size Range (µm)	Average Diameter (µm)
5.1 ± 0.1	95 - 500	324.83	0.1 - 500	131.76
7.0 ± 0.1	80 - 500	348.71	0.1 - 500	144.85
10.0 ± 0.2	75 - 500	345.65	0.3 - 500	179.15

The heavy fraction of flour particle size can be categorized into the whole glucomannan granule (200-500 µm) and broken glucomannan granule (< 200 µm). The maximum particle size of the heavy fraction of *Porang* flour was 500 µm due to the filter application. A 500 µm filter had effectively enabled both the whole and broken *Porang* glucomannan granules to pass through into cyclone separator. The use of the filter decreased the possibility of transferring double or more glucomannan particles. The cyclone separator was employed to collect them at the bottom of the cyclone separator as the heavy fraction of *Porang* flour.

The starting particle size at the heavy fraction collector depended on the suction velocity. The higher the suction velocity has made the stronger centrifugal force acting on the flour particles so that the smaller light particles were pushed to the cyclone wall and collected at a heavy fraction collector at the bottom of the cyclone. In contrast, the lower the suction velocity created the weaker centrifugal force so that the smaller light particles floating in the center of the cyclone and sucked into the light fraction collector at the top of the cyclone. Therefore, the cyclone suction velocity of 5 m/s produced larger starting particle diameter than the 7 m/s and the 10 m/s which was 95 µm for 5 m/s, 80 µm for 7 m/s, and 75 µm for 10 m/s..

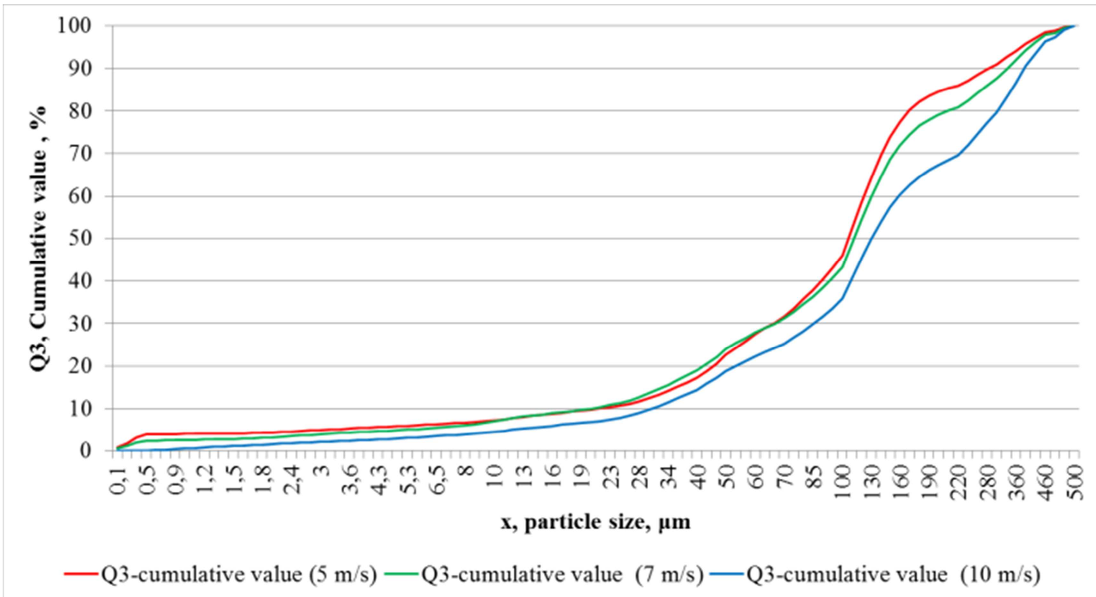

Fig 5. The light fraction of porang flour particle size distribution

Corresponding to the SEM figure [15], the calcium oxalate particles which are needle shape and attached themselves to the surface of *Porang* glucomannan particles were observed in the range of ± 20 μm. The cyclone separator was employed to clean and collect them at the top of the cyclone separator as the light fraction of *Porang* flour. The light fraction of *Porang* flour mainly consisted of impurities including starch and calcium oxalate with smaller particle sizes. However, there was a possibility that some lightweight big particles, such as dried *Porang* skins, could be categorized in light fraction flour. Moreover, the higher cyclone suction velocity produced the larger average particle diameter of the light fraction *Porang* flour (Fig. 5).

4) Yields and Production Capacity: The heavy fraction of flour was considered as cleaned *Porang* flour and was used in the yield and production capacity calculations which are presented in Table VII. It can be observed that the suction velocity of 5 m/s had higher heavy fraction yields reaching 57.1 % of the given chip input. If the suction velocity was increased, it gradually reduced the flour yield collected at the heavy fraction collector due to the more significant centrifugal force.

TABLE VII
YIELDS AND PRODUCTION CAPACITY

Cyclone Suction Velocity (m/s)	Chip Input (g/hour)	The Heavy Fraction of Porang Flour Production (g/hour)	The Heavy Fraction Yield (%)
5.1 ± 0.1	697.33	398.00	57.1 ± 5.3
7.0 ± 0.1	780.67	353.33	45.3 ± 3.5
10.0 ± 0.2	751.33	248.67	33.1 ± 3.1

D. The Chemical Performance Parameters: Water Content, Glucomannan, And Calcium Oxalate Content

As can be seen from Table VIII, the three different cyclone suction velocities used during the separation process resulted in different chemical characteristics of the flour. The highest glucomannan content was obtained using the 10 m/s cyclone suction velocity.

TABLE VIII
WATER CONTENT, GLUCOMANNAN CONTENT, CALCIUM OXALATE CONTENT OF PORANG FLOUR

Cyclone Suction Velocity (m/s)	Water Content (%)	Glucomannan Content (%)	Calcium Oxalate Content (%)
5.1 ± 0.1	8.65 ± 0.78	80.79 ± 1.74	0.21 ± 0.03
7.0 ± 0.1	9.09 ± 0.12	86.53 ± 0.39	0.12 ± 0.04
10.0 ± 0.2	7.98 ± 1.07	87.79 ± 0.19	0.29 ± 0.10

Based on comparisons of the various milling techniques presented in Table IX, it appears the CPFM technique has better glucomannan content with lower calcium oxalate content compared to other milling techniques after purification. In detail, there are two advantages to the batch type of ball mills. Firstly, the fine particles which occur in the batch ball milling process act as a resistance. In contrast, in the CPFM, fine particles which were smaller than outlet filter were collected by blowing air from the blower to the outlet. As a result, the milling process is more efficient as there is less resistance. Secondly, the CPFM process has a higher production capacity due to the continuous input and output materials. The CPFM technique can improve the milling time period of a stamp mill and batch type of ball mill as a result, it increased the milling production capacity. In order to become a commercial product in the market, purification is needed to eliminate the calcium oxalate content.

TABLE IX
COMPARISON OF VARIOUS MILLING TECHNIQUES FOR PORANG FLOUR

Milling Techniques	Purification	Glucomannan Content (%)	Calcium Oxalate Content (%)
Hammer mill [10]	Unpurified	-	0.80
Ball mill (batch type) [23]	Unpurified	43.99	22.72
Ball mill (batch type) [23]	Purified	70.35	3.23
Stamp mill [15]	Unpurified	67.02	0.398
Stamp mill [20]	Unpurified	64.80	2.10
Stamp mill [20]	Purified	81.70	0.19
CPFM*	Purified	80.79-87.79	0.12-0.29
Commercial product standard [12]	Unpurified	>70	0.08

* Current research

IV. CONCLUSIONS

The CPFM using a ball mill and cyclone separator can produce 248.67 to 398.00 gram/hour of cleaned *Porang* flour with glucomannan content ranging from 80.79% to 87.79% and calcium oxalate ranging from 0.12% to 0.29%, which is close to commercial product standard. The 5 m/s cyclone suction velocity had the highest yield and production capacity but had the lowest glucomannan content. The calcium oxalate content overall was under 0.3%, which is better compared when compared to other milling methods.

ACKNOWLEDGMENT

We would like to thank the Indonesian Ministry of Research, Technology and Higher Education for supporting *Porang* research through doctoral research scheme with contract number: 063/SP2H/LT/DRPM/IV/2017. I would also like to sincerely thank Dr. Alan McGee at Massey University, New Zealand for his patient assistance and guidance during the writing of this article.

REFERENCES

[1] G. O. Phillips and P. A. Williams, *Handbook of hydrocolloids*: CRC Press, 2000.

[2] M. Chua, T. C. Baldwin, T. J. Hocking and K. Chan, "Traditional uses and potential health benefits of Amorphophallus konjac K. Koch ex N.E.Br", *Journal of Ethnopharmacology*, vol. 128, pp. 268-278, 2010.

[3] C. M. Gallaher, J. Munion, R. Hesslink, J. Wise and D. D. Gallaher, "Cholesterol reduction by glucomannan and chitosan is mediated by changes in cholesterol absorption and bile acid and fat excretion in rats", *The Journal of nutrition*, vol. 130, pp. 2753-2759, 2000.

[4] F. H. Al-Ghazzewi, S. Khanna, R. F. Tester and J. Piggott, "The potential use of hydrolysed konjac glucomannan as a prebiotic",

Journal of the Science of Food and Agriculture, vol. 87, pp. 1758-1766, 2007.

[5] C. Wang, M. Xu, W.-p. Lv, P. Qiu, Y.-y. Gong and D.-s. Li, "Study on Rheological Behavior of Konjac Glucomannan", *Physics Procedia*, vol. 33, pp. 25-30, 2012.

[6] A. Yanuriati, D. W. Marseno and E. Harmayani, "Characteristics of glucomannan isolated from fresh tuber of Porang (Amorphophallus muelleri Blume)", *Carbohydrate Polymers*, vol. 156, pp. 56-63, 2017.

[7] O. Tatirat and S. Charoenrein, "Physicochemical properties of konjac glucomannan extracted from konjac flour by a simple centrifugation process", *LWT - Food Science and Technology*, vol. 44, pp. 2059-2063, 2011.

[8] L. K. Massey, H. Roman-Smith and R. A. L. Sutton, "Effect of dietary oxalate and calcium on urinary oxalate and risk of formation of calcium oxalate kidney stones", *Journal of the American Dietetic Association*, vol. 93, pp. 901-906, 1993.

[9] A. Bhandari, S. Koul, A. Sekhon, S. K. Pramanik, L. S. Chaturvedi, M. Huang, M. Menon and H. K. Koul, "Effects of Oxalate 0n HK-2 Cells, a Line of Proximal Tubular Epithelial Cells From Normal Human Kidney", *The Journal of urology*, vol. 168, pp. 253-259, 2002.

[10] A. Faridah, S. B. Widjanarko, A. J. I. Sutrisno and B. Susilo, "Optimasi Produksi Tepung Porang dari Chip Porang Secara Mekanis dengan Metode Permukaan Respons", *Jurnal Teknik Industri*, vol. 13, pp. 158-166, 2013.

[11] N. Chairiyah, N. Harijati and R. Mastuti, "Variation of Calcium Oxalate (CaOx) Crystals in Porang (Amorphophallus muelleri Blume)", *American Journal of Plant Sciences*, vol. 4, pp. 1765-1773, 2013.

[12] C. M. o. Agriculture, *Professional Standard of the people Republic of China for Konjac Flour*, 2002.

[13] F. C. C. (FCC), *Revised Monograph-Konjac Flour*, 1996.

[14] E. Commission, *Commission Directive 2001/30/EC of 2001, Amending Directive 96/77/EC Laying Down Specific Purity Criteria on Food Additives Other than Colours and Sweeteners*, Brussels, 2001.

[15] A. Faridah, "Comperation of Porang Flour (morphophallus muelleri) Purification Method: Conventional Maceration (gradient ethanol leaching) and Ultrasonic Maceration Method using Response Surface Methodology", *International Journal on Advanced Science, Engineering and Information Technology*, vol. 6, pp. 265-272, 2016.

[16] A. Faridah and S. B. Widjanarko, "Optimization of multilevel ethanol leaching process of porang flour (Amorphophallus muelleri) using response surface methodology", *International Journal on Advanced Science, Engineering and Information Technology*, vol. 3, pp. 74-80, 2013.

[17] D. A. Anggraeni, S. B. Widjanarko and D. W. Ningtyas, "Proporsi Tepung Porang (Amorphophallus Muelleri Blume): Tepung Maizena terhadap Karakteristik Sosis Ayam [In Press Juli 2014]", *Jurnal Pangan dan Agroindustri*, vol. 2, pp. 214-223, 2014.

[18] S. B. Widjanarko, Q. Amalia, M. B. Hermanto and A. Z. Mubarok, "Evaluation of the effect of yellow konjac flour-κ-carrageenan mixed gels and red koji rice extracts on the properties of restructured meat using response surface methodology", *Journal of food science and technology*, vol. 55, pp. 1781-1788, 2018.

[19] N. O. S. Dananjaya and A. Sutrisno, "Optimasi Proses Penepungan dengan Metode "Stamp Mill" dan Pemurnian Tepung Porang dengan Metode Ekstraksi Etanol Bertingkat untuk Pengembangan Industri Tepung Porang (Amorphophallus oncopylus)", Bachelor (STP) Thesis, Jurusan Teknologi Hasil Pertanian, Universitas Brawijaya, Malang, 2010.

[20] A. D. Kurniawati and S. B. Widjanarko, "Effects of Multiple Ethanol Leaching with Difference Concentration on Physical and Chemical Properties of Porang Flour (Amorphophallus oncophyllus)", Bachelor, Food Science and Technology Department, Brawijaya University, Malang, 2010.

[21] N. Nandiwilastio and S. B. Widjanarko, "Pengaruh Rasio Chips dengan Bola Penumbuk Ball Mill Terhadap Rendemen dan Kemampuan Hidrasi Tepung Porang", *Jurnal Pangan dan Agroindustri*, vol. 2, pp. 106-112, 2014.

[22] S. Mustafa and S. B. Widjanarko, "Pengecilan Ukuran Metode Ball Mill dan Pemurnian Kimia terhadap Kemurnian Tepung Porang (Amorphophallus Muelleri Blume)", *Jurnal Pangan dan Agroindustri*, vol. 3, 2015.

[23] S. B. Widjanarko, E. Widyastuti and F. I. Rozaq, "Pengaruh Lama Penggilingan Tepung Porang (Amorphophallus muelleri Blume) dengan Metode Ball Mill (Cyclone Separator) terhadap Sifat Fisik dan Kimia Tepung Porang", *Jurnal Pangan dan Agroindustri*, vol. 3, 2015.

[24] L. Wang, "Theoretical study of cyclone design", PhD, Biological & Agricultural Engineering, Texas A&M University, Texas, USA, 2004.

[25] J. G. Brennan, *Food Processing Handbook*: WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, 2006.

[26] J. W. Schlanz, *Grinding: An Overview of Operation and Design*: North Carolina State University Minerals Research Laboratory, 1987.

[27] C. Association of Official Analytical and W. Horwitz, *Official methods of analysis*: AOAC Washington, DC, 1980.

[28] H. Sugisawa and H. Edo, "The thermal degradation of sugars I. Thermal polymerization of glucose", *Journal of Food Science*, vol. 31, pp. 561-565, 1966.

[29] C. Promdej and Y. Matsumura, "Temperature effect on hydrothermal decomposition of glucose in sub-and supercritical water", *Industrial & Engineering Chemistry Research*, vol. 50, pp. 8492-8497, 2011.

[30] P. M. Rabinowitz, "Noise-induced hearing loss", *American family physician*, vol. 61, pp. 2759-2760, 2000.

[31] G. Wan, G. Sun, X. Xue and M. Shi, "Solids concentration simulation of different size particles in a cyclone separator", *Powder Technology*, vol. 183, pp. 94-104, 2008.