Polishing effect on the physicochemical properties of porang flour using centrifugal grinder

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Abstract. Porang tubers are an agricultural product from one of the endemic plants in Southeast and East Asia, which found in the Indonesian forest and is a vital source of glucomannan. The simple processing of porang tubers is made into chips, ground using mechanical milling followed by air fractionation. However, porang flour from mechanical milling still has high impurities, such as calcium oxalate more than 2% and not safe for human consumption. The polishing process using a centrifugal grinder is needed to remove impurities that still attached to the glucomannan cells by the friction principle. The purpose of this study was to investigate the effect of the polishing cycle on physicochemical properties of porang flour. The experimental design used polishing historical data and process was conducted in two replication. The results showed the polishing cycle had a significant effect (p < 0.05) on the glucomannan content, viscosity, degree of whiteness, calcium oxalate content, starch content, protein content, and fat content. The best of polished porang flour was obtained on the 5 times of polishing cycle based on multiple attributes calculations.

1. Introduction
Porang plants are a type of *Amorphophallus* genus, which grows in Indonesian forests, and belongs to non-cultivated or wild plants [1,2]. The most important of the chemical content of the corms of this plant is glucomannan. Glucomannan is a neutral polysaccharide composed of mannose and glucose with a ratio of 1.6:1 [3–6], which is applied to food and non-food products [7,8]. Moreover, porang tubers also contain high calcium oxalate, a compound that can cause health problems in humans [1, 9–15], making it very rare to be used for direct consumption and converted into dried porang chips [16]. Generally, the initial stage of the process of separating glucomannan and impurities, including calcium oxalate from porang chips was carried out by milling using mechanical machine followed by air clarification [9,10,17,18]. But this method considered to be less effective to separation components. Faridah et al. [10] reported the calcium oxalate content of porang flour milled using the stamp mill followed by air classification of 0.3-5.17%. Witoyo et al. [19] informed that the calcium oxalate content of porang flour produced using micro mill assisted cyclone separator by continuous process ranged from 3.92 – 5.71%. This calcium oxalate content is not suitable for human consumption, therefore it requires a further separation process. Furthermore, the other impurities, like protein, fat, starch, and ash content are also higher in the mechanical milled porang flour.
The polishing process is one of the efforts to reduce the impurity component that still passes through the mechanical milling process. The polishing process for porang flour using an abrasive type polishing machine has been done by Wachyuningsih [20] and Sary [21]. Wachyuningsih [20] claimed that 3 times of polishing cycle and 6 minutes of polishing time were able to produce porang flour with the best characteristics. Sary [21] informed the best time for polishing using an abrasive type of polishing machine is 15 minutes. Abrasive type polishing machine was effective in removing impurities, but was able to decrease the glucomannan content in porang flour [20, 21].

Centrifugal grinder is a modification of friction type of polishing machine that equipped with a water cooling system, to prevent overheating in the milling room during the process. The principle of polishing using centrifugal grinder based on the friction the porang flour with the polishing rotors, or between the porang flour, thus the impurities that surrounding the glucomannan cells will be eroded and easily separated by a cyclone separator in the device circuit. But, none information or publication about polishing porang flour using a centrifugal grinder and it’s only limited to the process of the production wheat flour or durum flour from wheat grains [22–25] or non-food materials [26]. This research was aimed to investigate the effect of the polishing cycle on the physicochemical properties of porang flour using a centrifugal grinder.

2. Material and methods

2.1. Materials

The raw material used in this study is porang flour (PF) which is produced by milling of the porang chips using micro mill assisted cyclone separator under optimum milling condition. The porang chips were collected from farmers in Nglyuy Village, Nglyuy District, Nganjuk Regency, East Java, Indonesia. All pro analysis chemical reagents were purchased from Merck Co. Ltd. The equipment for the polishing process used the centrifugal grinder, with process condition as follows: 20 Hz of feed rate speed, 30 Hz of rotor speed, and 10 Hz for fan mixing speed (According condition process was applied in the Pilot Plant Lab., Faculty of Agricultural Technology (FAT), Universitas Brawijaya (UB)).

2.2. Polishing process

Briefly, the polishing procedure of porang flour as follows: the dry chips were milling using disk mill with 20 mesh sieve and followed by the micro mill with 40 mesh sieve and fractionated by cyclone separator and obtained from the heavy fraction of porang flour (known as PF) [19]. 12.5 kg of PF was weighted using CMOS digital Scales (SD-30K Type) and entered in the input hopper. Turn on the panels of feed rate and fan mixing speed that have been set previously for 30 seconds to fill the polishing room, followed by setting the rotor speed to 30 Hz for the polishing process. Each of the polishing cycles obtained 2 fractions, namely the heavy (known as polished flour porang (PPF)) and light fractions. Each completed cycle (30 seconds after the hopper input was run out), the machine was turned off. The PPF was collected and sampled (100g) for further analysed. For the 2 - 5 polishing cycle, the PPF from the previous cycle inserted into the same input hopper, and followed the same procedure as previously described (modified from Wachyuningsih [20] and Sary [21]).

2.3. Experimental design and statistical analysis

In this study, the experimental design used the polishing of historical data from 0 to 5 times of polishing and process repeated for two replication. The mean of experimental data was analysed by one –way ANOVA using Minitab 17 trial version (Stat View, USA) at 95% of confidence level and followed by Tukey-test (95% of confidence level). The determination of best treatment for all parameters using multiple attributes calculations [27].

2.4. Methods of analysis

Calcium oxalate was determined as described by Ukpabi and Enjidoh in Iwouha and Kalu [28]. The degree of whiteness (DoW) was determined using the color reader (Minolta CR-100) as described by Impaprasert et al. [29]. Porang glucomannan content and its dry basis was determined by Chua et al.
methods [30] with minor modification. The porang flour viscosity was measured by Yanuriati et al method [31] with minor modification. Briefly, the measurement of 1% sol of porang flour was performed at room temperature using NDJ-1 rotational viscometer (12 rpm of agitated speed and 4 of the spindle). The protein, fat, and starch contents were determined by the standard AOAC method [32]. The protein was determined by the Kjeldahl method, fat content was evaluated by the Soxhlet extraction method, and starch was evaluated by acidic hydrolysis method.

3. Results and Discussion
3.1. Physicochemical properties of Porang flour (PF)

The physicochemical properties of PF were presented in Table 1. The calcium oxalate content on the PF was in the range of 1.24 – 2.64%. The polishing cycle had a significant effect (p < 0.05) on calcium oxalate content of PF. The trend showed the calcium oxalate had a negative correlation with the polishing cycle. The decreasing of calcium oxalate was caused impurities that covering the surface of the glucomannan granules eroded by friction between the polishing rotors and porang flour, or friction between the porang flour, and also the presence of a continuous fractionation process using a cyclone separator based on the principle of density. This result consistent with the previous study by Wachyuningsih [20].

The degree of whiteness of porang flour shown in Table 1. The DoW of PF was in the range of 57.89 – 59.92. The results of variance using one-way ANOVA showed the polishing cycle had a significant effect (p < 0.05) on the degree of whiteness of PF. The degree of whiteness in polished porang flour slightly increase until 2 times of the polishing cycle and little increase when the polishing cycle more than 2 times. The increasing degree of whiteness might be due to a reduction of the impurities (tobico), which envelop glucomannan cells, such as calcium oxalate, starch, protein, fat, and ash. Mawarni and Widjanarko [27] reported that the degree of whiteness related to impurity components. The fewer impurities that surround the glucomannan granule, so the porang flour will be brighter. This result was agreeable with the previous study by Sary [21], Paiva et al.[33] and Monks et al.[34].

Glucomannan content is the important parameter on porang flour quality. Glucomannan content on PF was in the range of 47.45 – 60.67 % d.b. The polishing cycle had a significant effect (p < 0.05) on glucomannan content of PF based on one-way ANOVA analysis. Glucomannan content increase with increasing polishing cycle. The increasing of glucomannan content negatively correlated with the impurity component surrounding the glucomannan cell. The more non-glucomannan components eroded during the polishing process due to the mechanical force of the machine or between porang flour, thus increasing the glucomannan content in PF. In addition, the mechanical force was considered capable of breaking and separating compact structures from non-glucomannan components that envelop glucomannan granules [20]. The impurity component which has been split and separated from the glucomannan granule will produce small particles that have a lower density than glucomannan so that it will follow the air velocity in the fractionation process using a cyclone separator.

The viscosity of PF was in the range 3625 – 10844 cPs. The analysis of variance using one-way ANOVA indicated that the polishing cycle had a significant effect (p < 0.05) on the viscosity of PF. The trend showed that the viscosity of porang flour increased with the increasing of the polishing cycle. Viscosity data presented in Table 1. In this present study, the viscosity correlated with glucomannan content. The higher the glucomannan affected on the higher viscosity in polished porang flour [35]. In addition, the increasing viscosity of porang flour is also influenced by the water absorbability and the hygroscopicity of the material [20]. Glucomannan was able to absorb water and float up to 138 - 200 times compared to starch which only expanded to 25 times [36].

The starch content of PF ranged from 3.37 – 36.53%. The analysis of variance by one-way ANOVA showed the polishing cycle had a significant effect (p < 0.05) on the starch content of PF. In general, the starch content decreased as a function of the polishing cycle increased. This trend is in line with the research of Brou et al. [37] about red sorghum polishing process through collision using a hammer mill. In another response, the protein content of PF ranged from 0.71 - 6.01%. In this study, polishing led to the linear decline of the protein content in the PF. Based on the one-way ANOVA, the
polishing cycle also had a significant effect (p < 0.05) on the protein content of PF. The data of the starch and protein content of PF are presented in Table 1.

The fat content of PF ranged from 0.06 - 0.47% (Table 1). Based on one-way ANOVA, the polishing cycle had a significant effect (p < 0.05) on the fat content of PF. Moreover, in general, the trend showed an increase in the polishing cycle, reducing the fat content on PF. This phenomenon might be due to the starch, protein and fat content (the impurities) that encapsulated glucomannan cell peeled off during the polishing process and separate by cyclone separator simultaneously. Similar results of protein and fat content affected by polishing reported by [33,34,38–40] with rice or pigmented rice as material research.

Table 1. Physicochemical properties of porang flour

| Parameter (%)   | Polishing Cycle (Times) | p-value |
|-----------------|-------------------------|---------|
|                 | 0          | 1       | 2      | 3      | 4      | 5     |
| Calcium Oxalate | 2.64b      | 2.17c   | 1.91bc | 1.76cd | 1.45bc | 1.24c | 0.000 |
| Glucomannan(*)  | 47.45c     | 55.69b  | 55.79b | 58.49ab | 60.04a | 60.67a | 0.000 |
| Degree of Whiteness(\*) | 57.89b | 58.18b  | 59.40a | 59.50a | 59.84a | 59.92a | 0.000 |
| Viscosity(**)   | 3625b      | 6375d   | 9000c  | 9625b  | 10625b | 10844a | 0.000 |
| Starch Content  | 36.53b     | 51.1bc  | 8.00b  | 5.61bc | 4.82bc | 3.37bc | 0.000 |
| Protein Content | 6.01a      | 1.36b   | 1.06c  | 0.86cd | 0.76d  | 0.71e  | 0.000 |
| Fat Content     | 0.47a      | 0.07c   | 0.18b  | 0.09c  | 0.10e  | 0.06e  | 0.000 |

Note: Different letters in the same row showed the significantly different (p < 0.05) based on the tukey test. *in dry basis, *no unit (100 values assumed as pure white), **in cPs

3.2. Determination of best treatment

The best treatment was obtained on the 5 times of polishing cycle, with 1.24% of calcium oxalate, 60.67 % d.b. of glucomannan, 59.92 of the degree of whiteness, 10844 cPs of viscosity, 3.37% of starch content, 0.71% of protein content, and 0.06% of fat content. Extraction and purification of PPF with chemicals solvents, such as ethanol are needed to obtain porang flour with high purify before application in food product. The viscosity, degree of whiteness and calcium oxalate of porang flour in this study were higher compared with the Wachyuningsih [20] data, but the glucomannan content was lower than her data. The characteristics of best porang flour reported by Wachyuningsih’s are as follows: the viscosity of 5250 cPs, degree of whiteness of 50.75, glucomannan of 72.66%, and calcium oxalate 0.61%. Moreover, the best results of this study had an advantage in the viscosity of porang flour compared with data reported by Sary [21]. The best results from Sari’s are as follows: 0.46% of calcium oxalate, 65.87% of glucomannan content, 60.59 of degree of whiteness, and 5222 cPs of viscosity. The different results might be caused by several factors, such as origin of raw materials, initial chemical composition of chips/tubers, pretreatment process, age of the tuber used, and the different analysis methods.

4. Conclusions

Polishing effect on the physicochemical characteristics of porang flour using centrifugal grinder was successfully investigated. The results showed that the polishing affected on the physicochemical properties of porang flour. The polishing cycle using centrifugal grinder was enhanced the glucomannan content, viscosity, and degree of whiteness, as well as decreased the non glucomannan component (calcium oxalate content, fat content, protein content and starch content) in the polished porang flour. The best of polished porang flour based multiple attributes calculations for all responses was obtained on the 5 times of polishing cycle, with 1.24% of calcium oxalate, 60.67 % d.b. of glucomannan, 59.92 of the degree of whiteness, 10844 cPs of viscosity, 3.37% of starch content, 0.71% of protein content, and 0.06% of fat content.
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