# The Quality Characteristics of Porang Flour Processed By Soaning, Flouring, Sifting, and Blowing Treatment

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**ABSTRACT**

Porang (*Amorphophallus oncophyllus*) is a raw material for glucomannan flour, which is widely used as a thickener in the food industry. However, the high oxalates in its flour can pose health risks when consumed in excess. Therefore, this study aimed to analyze the quality characteristics of porang flour processed through grinding with a hammer and disk mill, followed by polishing, sieving, and air blowing using a cyclone separator. The primary processing stages include the use of hammer and disk mills, a polishing machine, a Tyler sieving machine, as well as a cyclone separator equipped with a blower. The results showed that the quality of porang flour subjected to two polishing treatments produced a specific gravity of 0.559 g/cm$^3$. Furthermore, the optimal processing method included hammer milling with a Sanindo polished cycles. This led to the production of porang flour with the lowest calcium oxalate content (0.22%), high glucomannan concentration (31.56%), and high viscosity (14666.7 mPas).

**Keywords**: Blowing; flouring; polishing; porang chips; sifting

## INTRODUCTION

Porang (*Amorphophallus oncophyllus*) has become one of Indonesia's leading export commodities. It contains glucomannan, a valuable compound utilized in the food, pharmaceutical, and cosmetics industries. The glucomannan content ranges from 5-65%, with Indonesian porang typically containing between 14 and 35% (Anggraeni et al., 2014). Porang cultivation is widespread across Indonesia, particularly in the provinces of West Java, East Java, Yogyakarta, North Sumatra, Banten, Bali, East Nusa Tenggara, and South Sulawesi. The harvested tubers are distributed to various regions for processing into porang chips. While porang processing factories operate in multiple locations, the largest facilities are concentrated in West Java and East Java. These factories produce several derivative products, including porang chips, porang flour, and glucomannan flour (Lempang, 2016).

Various studies have explored methods to produce porang flour with low calcium oxalate, a development that could drive the industry toward adopting improved processing technologies. Therefore, appropriate methods are needed to minimize the insoluble crystalline compound content (Mawarni & Widjanarko, 2015). The production of porang flour includes several stages, such as washing, peeling, chopping, drying, flouring, and the separation of calcium oxalate. The separation can be achieved through physical and chemical methods. Physical separation includes milling,

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polishing, sieving, and blowing air with a cyclone separator, while the chemical method uses ethanol. A previous study conducted by Wahjuningsih & Kunarto (2011) and Mawarni & Widjanarko (2015) produced Porang flour with a calcium oxalate content of 0.89% and a whiteness of 69.95% using hammer and disk mill methods.

A previous study by (Anggraeni et al., 2014) produced porang flour with a calcium oxalate content of 0.89% and a whiteness of 69.95% using the disk mill flouring method. However, a hammer mill flouring tool was not applied, and the physical and chemical properties of porang flour were not tested. Therefore, this study adopted a calcium oxalate separation method by milling with both hammer and disk mills, followed by polishing, sieving, and air blowing using a cyclone separator. Polishing aims to erode the outer layer of glucomannan in order to obtain low-oxalate products. Air blowing facilitated the separation of glucomannan from impurity components based on material weight. Meanwhile, sieving allowed for the removal of impurity components according to particle size without reducing the glucomannan content (Anggraeni et al., 2014). The results showed that the processing method successfully produced flour with low oxalate.

## METHODS

The research was conducted from May 2023 to September 2023 at the Food and Postharvest Engineering Laboratory, Biotechnology Laboratory, Department of Food and Agricultural Products Technology, as well as the incubator unit, Faculty of Agricultural Technology, Universitas Gadjah Mada, Yogyakarta.

### Materials

The main materials used include porang chips from PT. Sanindo Porang Berkah, West Java and PT. Mareefa Alam Samudra (MAS), East Java. The glucomannan content test required phenol ($C_6H_5OH$), sodium hydroxide (NaOH), sodium hydrogen sulfite ($NaHSO_3$), potassium hydrogen tartrate ($KC_4H5O_6$), formic acid ($CH_2O_2$), 3,5- Dinitrosalicylic acid (DNS), D-glucose, sulfuric acid ($H_2SO_4$), and distilled water. Calcium Oxalate analysis was conducted using distilled water, 6 M HCL solution, 0.05 M $KMnO_4$ solution, filter paper, concentrated Ammonia ($NH_4OH$) solution, 5% $CaCl_2$ solution, and 20% $H_2SO_4$ solution.

The tools used include a disk mill (Shandong Jimo brand, 8800 rpm), a hammer mill (2702 rpm), a sanding machine, Tyler Sieve (USA Standard Testing Stive brand), and a Cyclone separator machine, which comprised of pipes, cyclones, supporting frames, and blowers (3000 rpm, 220 W) for impurity removal. The impurities were calcium oxalate, starch, and other minerals with glucomannan particles in porang flour. Other instruments included analytical balance (Ohaus brand), mesh sieve, viscometer (Brookfield MA 02072 USA model), oven (Sanyo brand), and color meter (TES 135A brand).

### Study Implementation

#### Flouring stage

Flouring is the process of reducing the size of the material into smaller particles. The dried porang chips were reduced in size through a grinding process conducted using a hammer and disk mills. The working principle of the hammer mill was based on a hammer rotating on its axis, while the disk mill relied on the pressure and friction between two discs, which rotated simultaneously to crush the ground material. Both mills feature protrusions that function to break down chips into flour, with particle size controlled by the filter. Finally, grounded products exited through an outlet as fine grains (Wahjuningsih & Kunarto, 2011).

#### Polishing stage

This study adopted three variations of polishing treatment in producing porang flour, namely two rounds, one round, and none. The unpolished sample directly entered the flouring process using a hammer mill. Polishing aimed to separate small fractions (porang flour cell walls, calcium oxalate, and starch) from large fractions (mannan). The milled porang flour was put into a polishing machine, where it was subjected to a friction process between the cylinder and polishing chamber, which striped the outer layer (Mawarni & Widjanarko, 2015).

#### Sieving stage

Porang flour is then sifted for 10 minutes using a Tyler sieve with mesh sizes of 30, 40, 50, 60, 80, 100, and pan. Only fractions retained on mesh 60 (sieve hole diameter 0.25 mm) and 80 (sieve hole diameter 0.177 mm) proceeded for further processing (Anggraeni et al., 2014).

#### Calcium oxalate removal

A cyclone device was used to separate starch and calcium oxalate particles, and the process was conducted 7 times for each grinding variation. The flour mixture retained on 60 and 80-mesh sieve was processed using a cyclone separator connected to a blower through a horizontal pipe. During the separation process, unwanted particles rise to the top in the blower while the desired fraction falls through an output pipe directed downward (Mawarni & Widjanarko, 2015).

## Data Analysis Method

### Density analysis

In this study, both bulk and tapped density were adopted in the procedure. Bulk density was obtained from material in a certain container without any force being applied, while tapped density was associated with material subjected to forces in the form of stirring and tapping. The difference between these two types signified the degree of compaction (Panjaitan et al., 2016).

For bulk density testing, the material was put into a 10 ml measuring cup, and the weight was recorded. The volume of the glass was immediately observed. The test was repeated three times, and bulk density was calculated using Equation 1.

$$\text{Bulk density} = \frac{sample\ mass}{volume} (g/cm^3) \quad (1)$$

For tapped density, the same sample was put into a 10 ml measuring cup and tapped five times. The volume on the measuring cup was read and weighed again. The value of tapped density was calculated using the Equation 2.

$$\text{Tapped density} = \frac{sample\ mass\ after\ tapped}{sample\ volume\ after\ tapped} (g/cm^3) \quad (2)$$

### Water content analysis

The water content in porang flour was determined using the thermogravimetric method. The principle includes evaporating the water in the material using heat energy. A 2 g sample of porang flour was placed in an oven at 105 °C for 24 hours. The solid mass obtained was used to calculate water content by subtracting it from the total mass. After obtaining the water mass, the value was entered into Equations 3, 4, 5, and 6. In porang flour, the initial and final water content was derived from the exhalation process. Water content based on wet and dry weight had a theoretical limit of 100% and more than 100%, respectively.

$$KA_{(bb)} \frac{mass\ of\ water}{mass\ of\ wat\ material}\ x\ 100\% \quad (3)$$

$$KA_{(bk)} \frac{mass\ of\ water}{mass\ of\ dry\ material}\ x\ 100\% \quad (4)$$

$$KA_{b.b} = \frac{KA_{b.k}}{1 + KA_{b.b}} \quad (5)$$

$$KA_{b.k} = \frac{KA_{b.b}}{1 - KA_{b.b}} \quad (6)$$

### White degree analysis

Coloring as the quality parameter of porang flour was measured using colorimetry. The indices L*, a*, and b* were used to calculate whiteness with the Equation 7 (Mustafa & Widjanarko, 2015).

$$W = 100 - \sqrt{(100 - L)^2} + a^2 + b^2 \quad (7)$$

Where:
W = Degree of vaginal discharge
L* = Brightness
a* = Red if marked (+) and green if marked (-)
b* = Yellow if marked (+) and blue if marked (-)

### Viscosity analysis

The viscosity of porang flour was measured using the method discovered in NY/T 494-2002 (Anggraeni et al., 2014). The instrument used was a Brookfield viscometer, and the measurements were conducted at RPM 0.5 with spindle number 3. Previously, 2 g of porang flour was dissolved in 200 mL of distilled water and stirred using a stirrer for approximately 30 minutes. Viscosity measurements were performed in 36 repetitions with three restarts of the viscometer.

Viscosity, an indicator of fluid flow resistance, is critical in industrial applications to optimize process efficiency and safety. The value is often required in process operations such as heating, cooling, and homogenization, as it varies with temperature and pressure (Pasaribu et al., 2019). Viscosity is the amount of force that inhibits fluid from flowing. The viscosity value ($\mu$) is calculated as the ratio of applied force ($\tau$) and the resulting flow rate $\left(\frac{dx}{dt}\right)$.

The viscosity of the porang flour solution was measured using a Brookfield viscometer, where a statist was immersed into the fluid and rotated at a constant speed through a calibrated spring. The principle of this measurement relied on changes in the shape of the spring, which was signified by the pointer and corresponded with the viscosity of the fluid. The viscosity value was obtained by comparing the needle reading with spindle table values and rotational speed. A total of 12 measurements were obtained for each treatment. This data is obtained from reading the indicator scale, with indicator scale readings converted to viscosity values through multiplication by a conversion factor of 200. The converted values were then averaged to obtain three replicate data.

**Analysis of oxalate levels**

A 2 g of porang flour was suspended in 190 mL of distilled water in a 250 mL Erlenmeyer flask, followed by the addition of 10 mL of 6 M HCl. The mixture was heated at 100 °C for 1 hour with a hot plate before distilled water was added to reach a final volume of 250 mL. After filtration, the filtrate was divided into two equal portions of 125 mL. Each portion was transferred to a beaker, where four drops of methyl red indicator were added before a concentrated $NH_4OH$ solution was introduced dropwise until the test solution changed from pink to greenish blue. The mixture was then heated to 90 °C, cooled, and filtered to remove precipitated iron ions. The filtrate was reheated to 90 °C, and 10 mL of 5% $CaCI_2$ solution was added while stirring continuously. Following cooling, the solution was left at 5 °C overnight, then centrifuged at 2500 rev/min for 5 minutes. The supernatant was carefully decanted, and the precipitate was dissolved in 10 mL of 20% $H_2SO_4$. For the permanganate titration, the two filtrates were combined to obtain a total volume of 300 mL. A 125 mL portion was boiled and titrated with 0.05 M $KmnO_4$ solution (standardized) until a stable pale pink color appeared for 30 seconds. Finally, calculation analysis of calcium oxalate levels was conducted using the Equation 8.

$$\text{Calcium Oxalate}\left(\frac{\text{mg}}{100}g\right)=\frac{Volume\ KM\ n0_4\ x\ 0.00225\ x\ 2{,}4}{weight\ of\ flour\ x\ 5}\ x\ 10^5 \quad (8)$$

**Analysis of Glucomannan Levels**

The determination of the glucomannan content in porang flour followed the Professional Standard of the People's Republic of China for the Konjac Flour method (Ningtyastuti et al., 2023) This colorimetric method used 3,5-dinitrosalicylic as an indicator, with measurements conducted using either UV-Vis or Visible light spectrophotometer at a wavelength of 550 nm. The selected wavelength corresponded with the color intensity of the amino compounds formed, which was related to the presence of reduced sugar resulting from the reaction between 3,5-dinitrosalicylic and glucose/mannose (Anggraeni et al., 2014). The measurement principle relied on the difference between the mass of gluconic acid produced from the breakdown of glucomannan and the mass of gluconic acid derived from free glucose/mannose in the porang flour solution. These values were obtained from their absorbance readings, which were compared against a standard glucose curve. The absorbance value was calculated as the log of $^1/_T$ with base 10. Transmittance (T) is the percentage of light received by the detector against the initial radiation intensity. This measurement accounts for reflection at the cuvette-sample interface, scattering within the sample, and absorption of the analyte (Hui, 2006). The final glucomannan content was determined by comparing the absorbance of the porang flour solution and its hydrolysate against the standard glucose curve. These values, alongside the mass of porang flour used, the wet-base moisture content, and the constant $\varepsilon$ = 0.9, were applied in Equation 9 to obtain the glucomannan percentage.

$$\text{Calcium Oxalate}\left(\frac{\text{mg}}{100}g\right)=\frac{Volume\ KM\ n0_4\ x\ 0.00225\ x\ 2{,}4}{weight\ of\ flour\ x\ 5}\ x\ 10^5 \quad (9)$$

Information:
GC = percentage of glucomannan content (%)
T = mass of glucose from hydrolysis of porang flour solution (mg)
$T_0$ = mass of glucose from porang flour solution (mg)
M = mass of porang flour used (g)
W = sample water content

**Statistical Analysis**

A two-factor analysis of variance (ANOVA) was performed at a significance level of 0.05. When a significant effect was identified, the Duncan Multiple Range Test (DMRT) was applied as a Post hoc test to determine which treatment factors influenced the quality of porang flour. Each treatment was conducted in triplicate, leading to a total of 36 observations.

## RESULTS AND DISCUSSION

**Characteristics of Porang Flour**

The results of the quality characteristics of porang flour are presented in Table 1. The density values were in the interval 0.498-0.559g/cm$^3$ and were determined using the bulk density method due to the granular nature of flour. It was important to acknowledge that these values can be influenced by the blowing process. Observation of the bulk density of porang flour processed with hammer and disk mills tools, incorporating two, one, and no polishing, are presented in Table 1. Blowing led to the reduction in bulk density, possibly due to the removal of impurities such as calcium oxalate, starch, and other minerals (Putri et al., 2014).

The impurities had finer particle sizes with a smaller specific gravity. After exhaling, the impurities were blown away by airflow through the Cylon, leaving behind porang flour containing glucomannan with a higher specific gravity. The glucomannan particles are 10-20 times larger than starch cells (Putri et al., 2014). This was also explained by Widari & Rasmito (2018), that finer particles contribute to higher glucomannan

Table 1. Average value of characteristics of porang flour

| Treatment | Characteristics of porang flour | | | | | |
|---|---|---|---|---|---|---|
| | Density (g/cm$^3$) | Water content (% b.b) | Whiteness index | Viscosity (mPas) | Calcium oxalate (%) | Glucomannan content (%) |
| Sanindo Hammer mill 2 times figure | 0.559$^a$ | 11.86$^a$ | 61.68$^a$ | 14666.7$^a$ | 0.22$^b$ | 31.56$^a$ |
| Sanindo Hammer mill 1 times figure | 0.549$^a$ | 11.98$^a$ | 61.17$^a$ | 6666.7$^b$ | 0.26$^a$ | 29.63$^b$ |
| Sanindo Hammer mill without figure | 0.533$^b$ | 12.00$^a$ | 60.30$^a$ | 4333.3$^b$ | 0.25$^a$ | 26.04$^c$ |
| MAS Hammer mill 2 times figure | 0.515$^a$ | 12.56$^a$ | 51.37$^a$ | 10666.7$^a$ | 0.25$^b$ | 30.82$^a$ |
| MAS Hammer mill 1 times figure | 0.555$^a$ | 12.58$^a$ | 58.15$^a$ | 5000.0$^b$ | 0.37$^a$ | 28.50$^b$ |
| MAS Hammer without figure | 0.535$^b$ | 12.72$^a$ | 53.49$^a$ | 3666.7$^b$ | 0.37$^a$ | 24.36$^c$ |
| Sanindo Disk mill 2 times figure | 0.502$^a$ | 12.67$^a$ | 59.05$^a$ | 7000.0$^a$ | 0.32$^b$ | 31.14$^a$ |
| Sanindo Disk mill 1 times figure | 0.533$^a$ | 12.69$^a$ | 58.95$^a$ | 5000.0$^b$ | 0.32$^a$ | 26.59$^b$ |
| Sanindo Disk mill without figure | 0.498$^b$ | 12.80$^a$ | 59.31$^a$ | 4000.0$^b$ | 0.34$^a$ | 24.62$^c$ |
| MAS Disk mill 2 times figure | 0.547$^a$ | 12.27$^a$ | 55.10$^a$ | 5000.0$^a$ | 0.37$^b$ | 25.50$^a$ |
| MAS Disk mill 1 times figure | 0.499$^a$ | 12.06$^a$ | 57.30$^a$ | 4000.0$^b$ | 0.37$^a$ | 24.58$^b$ |
| MAS Disk mill without figure | 0.509$^b$ | 12.28$^a$ | 56.27$^a$ | 3000.0$^b$ | 0.39$^a$ | 25.30$^c$ |

Notes: Different letters in the same row are significantly different ($p<0.05$)

levels, as larger sizes do not only occupy the available volume. As shown in Table 1, significant differences were observed across factors affecting porang flour density. Flour processed using the Sanindo disk mill without polishing had a lower density than the other treatments. A smaller density suggests that the larger particle size of porang flour is larger, which is indicative of higher glucomannan content (Mustafa & Widjanarko, 2015). The particle size of porang flour containing glucomannan ranges from 0.149-0.177 mm. This was also mentioned in a previous study by Sari & Widjanarko (2015), where particle size corresponded with higher glucomannan content. A two-factor ANOVA statistical test was conducted at a significance of 0.05 on porang flour to determine the factors influencing porang flour density. Based on Table 2, variations in chip type, tools, and polishing influenced the density value. A post hoc test using Duncan's multiple range test (DMRT) was performed, as detailed in Table 1. The results of the two-factor ANOVA test are presented in Table 2.

The water content value of porang flour, as presented in Table 1, ranged from 11.86 – 12.80 (%bb). Data were collected to assess whether flour met the Indonesian National Standard (SNI) Number 7939 of (2013), ensuring its suitability for storage and subsequent processing, such as extraction.

The observed water content values for porang flour, processed using hammer and disk mills with varying levels of polishing, are detailed in Table 1. These results were in line with the BSN quality standard I, which set a maximum of ≤13. Significant differences in values were observed due to variations in treatments. The interaction of factors in this study led to water content values that exceeded the national limit of 12%

Table 2. ANOVA statistical test: two-factor density of porang flour

| | Significance | |
|---|---|---|
| | Influential | No effect |
| Chips | | 0.507 |
| Tool | 0.000 | |
| Polishing | 0.005 | |
| Chips and tool | | 0.011 |
| Chips and polishing | | 0.071 |
| Tool and polishing | | 0.044 |
| Chips, tools, and polishing | 0.000 | |

Table 3. ANOVA statistical test: two-factor porang flour water content

| | Significance | |
|---|---|---|
| | Influential | No effect |
| Chips | | 0.429 |
| Tool | | 0.076 |
| Polishing | | 0.532 |
| Chips and tool | 0.000 | |
| Chips and polishing | | 0.768 |
| Tool and polishing | | 0.780 |
| Chips, tools, and polishing | | 0.945 |

for porang flour. Furthermore, water content values were determined through drying. According to Chinese government standards, the majority of porang flour fell into various classifications. As shown in Table 3, the high level of moisture in Sanindo disk mill porang flour without polishing was caused by the higher glucomannan content. Glucomannan readily absorbs water up to 200 times its weight and can inhibit syneresis (Ningtyastuti et al., 2023).

A two-factor ANOVA statistical test was conducted at a significance level of 0.05 factors to determine factors influencing water content. As shown in Table 3, variations in chip type, tools, and polishing had a significant impact. Therefore, Duncan's further test was performed, as detailed in Table 1. The results of the two-factor ANOVA test are presented in Table 3.

The whiteness values of porang flour obtained in this study are presented in Table 1, with the lowest and highest recorded at 51.37% and 61.68%, respectively. These values were lower than those reported in previous studies, which ranged from 79.89 to 88.76% (Mawarni & Widjanarko, 2015). The presence of bleaching agents such as sodium bisulfite and vitamin C was proved to increase the whiteness index of porang flour.

Colour measurements were conducted using a color meter at the end of exhalation. As shown in Table 1, there was a change in the color of porang flour after exhalation. During this process, impurities were removed through the cylinder, leaving behind flour with a higher glucomannan content and greater specific gravity (Panjaitan et al., 2016). The color of porang flour containing glucomannan tends to be darker because it has a larger particle size.

A two-factor ANOVA statistical test was performed at a significance level of 0.05. As shown in Table 4. Based on Table 4, no significant differences were observed based on chip types, tools, and polishing. Therefore, Duncan's further test was conducted, as detailed in Table 1. The results of the two-factor ANOVA test are presented in Table 4.

Porang flour contains glucomannan, which forms a Kendal solution in water and can expand into a gel. The viscosity measurements were conducted to evaluate this property, with the results presented in Table 1. In this study, the viscosity value of porang flour solution ranged from 3000-14666.7 mPas, which was lower than the standardized viscosity of konjac flour set by the Chinese government (Azizi & Kurniawan, 2021). Based on Table 1, the highest value was observed in the sample processed using a Sanindo hammer mill with two polishing stages. The viscosity measurements were in line with the results of previous studies. According to Pasaribu et al. (2019), flour retained on a 60and 80-mesh sieve recorded 1800 cPs and 4 cPs, respectively. These two values were relatively not different from

Table 4. ANOVA statistical test: two-factor whiteness of porang flour

| | Significance | |
|---|---|---|
| | Influential | No effect |
| Chips | | 0.744 |
| Tool | | 0.170 |
| Polishing | | 0.881 |
| Chips and tool | | 0.592 |
| Chips and polishing | | 0.916 |
| Tool and polishing | | 0.796 |
| Chips, tools, and polishing | | 0.614 |

Table 5. ANOVA statistical test: two-factor viscosity of porang flour

| | Significance | |
|---|---|---|
| | Influential | No effect |
| Chips | 0.000 | |
| Tool | 0.000 | |
| Polishing | 0.000 | |
| Chips and tool | 0.000 | |
| Chips and polishing | 0.000 | |
| Tool and polishing | 0.000 | |
| Chips, tools, and polishing | 0.000 | |

Table 6. ANOVA statistical test: two-factor calcium oxalate content of porang flour

| | Significance | |
|---|---|---|
| | Influential | No effect |
| Chips | 0.000 | |
| Tool | 0.000 | |
| Polishing | 0.014 | |
| Chips and tool | | 0.181 |
| Chips and polishing | | 0.271 |
| Tool and polishing | 0.097 | |
| Chips, tools, and polishing | | 0.276 |

those obtained in this study. A two-factor ANOVA statistical test was performed at a significance of 0.05 factors to assess the influence of chip types, tools, and polishing on viscosity. As shown in Table 5, no significant differences were observed. Therefore, Duncan's further test was performed, as detailed in Table 1. The results of the two-factor ANOVA test are presented in Table 5.

Table 5 shows the relationship between chips, tools, and polishing in determining viscosity. To identify the polishing factor affecting the viscosity of Poruang flour, Duncan tests were conducted. The results in Table 1 showed that two polishing cycles produced the highest value viscosity. Meanwhile, one and no polishing were not significantly different. According to Putri et al. (2014), viscosity depended on glucomannan content, which binds free water in a solution. Factors such as total concentration, sugar and salt content, temperature, and hydrocolloids also played a role. Higher glucomannan levels in twice-polished flour increase viscosity due to its hydrophilic nature, enhancing solubility and thickening. Calcium oxalate, a dicarboxylate with two adjacent carboxylate groups (Wahjuningsih & Kunarto, 2011), was analyzed using titration.

Before titration, a sample of porang flour was prepared first, and the remaining calcium oxalate, after soaking, was dissolved in 6 M HCl and distilled water. The mixture was then heated in a pan containing water until it boiled for an hour. The HCl solution was chosen as the solvent in this stage because calcium oxalate can dissolve in dilute acid (Widari & Rasmito, 2018). Table 1 showed that polished Porang flour contained 0.22-0.39% calcium oxalate. The lowest level (0.22%) was found in twice-polished flour from the Sanindo hammer mill, while the highest was in unpolished flour from the MAS disk mill.

A two-factor ANOVA statistical test was conducted at a significance level of 0.05 to determine factors influencing the calcium oxalate levels of porang flour. The results in Table 6 showed no significant difference due to chips, tools, and polishing factors. Therefore, Duncan's further test was performed, as detailed in Table 1. The results of the two-factor.

Statistical analysis in Table 6 showed no effect of chips, tools, and polishing on the calcium oxalate content of porang flour, as the significance value (0.276) exceeded 0.05. Duncan's further test was then performed to identify factors with significant differences. Table 1 shows that two, one, and no polishing led to distinct calcium oxalate levels because they belonged to different subsets. Twice grinding produced the lowest calcium oxalate content due to the additional processing steps (Guna et al., 2020). Merisa, (2015) stated that more polishing reduced calcium oxalate levels, thereby enhancing flour quality.

Glucomannan content analysis began by determining the glucose standard curve using six concentrations, measured at a wavelength of 550 nm

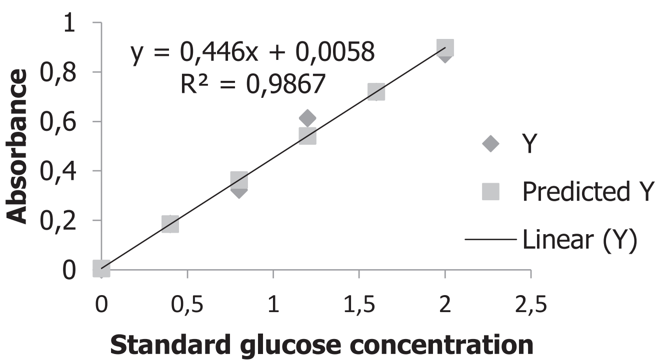


Figure 1. The standard glucose curve obtained

with a spectrophotometer. A color change occurred before and after boiling for 5 minutes. The addition of glucose to the solution produced a darker color and increased absorbance values (Putri et al., 2014). A graph of the absorbance values was plotted to obtain a linear equation of $y = 0.446x + 0.0058$ with a coefficient of determination ($R^2$) of 0.9867, as shown in Figure 1. This equation was used to calculate the glucose content in the glucomannan extract (EG) and hydrolysate (HG).

Table 1 presents the glucomannan levels, which ranged from 24.36-31.56%. The highest content, 31.56%, was found in porang flour processed with the Sanindo hammer mill and polished twice, while the lowest, 24.36%, was in the unpolished MAS hammer mill sample. These results were relatively higher than in the previous study, where levels ranged from 28.76-63%, depending on harvest age (Wahjuningsih & Kunarto, 2011). Higher glucomannan levels were generally associated with increased viscosity (Faridah & Widjanarko, 2014).

Several suggestions that could influence differences in the viscosity of Porang flour include variations in starch content and the character of the glucomannan compound between treatments. This was shown in the results of a previous study where a lower percentage of soluble solids such as ash, starch, protein, fat, and calcium oxalate could increase the viscosity (Sari & Widjanarko, 2015). Subsequently, a two-factor ANOVA statistical test was conducted with a significance of 0.05 factors to determine factors

Table 7. ANOVA statistical test: two-factor porang flour glucomannan content

| | significance | |
|---|---|---|
| | Influential | No effect |
| Chips | | 0.058 |
| Tool | | 0.020 |
| Polishing | 0.001 | |
| Chips and tool | | 0.523 |
| Chips and polishing | | 0.467 |
| Tool and polishing | | 0.300 |
| Chips, tools, and polishing | | 0.263 |

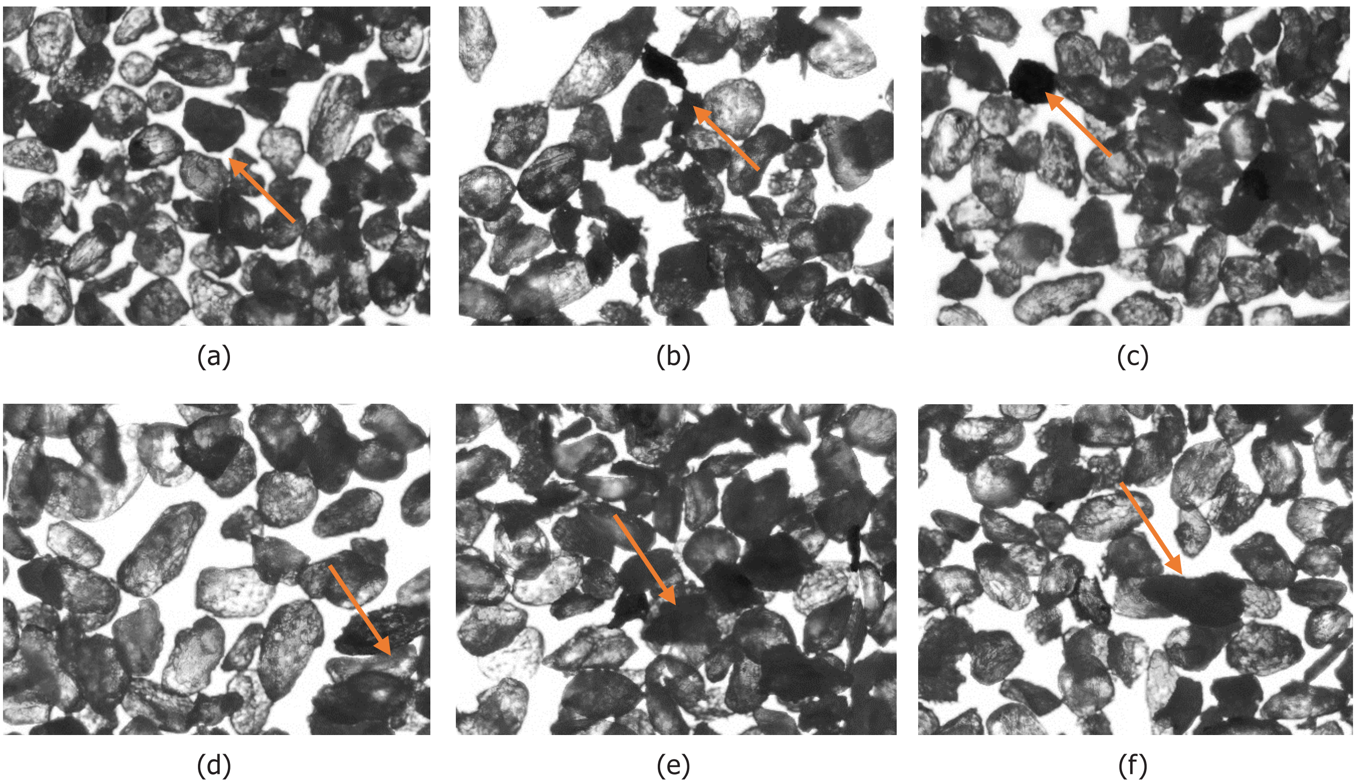

Figure 2. Visual of porang flour using opti lab, a) Sanindo flour polished twice, b) Sanindo flour polished once, c) Sanindo flour without polished, d) MAS flour polished twice, e) MAS flour once polished, f) MAS flour without polishing.

that influenced the value of glucomannan content. As shown in Table 7, the glucomannan content value of porang flour did not differ significantly due to chips, tools, and polishing. Therefore, Duncan's further test was performed, as detailed in Table 1.

Table 7 shows the possibility of an effect of chips, tools, and polishing on the levels of glucomannan produced. Therefore, Duncan's further test was performed to determine which factors in polishing influence the viscosity value of porang flour, with the results presented in Table 1. Based on observation, two times polishing was the best, as it produces glucomannan levels above the others. It is significantly different from one-time polishing and without polishing. Meanwhile, one and no polishing were not significantly different. According to Putri et al., (2014), the number of polishing is directly proportional to the glucomannan content. The level of porang flour is influenced by various factors, including the type of plant, age, harvest, drying treatment, grinding, and polishing equipment used. Qualitative (visual) analysis of porang flour was conducted using an Opti lab microscope. Finally, the flour particles were observed with 10x magnification.

Figure 2 shows the change in the appearance of impurity compounds with a 10x optical lab magnification covering the glucomannan granules. The two-time polishing treatment compared to the one-time counterpart and untreated samples, in line with visual observation and chemical analysis. The double-polished treatment appeared cleaner, showing granules indentations. Needle-like calcium oxalate crystals remained attached to the surface of the granule, while other impurities were removed through polishing, milling, sieving, and blowing.

## CONCLUSION

In conclusion, the quality of Sanindo and MAS porang flour treated using hammer mills and mills with two, one, and no polishings showed a density range of 0.498-0.559g/cm$^3$. Statistical analysis presented no significant differences in density among treatments. The water content, whiteness value, viscosity, calcium oxalate, and glucomannan content ranged from 11.86 – 12.80(%bb), 51.37-61.68%, 14666.7-3000 mPas, 0.22-0.39%, and 24.36-31.56%, respectively. The twice-polished Sanindo hammer mill flour was the best treatment, with the lowest calcium oxalate content, high glucomannan content, and high viscosity of 0.22%, 31.56%, and 14666.7 mPas, respectively. Further study was recommended using different chips to characterize low oxalate porang flour.

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## CONFLICT OF INTEREST

The authors declared the absence of competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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