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Porang flour optimization as a natural tablet binder for bay leaf extract formulation

Tantri Liris Nareswari[1]*, Salsabila Fauziah Anandar[1], Okta Nama Putra[2], Sarmoko[1], Nur Adliani[1]

ABSTRACT

Background: The Indonesian pharmaceutical industry relies heavily on imported pharmaceutical raw materials (PRMs), with 90-95% of materials being sourced from abroad, thus leading to increased production costs. Porang tuber (*Amorphophallus oncophyllus*) contains glucomannan with adhesive properties, making it a potential local alternative for tablet binding agents.

Purpose: To optimize bay leaf extract (*Syzygium polyanthum*) tablet formulation using porang tuber flour and polyvinylpyrrolidone (PVP) as binders through simplex lattice design (SLD).

Methods: Porang flour was prepared and characterized for moisture and calcium oxalate content. A tablet formulation optimization study was conducted using Design Expert 13 with porang flour (5-10%) and PVP (0-5%) as independent variables. Responses evaluated included angle of repose, tablet hardness, and disintegration time. The optimized formula was verified and comprehensively characterized.

Results: The yield of porang flour obtained in this study was 10.39% (w/w). The moisture content and calcium oxalate content of the porang flour was 10.19% and 34.20 ± 3.12 mg/100 g, respectively. The optimum formula contained 9.86% porang flour and 0.14% PVP, with a desirability value of 0.98. The tablets exhibited satisfactory physical properties: angle of repose 24.70±0.36°, hardness 6.29±0.19 kg, and disintegration time 8.46±0.69 minutes. Statistical analysis confirmed no significant differences between predicted and experimental values ($p>0.05$).

Conclusion: This study serves as an initial investigation into the potential of locally-sourced porang flour as a natural alternative to synthetic binders in tablet formulations. The results indicate that porang flour may offer a viable option as a functional excipient in pharmaceutical applications. Further research is needed to evaluate its use as a single binder, its compatibility with various active ingredients, and its stability over prolonged storage periods.

Keywords: bay leaf extract, glucomannan, porang flour, simplex lattice design, tablet binder

Introduction

The pharmaceutical industry in Indonesia faces increasing import costs annually. The country's heavy dependence on imported pharmaceutical raw materials (PRMs)—approximately 90-95% of all materials—has significantly raised operational and production expenses. However, Indonesia possesses substantial potential for developing its own PRM industry, particularly in plant-based, microorganism-based, and marine biota-based materials. One promising local resource that can be utilized as a pharmaceutical excipient is the porang plant (*Amorphophallus oncophyllus*).

Despite its potential, the benefits and applications of the porang plant remain largely unknown to the general public. Currently, porang tubers are primarily exported to Japan, with demand increasing yearly. Research has demonstrated that porang contained significant amounts of glucomannan, ranging from 15-64%, with ethanol solvent or enzymatic hydrolisis methods achieving purities exceeding 90% [1,2]. This glucomannan possesses valuable properties applicable

[1]Department of Pharmacy, Faculty of Science, Institut Teknologi Sumatera, South Lampung 35365, Indonesia

[2]Research Center for Agroindustry, National Research and Innovation Agency (BRIN)

*Corresponding author: Jl Terusan Ryacudu, Way Hui, Jatiagung, South Lampung 35365, Lampung Indonesia.
E-mail: tantri.nareswari@fa.itera.ac.id

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to pharmaceutical formulations. However, widespread utilization of porang is limited by its calcium oxalate content (0.19-0.4%), which causes skin irritation upon contact and can lead to kidney problems if consumed in large quantities [3]. The use of ethanol and enzymatic hydrolysis for porang tuber extraction is often limited by economic constraints; however, various studies have successfully adopted lower-cost and greener extraction methods, including water-based systems enhanced with NaCl or rice husk ash [4–8].

Glucomannan from porang has shown considerable promise as a pharmaceutical excipient. Aanisah et al. reported that glucomannan has excellent potential as a filler-binder in direct compression, as a tablet disintegrant, or as a gelling agent due to its strong hydrophilicity and high viscosity [9]. In addition, porang flour effectively binds paracetamol tablets, with higher concentrations increasing tablet hardness while decreasing friability and controlling drug release [10].

For this study, we selected bay leaf extract (*Syzygium polyanthum*) as our active ingredient based on its well-documented medicinal properties. Agung (2021) reported that bay leaf extract effectively reduces triglyceride and total cholesterol levels in dyslipidemia patients, primarily attributed to its flavonoid content, particularly quercetin [11]. Furthermore, bay leaf extract possesses anti-inflammatory properties by reducing C-reactive protein and myeloperoxidase levels in myocardial infarction models [12].

Based on these considerations, this study aimed to optimize tablet formulations containing bay leaf extract using a combination of porang tuber powder and polyvinylpyrrolidone (PVP) as binders. We evaluated this combination using the Simplex Lattice Design (SLD) method, which enables the determination of optimal ingredient proportions (totaling 100%). This approach aligns with methods used in previous pharmaceutical formulation optimization studies [13,14]. Tablets were prepared using the wet granulation method, and the physical properties of both the granules and finished tablets were subsequently evaluated. This study serves as an initial investigation into the potential of locally sourced porang flour as a natural substitute for synthetic binders in tablet formulations.

Methods

Porang flour preparation and characterization

Porang tubers were obtained from Bumi Arum plantation, Pajaresuk Village, Pringsewu District, Pringsewu Regency, Lampung. The porang plant was identified at the Herbarium of the University of Lampung, Department of Biology, Faculty of Mathematics and Natural Sciences, University of Lampung. Based on the identification results, the porang tuber used in this study was *Amorphophallus oncophyllus* from the Araceae family.

The porang tubers were peeled and sliced to approximately 0.2 cm thickness, then rinsed thoroughly. The slices were boiled at 60°C for 25 minutes in a 15% NaCl solution [5]. The boiled slices were then soaked overnight in rice husk ash [7]. Following the soaking process, the porang slices were thoroughly rinsed with water and sun-dried under a black cloth cover. The dried chips were ground and sieved using a 60-mesh sieve [15].

Porang flour characterization included organoleptic evaluation of color, odor, shape, and taste [3]. The yield was calculated as the ratio of the final weight to the initial weight of the sample [16]. Moisture content was determined using the gravimetric method. Weighing bottles were heated in an oven for 60 minutes, cooled in a desiccator for 15 minutes, and weighed as the initial weight. Two grams of porang flour were placed in the weighing bottle and weighed. The bottle with the sample was heated in an oven at 105°C for 3 hours, then cooled and weighed. This heating process was repeated until a constant weight was achieved [17].

Calcium oxalate content was determined using permanganometric titration, which consisted of three stages: digestion, calcium oxalate precipitation, and titration with permanganate solution. For digestion, 2 g of porang flour was placed in a 250 mL Erlenmeyer flask, suspended in 190 mL distilled water, and 10 mL of 6 M HCl was added. The suspension was heated at 100°C for 1 hour, then cooled. Distilled water was added to the mark, the solution was filtered, and the filtrate was divided into two portions. For calcium oxalate precipitation, the filtrate was placed in a beaker, and 4 drops of methyl red indicator were added. Concentrated NH_4OH was added dropwise until the color changed from pink to stable pale yellow. The filtrate was heated to 90°C, cooled, and the precipitate containing iron ions was filtered. The filtrate was stored overnight at 5°C. For titration, the supernatant was decanted, and the precipitate was dissolved. The filtrates were combined to a volume of 300 mL, and 125 mL of the filtrate was heated until almost boiling. The hot filtrate was titrated with 0.05 M $KMnO_4$ solution until a stable pink

Table 1. Formula Design

Ingredients (mg)	F0	F1	F2	F3	F4	F5	F6	F7	F8	Function
Bay leaf extract	33	33	33	33	33	33	33	33	33	Active ingredient
Porang flour	0	10	5	8.75	6.25	10	5	7.5	7.5	Binder
PVP	5	0	5	1.25	3.75	0	5	2.5	2.5	Binder
Amprotab	5	5	5	5	5	5	5	5	5	Disintegrant
Mg Stearate	1	1	1	1	1	1	1	1	1	Lubricant
Aerosil	33	33	33	33	33	33	33	33	33	Adsorbent
Lactose hydrate (ad)	100	100	100	100	100	100	100	100	100	Filler

color persisted for 30 seconds. The oxalate content was calculated using Equation 1 [18].

$$\text{Calcium oxalate content (mg/100g)} = (KMnO_4 \text{ volume} \times 0.00225 \times 2.4)/(\text{flour weight} \times 5)\times 10^5 \quad (1)$$

where: $KMnO_4$ volume is measured in mL; 0.00225 represents that 1 cm^3 of 0.05 M $KMnO_4$ solution is equivalent to 0.00225 g of anhydrous oxalic acid; 2.4 is the dilution factor; and 5 represents the $KMnO_4$ redox reaction factor.

Tablet formulation and optimization

Design Expert 13 software was used to determine the optimal formula using the Simplex Lattice Design (SLD) method. The experimental design generated eight formula variations, with the addition of F0 as a control formula. Two component factors, porang tuber flour and PVP, were used as independent variables. The concentration range for porang tuber flour was 5% (lower limit) to 10% (upper limit), while the range for PVP was 0% (lower limit) to 5% (upper limit), which were based on literature review [19,20]. The formula designs are presented in Table 1.

Mucilage of combined porang flour and PVP was prepared according to the suggested formula concentrations. A glass beaker containing 100 mL of distilled water was heated, and the combination of porang flour and PVP was gradually added while stirring until homogeneous mucilage was obtained. The mucilage concentration was adjusted according to the desired formulation requirements [21].

Bay leaf extract granules were prepared using the wet granulation method, involving 9 formulations with varying combinations of porang tuber flour and PVP binders. All ingredients were weighed according to the determined formulation. Bay leaf extract was dissolved in ethanol in a mortar, then Aerosil was added and mixed until homogeneous. Amprotab and lactose were gradually added to the mortar until homogeneous. The mucilage was then slowly added until a compact mass was achieved. The granules were formed using a No. 14 mesh sieve, then dried in an oven at 40-50°C until the moisture content was < 5%. The dried granules were then sieved again using a No. 16 mesh sieve. The formed granules were then mixed with magnesium stearate as a lubricant until homogeneous. Tablets were compressed using a single-punch tablet press, with each tablet weighing 500 mg and a punch diameter of 13 mm. Physical evaluation was performed on both the formed granules and tablets [21].

Physical property evaluation

Three primary responses were evaluated for the SLD optimization: granule angle of repose and tablet hardness and disintegration time. For the angle of repose test, twenty-five grams of granules were placed in a funnel with the bottom opening covered, and the granule surface was leveled. A base was placed under the funnel, and we opened the cover at the bottom of the funnel to allow the granules to flow. The height and diameter of the formed granule cone were measured, and the angle of repose was calculated using the formula $\tan \alpha = h/r$, where α = angle of repose; h = height of the pile; r = radius of the granule cone [22].

For tablet hardness testing, five tablets from each formulation were tested using a tablet hardness tester. Each tablet was placed vertically on the hardness tester, and the pressure that caused the tablet to break was recorded. The tablet hardness requirement was set between 4 and 8 kg [23]. For disintegration time testing, distilled water was heated to body temperature (approximately 37°C) as the test medium. Three tablets were placed in the testing apparatus basket. The apparatus was started, moving up and down at a rate

of 30 times per minute. The time required for each tablet to disintegrate was recorded as the disintegration time. The required disintegration time for uncoated tablets was less than 15 minutes [22].

Determination and verification of optimum formula

For optimization of tablet formulation, three target responses were used: angle of repose, tablet hardness, and disintegration time. The responses were entered into Equation 2.

$$Y = a[A] + b[B] + ab[A][B] \quad (2)$$

Where Y is the measured response, A is the proportion of porang tuber flour, and B is the proportion of PVP. The SLD formula was used to predict the optimum mixture of the two combined variables using Design Expert software [24].

The granules and tablets obtained from the optimized formula suggested by Design Expert software were evaluated for granule flow properties, tablet hardness, and disintegration time. After all response data were input into the software, an optimum formula recommendation was generated. The selection of the optimum formula was based on the highest desirability value, closest to one. The response data of the optimum formula were tested using the Shapiro-Wilk method to determine whether the data were normally distributed, with a 95% confidence level [25].

Characterization of optimum formula

The optimum formula was characterized by evaluating the angle of repose, granule particle size distribution, moisture content, bulk density, and granule compressibility, as well as tablet weight uniformity, hardness, friability, and disintegration time. The methods for angle of repose, hardness, and disintegration time were evaluated according to the SLD optimization methods.

Granule particle size distribution test. The granule particle size distribution was determined using the sieving method. Five grams of granules were weighed. Mesh sieves were arranged from the smallest to the largest mesh number. The granules were placed in the top sieve, and the sieving machine was run for 5 minutes. The granules retained on each sieve were then weighed [26].

Granule moisture content test. The moisture content of the granules was tested using a moisture balance. One gram of granules was placed in aluminum foil, tared, and the moisture content was measured by pressing the start button on the device. The result was expressed as a percentage of moisture content. The requirement for good moisture content was between 2% and 5% [27].

Granule bulk density and compressibility test. Twenty-five grams (M) of granules were weighed and placed in a 100 mL measuring cylinder, and the volume was measured (V_bulk). The measuring cylinder containing the sample was then tapped 300 times to obtain the tapped volume (V_tapped), and the compressibility index was calculated.

Tablet weight uniformity test. Tablet weight uniformity was tested by weighing 20 tablets and calculating the average. The tablets were then weighed individually, and the deviation in tablet weight was calculated [22].

Tablet friability test. Tablet friability was tested using a friability tester. Twenty tablets were randomly selected and weighed as the initial weight. The tablets were placed in the device, which was run for 100 rotations or 5 minutes at a speed of 25 rpm. After testing, the tablets were weighed again, and the tablet friability was calculated.

Results

Porang flour characterization

The yield of porang flour obtained in this study was 10.39% (w/w), which meets the standard for good yield (>10%) as reported by Wardaningrum [28]. The moisture content of the porang flour was 10.19%, meeting the criteria for Class I quality porang flakes according to the National Standardization Agency [18]. This moisture level is critical for flour quality, as higher moisture content can potentially lead to bacterial or fungal contamination, reducing shelf life and quality [29]. The calcium oxalate content was determined to be 34.20 ± 3.12 mg/100 g, which meets Standard Quality II requirements in the Indonesian National Standard [18].

Tablet formulation optimization

The optimal formula determination was conducted using the Simplex Lattice Design (SLD) method through Design Expert software. The responses evaluated were angle of repose for granule evaluation, and hardness and disintegration time for tablet physical evaluation. These parameters were selected because the type and amount of binder significantly affect tablet hardness and disintegration properties.

Table 2. ANOVA results for angle of repose response

Source	Sum of Squares	df	Mean square	F-value	p-value	z
Model	26.12	1	26.12	55.83	0.0	Significant
Linear mixture						
Lack of Fit	1.71	3	0.57	1.55	0.36	Not significant

Table 3. ANOVA results for tablet hardness and disintegration time responses

Response	Source	Sum of squares	df	Mean square	F-value	p-value	
Hardness	Model quadratic	11.86	1	11.86	196.23	0.00	Significant
	[(1)]Linear Mixture						
	Lack of Fit	0.59	2	0.02	0.27	0.78	not significant
Disintegration Time	Model quadratic	282.39	1	282.39	79.38	0.00	Significant
	[(1)]Linear Mixture						
	Lack of Fit	11.90	2	5.95	3.03	0.19	not significant

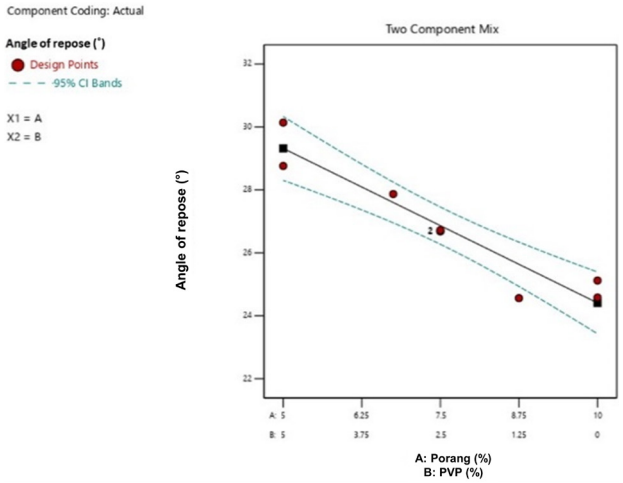

Figure 1. Contour plot of angle of repose response. Effect of porang flour and PVP concentrations on granule flow properties. Higher PVP concentrations result in larger angle of repose values, indicating reduced flow properties

Porang flour was used as factor A and PVP as factor B to investigate their influence on tablet physical properties. The concentration ranges used were 5%-10% for porang flour (natural binder) and 0%-5% for PVP (synthetic binder). The higher concentration range for natural binder compared to synthetic binder was intentional, aiming to reduce dependency on imported synthetic materials [30].

The analysis of granule angle of repose was performed to determine the effect of combining porang flour and PVP binders on tablet formulation. The angle of repose is closely related to cohesive forces between granule particles; smaller angles indicate better flow properties [31]. The ANOVA results for the angle of repose response are presented in Table 2. The analysis employed a linear model with $p<0.05$ (0.00), indicating that the combination of porang flour and PVP binders significantly affected the angle of repose response [32]. The lack of fit had a p-value of 0.3628 (>0.05), demonstrating that the model appropriately fits the obtained response with minimal noise [14]. The analytical equation for the angle of repose response was Y = 24.41 (A) + 29.32 (B), where Y represents the angle of repose response, A is porang flour concentration, and B is PVP concentration. Both binder components showed positive coefficient values, indicating that they increase the angle of repose. PVP (+29.32) demonstrated a greater effect compared to porang flour (+24.41), possibly due to smaller particle sizes resulting in stronger attractive forces between granule particles. As shown in Figure 1, the contour plot demonstrates that the combination of PVP (5%) and porang flour (5%) produces the largest angle of repose value, with the angle of repose increasing as PVP concentration increases [13].

For tablet hardness and disintegration time responses, ANOVA analysis results are presented in Table 3. The analysis was conducted using a quadratic model, with both responses showing $p<0.05$, indicating model significance and validity, while lack of fit values showed $p>0.05$ (not significant), reflecting the model's alignment with observed responses [14]. The analytical equations were $Y_1 = 6.24\ (A_1) + 21.07\ (B_1) - 16.45\ (AB_1)$ for hardness and $Y_2 = 8.81\ (A_2) + 24.93\ (B_2) -$

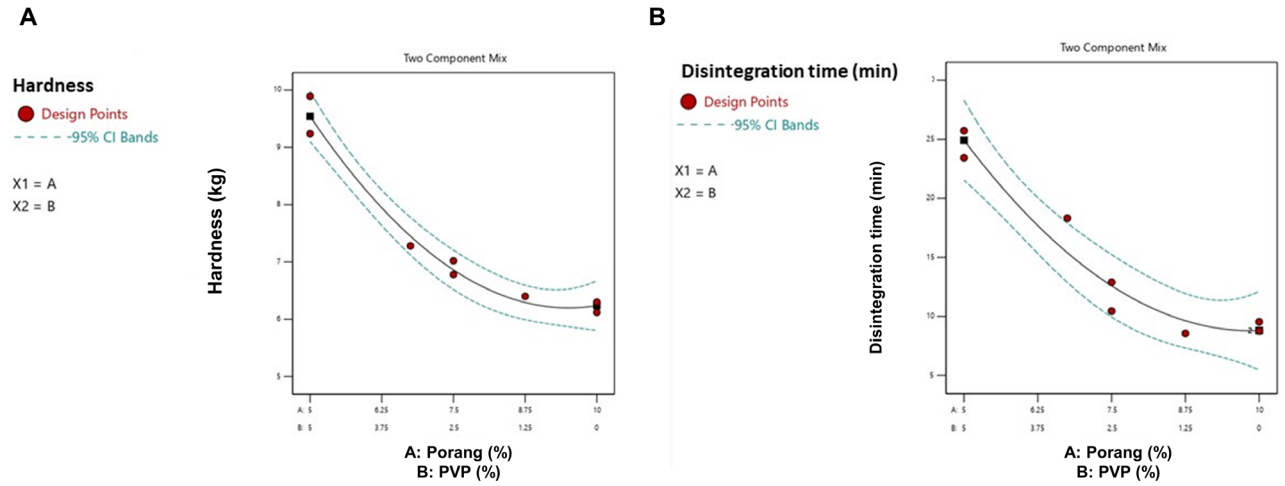

Figure 2. Contour plots of tablet physical responses. (A) Hardness response showing PVP's stronger influence compared to porang flour. **(B)** Disintegration time response demonstrating accelerated disintegration with binder combination due to synergistic effects

Table 4. Tablet formula optimization results

Name	Goals	Lower limit	Upper limit	Importance
Angle of repose	Minimize	24.56	30.14	+++
Hardness	In range	4	8	+++
Disintegration time	Minimize	0	15	+++

17.08 (AB_2) for disintegration time. Both porang flour and PVP binders showed positive effects when used individually and negative effects for combination use. PVP demonstrated greater effects on both hardness (+21.07) and disintegration time (+24.93) compared to porang flour (+6.24 and +8.81, respectively). The negative interaction terms (-16.45 for hardness and -17.08 for disintegration time) indicate that the combination of both binders can reduce tablet hardness and disintegration time compared to using PVP alone. This synergistic effect may be attributed to porang flour's water-binding and swelling properties, which allow water penetration into tablet gaps through inter-particle spaces [33]. The contour plot graphs in Figure 2 illustrate these relationships, with Figure 2A showing the hardness response and Figure 2B displaying the disintegration time response patterns.

The optimization criteria and results are summarized in Table 4. The optimization process utilized a desirability function with specified target responses adjusted to respective importance values. All parameters (angle of repose, hardness, and disintegration time) were assigned high importance values (+++). The optimization criteria included minimizing angle of repose (range: 24.56-30.14°), maintaining hardness within range (4-8 kg), and minimizing disintegration time (0-15 minutes). As presented in Table 5, the optimization yielded a formula containing 9.86% porang flour and 0.14% PVP, with a desirability value of 0.98. This high desirability value indicates that the optimum formula meets the desired standards [34]. The analysis shows that porang flour concentration was significantly higher than PVP, aligning with the objective of reducing dependence on imported pharmaceutical excipients.

Optimum formula verification

The optimum formula predicted by Design Expert software was verified by comparing SLD prediction values with responses obtained from actual experiments using paired sample t-tests with 95% confidence level [14]. The verification results are detailed in Table 6, which shows no significant differences between predicted and experimental values for all responses: angle of repose (predicted: 24.55°, experimental: 24.70 ± 0.36°, p=0.52), hardness (predicted: 6.22 kg, experimental: 6.29 ± 0.07 kg, p=0.24), and disintegration time (predicted: 8.79 minutes, experimental: 8.46 ± 0.32 minutes, p=0.88). All p-values were >0.05, confirming

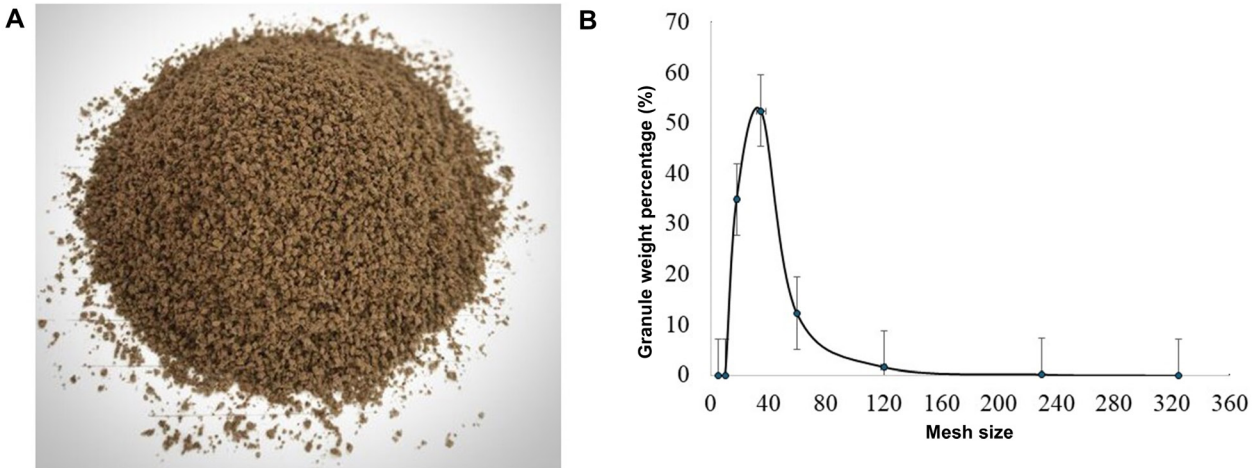

Figure 3. Characterization of optimized formulation. (A) Physical appearance of granules showing uniform brown color and granular form. **(B)** Particle size distribution showing normal distribution with bell-shaped curve and <10% fines content.

Table 5. Optimization formula results and predicted response values

Porang flour (%)	PVP (%)	Angle of repose (°)	Hardness (kg)	**Disintegration time (min)**	**Desirability**
9.86	0.14	24.55	6.22	8.79	0.98

Table 6. Paired sample t-test results

Testing response	**Prediction value**	**Testing value**	**Significance**	**remarks**
Angle of repose (°)	24.55	24.70 ± 0.36	0.52	Not significantly different
Hardness (kg)	6.22	6.29 ± 0.07	0.24	Not significantly different
Disintegration Time (min)	8.79	8.46 ± 0.32	0.88	Not significantly different

that the predicted values from the optimum formula are valid [35].

Physical characterization of optimized tablets

The verified optimized formula was comprehensively characterized to ensure compliance with Indonesian Pharmacopoeia requirements. Figure 3A shows the physical appearance of the optimized granules, which revealed satisfactory properties across all parameters. Organoleptic evaluation showed granules with uniform granular form, characteristic bay leaf extract odor, slightly bitter taste, and brown color matching the extract [36]. The moisture content was 2.19 ± 0.19%, meeting the requirement of 2-5% and indicating good storage stability. The angle of repose was 24.7 ± 0.36°, demonstrating excellent flow properties as it falls within the optimal range of 25°-30° [37]. Particle size distribution testing results are illustrated in Figure 3B, which revealed normally distributed granules with a bell-shaped curve, indicating uniform particle size essential for consistent die filling during tablet compression [21]. The fines value was <10%, meeting pharmaceutical requirements [38]. Bulk and tapped densities were 0.47 ± 0.011 g/mL and 0.52 ± 0.014 g/mL, respectively, resulting in a compressibility of 9.38% ± 0.266%. This compressibility value falls within the "excellent" category (<10%), indicating that granules can be easily compressed into compact tablet masses [22].

Tablet characterization demonstrated excellent pharmaceutical properties. Weight uniformity testing showed an average weight of 502.33 ± 4.60 mg, meeting pharmacopeial requirements for tablets >300 mg [22]. The hardness was 6.29 ± 0.19 kg, falling within the acceptable range of 4-8 kg and ensuring adequate mechanical strength [39]. Friability testing yielded 0.51 ± 0.03%, well below the requirement of <0.8%, indicating that tablets would maintain integrity during handling and transport [40]. The disintegration time

was 8.46 ± 0.69 minutes, satisfying the requirement for uncoated tablets (<15 minutes) and ensuring appropriate drug release characteristics [22]. These comprehensive results demonstrate that the optimized formulation successfully produces tablets with all physical properties meeting pharmaceutical standards while utilizing predominantly natural, locally-sourced excipients.

Discussion

The yield of porang flour obtained in this study (10.39%) was higher than that reported by Pratama, who achieved 8.83% [41]. This difference can be attributed to variations in processing methods and the maturity of the porang plants used. Higher yield values indicate greater efficiency in the drying process, as they represent reduced material losses and damage [42]. Furthermore, higher yields typically correlate with greater retention of chemical components within the sample [43].

Porang tubers naturally contain oxalate compounds, including oxalic acid (water-soluble) and calcium oxalate (water-insoluble) [4]. The presence of calcium oxalate causes an itching sensation upon contact and can lead to kidney problems if consumed in excessive amounts. Therefore, treatment to reduce calcium oxalate content is essential. Our method employed heating with 15% NaCl solution and soaking with rice husk ash, resulting in a calcium oxalate content of 34.20 ± 3.12 mg/100 g, which meets SNI Quality Standard II requirements.

The effectiveness of 15% NaCl solution in reducing oxalate content aligns with previous study that higher NaCl concentrations correlate with greater oxalate reduction [42]. This reduction likely occurs through an ionization reaction between NaCl and calcium oxalate, where Na^+ and Cl^- ions from the NaCl solution act as reactive species that participate in forming water-soluble compounds—sodium oxalate and calcium chloride [42].

Rice husk ash also significantly contributed to oxalate reduction in the flour [7]. The porous structure and high adsorption capacity of rice husk ash positively affect calcium oxalate reduction [8]. Additional research has demonstrated that higher concentrations of rice husk ash correlate with greater calcium oxalate reduction.

The tablet formula was designed using Design Expert software, which involves three experimental phases: screening, characterization, and optimization [44]. The angle of repose was selected as a response parameter to assess granule flow properties, which are crucial for determining content uniformity and evaluating granule behavior during compression in the punch die.

The concentration and selection of appropriate binders affect tablet physical properties, as evidenced by granule and tablet physical evaluation results, particularly tablet hardness and disintegration time. The binder function directly opposes that of disintegrants, as disintegrants help tablets break down into granules in the digestive tract [22]. Porang contains glucomannan, a water-soluble fiber with adhesive properties that can be utilized as a tablet binder [33]. PVP is a synthetic binder with hygroscopic properties that can increase moisture content [31]. The typical concentration range for PVP as a tablet binder is 0.5-5% [45].

The ANOVA results for the angle of repose showed that both binders had a positive effect on this parameter, with PVP demonstrating a stronger influence. This greater effect of PVP may result from its ability to produce smaller particle sizes, leading to stronger inter-particle attractive forces that cause granule pile-up and reduced flow [33].

For tablet hardness and disintegration time responses, both binders showed positive coefficients when used individually, indicating their ability to increase tablet hardness and extend disintegration time. PVP had a notably stronger effect on both parameters compared to porang flour. The stronger influence of PVP on hardness may be attributed to its ability to create particles with strong inter-particle attractive forces, significantly affecting tablet hardness [33].

Interestingly, the combination of both binders produced negative interaction terms, suggesting that their combined use may reduce tablet hardness and disintegration time compared to using PVP alone. This synergistic effect could be attributed to porang flour's water-binding and swelling properties, which allow water to penetrate tablet pores through inter-particle spaces, thereby accelerating tablet disintegration [33]. This finding aligns with research by Aanisah et al., who noted that glucomannan possesses strong hydrophilicity that can be beneficial as a disintegrant [9]. By leveraging this property, the combination of porang flour with PVP creates a balanced formulation that maintains adequate hardness while ensuring appropriate disintegration.

The optimization process yielded a formula with a high proportion of porang flour (9.86%) and minimal PVP (0.14%), aligning with our goal of reducing dependence on imported synthetic binders. The high desirability value (0.98) indicates that this formula satisfies all established criteria for angle of repose, hardness, and disintegration time. This result is particularly significant given that approximately 90-95% of pharmaceutical raw materials in Indonesia are currently imported, contributing to high operational and production costs.

The granule moisture content (2.19 ± 0.19%) was within the acceptable range of 2-5%. This parameter is critical because excessive moisture can affect storage stability and material quality due to microorganism growth [46]. High granule moisture can also complicate compression, as the granule mass tends to adhere to the punch die machine. Conversely, granules with low moisture levels may result in friable tablets, negatively affecting hardness, friability, and disintegration time [47].

The angle of repose result (24.7 ± 0.36°) aligned with research by Nur Cahyani (2023) on the combination of PVP and starch binders in tablets, with results showing excellent flow properties (angle <25°) [33]. The particle size distribution test revealed normally distributed granules with a bell-shaped curve, indicating uniform particle size [21]. Uniform particle size is essential for consistent die filling during tablet compression, ultimately affecting tablet weight uniformity and content uniformity.

The compressibility value (9.38% ± 0.266%) was within the "excellent" category (<10%), indicating that the granules could be easily compressed into compact tablet masses [37]. This excellent compressibility suggests that the porang flour-PVP combination creates granules with optimal porosity and deformation characteristics, consistent with findings by Sugiyono & Perwitosari, who showed that porang flour can serve as an effective binder in paracetamol tablets [10].

Tablet hardness (6.29 ± 0.19 kg) fell within the acceptable range of 4-8 kg. Hardness can be influenced by multiple factors, including compression pressure, binder type, granulation method, powder quantity, tablet design, size, weight, material compressibility, and compression machinery [10]. The friability test result (0.51 ± 0.03%) met the requirement of less than 0.8% [40], indicating that the tablets would maintain their integrity during handling and transport.

The disintegration time (8.46 ± 0.69 minutes) met the requirement for uncoated tablets (<15 minutes) [22]. This balanced disintegration time is particularly noteworthy, as binders typically extend disintegration time; however, our formulation achieved adequate hardness without compromising disintegration. This balance may be attributed to the unique properties of glucomannan in porang flour, which possesses both binding capabilities and water-absorbing properties that can facilitate tablet disintegration.

The overall physical characteristics of the optimized tablets suggest that porang flour can effectively replace the majority of synthetic binders in tablet formulations. This finding has significant implications for the Indonesian pharmaceutical industry, which currently relies heavily on imported excipients. By utilizing locally available porang, which contains 15-64% glucomannan, pharmaceutical manufacturers could reduce costs while supporting local agriculture [1,2].

Bay leaf extract (*Syzygium polyanthum*) was selected as the active ingredient due to its well-documented medicinal properties, particularly for managing cholesterol levels. This choice aligns with research by Agung (2021), who demonstrated that bay leaf extract effectively reduces triglyceride and total cholesterol levels in dyslipidemia patients [11]. The therapeutic effects of bay leaf extract are attributed to its flavonoid content, particularly quercetin, which inhibits LDL oxidation and may inhibit the HMG-CoA reductase enzyme, thereby leading to decreased cholesterol synthesis.

The developed tablet formulation provides a convenient dosage form for delivering bay leaf extract as a potential cholesterol-lowering agent. While our study focused primarily on the physical properties of the tablets rather than their pharmacological effects, the successful development of a stable tablet formulation with optimal physical characteristics lays the groundwork for future clinical studies on the efficacy of bay leaf extract tablets in managing cholesterol levels.

Conclusion

Based on the research conducted, porang tubers demonstrate significant potential as a raw material for excipients in tablet production due to the adhesive properties of their glucomannan content. Through appropriate processing techniques, including treatment with 15% NaCl solution and rice husk ash, calcium oxalate levels were successfully reduced to meet quality

standards, rendering the porang flour suitable for pharmaceutical applications.

The Simplex Lattice Design optimization yielded an optimal tablet formulation containing 9.86% porang flour and 0.14% PVP. This formulation successfully produced tablets with minimal use of synthetic binders while meeting all physical requirements for both granules and tablets according to Indonesian Pharmacopoeia standards. The optimized formula demonstrated excellent flow properties, appropriate hardness (6.29 ± 0.19 kg), low friability (0.51 ± 0.03%), and suitable disintegration time (8.46 ± 0.69 minutes).

The high proportion of porang flour and minimal PVP content in the optimized formula effectively supports the objective of reducing dependence on imported pharmaceutical raw materials while utilizing Indonesia's abundant natural resources. These findings suggest that porang flour could contribute to pharmaceutical industry sustainability and cost reduction.

This study demonstrates that locally sourced porang flour can serve as an alternative excipient to substitute a significant portion of imported synthetic binders in pharmaceutical tablet formulations, as evidenced by the successful formulation of bay leaf extract tablets. The results indicate promising potential for broader applications in the pharmaceutical industry.

Further research should explore the application of porang flour as a pharmaceutical excipient with various active ingredients and investigate its stability and compatibility characteristics over extended storage periods.

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Conflict of Interest

Authors declare no conflict of interest.

Author contributions

SFA, TLN, SS wrote the initial script; TLS, SFA, ONP, SS, NA contributed to data interpretation and final approval of the manuscript.

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