Preparation and Characterization of Microcrystalline Cellulose from Nata de Ganyong as an Excipient for Capsule Product

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Abstract
One imported raw material widely used as an excipient (filler-binder) in tablet manufacturing is microcrystalline cellulose (MCC). The microcrystalline cellulose commonly found on the market is widely known by the trade name Avicel. Avicel is a relatively expensive additive. In accordance with the Regulation of the Minister of Health of the Republic of Indonesia No. 87 of 2013 regarding the roadmap for pharmaceutical raw material development, efforts to achieve self-sufficiency using biological resources are being undertaken to address the high costs of importing pharmaceutical raw materials. Indonesia's greatest opportunity lies in developing a biotechnology-based industry, as this type of industry does not rely on upstream chemical industry products but allows for direct production within a bioreactor or fermenter. Therefore, this study aims to produce a tablet excipient from nata de ganyong. This study employs an experimental laboratory method. The first stage involves the preparation and botanical identification of *Canna edulis* (ganyong) tubers. The second stage entails processing the *Canna edulis* tubers into nata de ganyong via fermentation using *Acetobacter xylinum*, followed by quality evaluation of the resulting nata (including organoleptic tests, thickness measurement, and analysis of moisture content and yield). Subsequently, microcrystalline cellulose is isolated from the nata de ganyong. This is followed by an evaluation of the MCC powder and the formulation of capsules using the nata de ganyong-derived MCC as an excipient. Capsule evaluations included tests for weight uniformity, disintegration time, and hygroscopicity; all results were satisfactory and met pharmaceutical standards.

Keywords: capsule, nata, fermentation, *Acetobacter xylinum*, microcrystalline cellulose (MCC)

1. Introduction

The Indonesian pharmaceutical industry currently relies on imported raw materials from various countries. Approximately 96% of the raw materials used in the industry are imported—a significant figure. In 2014, the total value of pharmaceutical raw material imports reached IDR 14.8 trillion, comprising IDR 8.0 trillion in natural materials and IDR 6.8 trillion in chemical Active Pharmaceutical Ingredients (APIs). This situation requires urgent attention, particularly given the ongoing COVID-19 pandemic and the critical need for medicines.

The high value of raw material imports presents a challenge for Indonesia; however, the country could leverage its abundant natural resources as a major opportunity to develop domestic raw materials capable of replacing these imports.

Microcrystalline cellulose (MCC) is one such imported raw material used in tablet manufacturing. MCC is a partially depolymerized α-cellulose, purified into a white, odorless, and tasteless crystalline powder composed of porous particles, with a degree of polymerization of ≤ 350.

MCC possesses excellent binding capabilities, functions effectively as a lubricant and binder, and exhibits strong cohesive properties. The MCC currently used by the pharmaceutical industry is Avicel®, a product introduced by FMC Corp. in 1964.

The most common sources of microcrystalline cellulose (MCC) are wood and cotton. Reliance on wood can deplete timber supplies due to extensive logging, forcing Indonesia to import MCC. MCC imports tend to rise throughout the year, reaching a total of 69,717 tons. However, given the high cost of importing pharmaceutical raw materials, efforts are being made to achieve self-sufficiency by utilizing biological resources. One opportunity for Indonesia lies in developing a biotechnology-based industry, where materials can be produced directly in bioreactors or fermenters. In this context, an alternative method for obtaining MCC is through fermentation using the bacterium *Acetobacter xylinum*. This bacterium produces cellulose that can be further processed into MCC.

Research has been conducted on the preparation and characterization of MCC derived from nata de coco. Characterization results show that nata de coco-derived MCC shares similar infrared and X-ray spectra—as well as the same chemical formula (C6H10O5)—with Avicel® PH 102. A key advantage of cellulose derived from nata de coco (bacterial cellulose) over other sources is its freedom from lignin and hemicellulose contamination, making it a suitable alternative source of cellulose.

Coconut water contains vitamins, protein, carbohydrates, and various essential minerals such as potassium, sodium, magnesium, calcium, and phosphorus. Additionally, it contains carbohydrates in simple forms, including sucrose, glucose, fructose, sorbitol, and inositol. The carbohydrate content of coconut water is 3.8 g/100 g. In contrast,*Canna edulis* (ganyong) contains 22.6 g/100 g of carbohydrates. Beyond carbohydrates, *Canna edulis* also contains protein (1 g/100 g), fat (100 mg/100 g), phosphorus (70 mg/100 g), calcium (21 mg/100 g), iron (20 mg/100 g), and vitamin B1 (0.1 mg/100 g) (10). Given its carbohydrate content, *Canna edulis* has the potential to be processed into nata through fermentation by *Acetobacter xylinum* bacteria.

2. Materials and Methods

This study employed a laboratory-based experimental method. The first stage involved the preparation and botanical identification of *Canna edulis* (ganyong) tubers. The second stage entailed processing the tubers into nata de ganyong via fermentation using *Acetobacter xylinum*, followed by quality evaluation—specifically organoleptic assessment, thickness measurement, and analysis of moisture content and yield. Subsequently, microcrystalline cellulose was isolated from the nata de ganyong through extraction with sodium hydroxide and hydrolysis with 2.5 N hydrochloric acid. The isolated microcrystalline cellulose underwent evaluation, including characterization tests (organoleptic, identification, pH, starch, solubility, flow properties and angle of repose, compressibility, specific gravity, and loss on drying) and physicochemical analysis (infrared spectroscopy, scanning electron microscopy, and X-ray diffractometry). Finally, the material was encapsulated using size-zero capsules, and the capsules were evaluated for weight uniformity, disintegration time, and hygroscopicity.

The materials used were : Oven, drying cabinet, blender, stainless steel pan, plastic tray, paper, Büchner funnel, laboratory glassware, analytical balance, UV-Vis spectrophotometer, infrared spectrometer, Scanning Electron Microscope (SEM), X-ray diffractometer, single-punch tablet press, pH meter, moisture analyzer, funnel (for angle of repose test), caliper, hardness tester, friability tester, disintegration tester, and dissolution apparatus. *Canna edulis* (*Canna edulis* Ker Gawl.) tubers, *Acetobacter xylinum* bacterial starter, urea, glacial acetic acid, sugar, sodium hydroxide, hydrochloric acid, distilled water, Avicel® PH 102, and 70% alcohol.

3. Result and Discussion

Production of *nata de ganyong*

Nata de ganyong is produced from 6 kg of canna (ganyong) tubers, which are processed into a canna extract by blending with water at a 1:4 ratio, yielding 24.5 kg of extract. Additional nutrients—such as glacial acetic acid, urea, and sugar—are incorporated into this medium. Bacteria are then inoculated into the mixture, resulting in a total batch weight of 26.6 kg. From this 26.6 kg of canna extract, 22,020 grams of nata de ganyong are obtained, resulting in a yield of 82.7820%.


Fig 1 . Nata de ganyong (nata from *Canna edulis*)

Evaluation of the quality of nata de ganyong

Evaluation of the quality of nata de ganyong is carried out to determine the quality of the nata de canna which is produced and adjusted to the specified requirements. Tests carried out include organoleptic tests, nata thickness tests, and water content and yield tests.

a. Organoleptic test

Organoleptic testing is the analysis of a product using the five human senses. The purpose of this test is to determine the organoleptic properties and acceptability of the nata de cannayong that has been made. The quality requirements for nata such as color, smell, taste and texture refer to the quality requirements for nata in packaging as stated in the Indonesian National Standard (SNI) 01-4317 of 1996. The test results show that the nata is white, slightly cloudy, tasteless, slightly sour and chewy (not transparent when pressed with a finger), the surface is flat.

b. Test the thickness of the nata

The thickness of the nata de ganyong produced is an average of 1.2805 cm. According to Putriana and Aminah (2013), generally the thickness of nata de coco ranges from 1-1.5 cm. This is influenced by the addition of sucrose and the length of fermentation. The longer the fermentation and the higher the concentration of sucrose added, the more *Acetobacter xylinum* bacteria will form a layer of cellulose due to the breakdown of sugar into polysaccharides, so that the resulting nata is thicker.

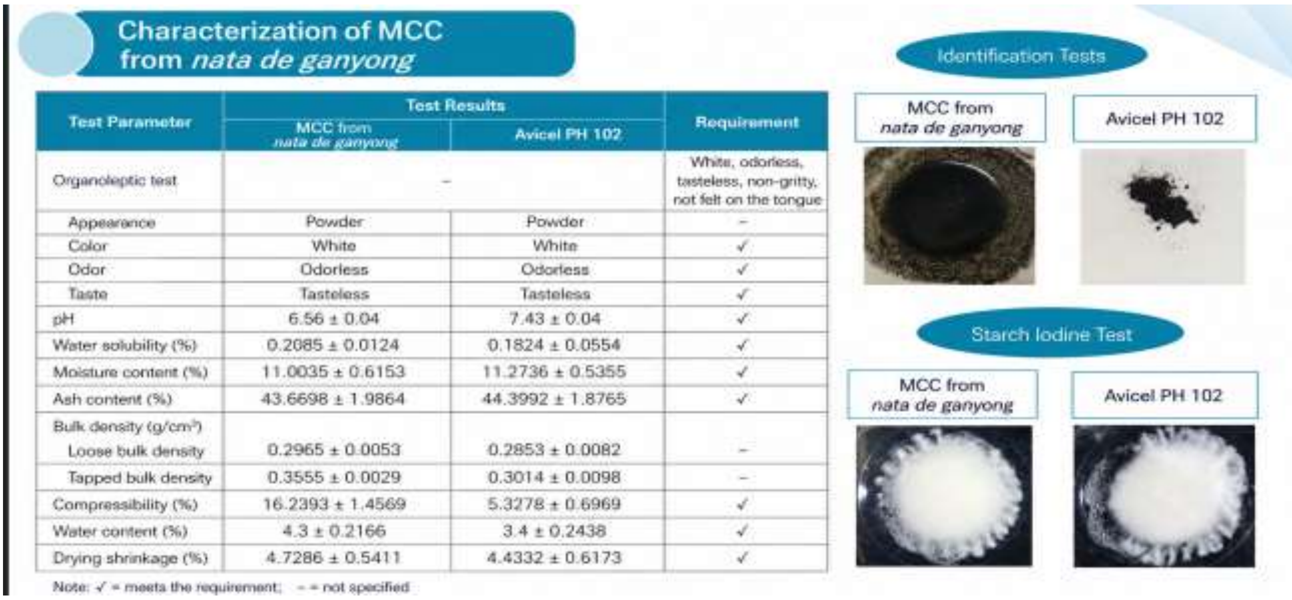
c. Test water content and yield

The water content test is a test that aims to determine the water content contained in a material. The water content contained in the nata de ganyong produced is 98.19%. According to Tamimi et al (2015), quoted in Rachmawati (2017), the water content value of nata is not influenced by treatment, because nata is generally a food product that contains a lot of water. The yield from nata de cannayong was 1.81%. According to Amiarsi et al. (2015) in Rachmawati (2017) stated that in the formation of cellulose into nata, the growth of *Acetobacter xylinum* bacteria is influenced by sucrose and ammonia.

Results of Isolation microcrystalline cellulose from nata de ganyong

Fig 2. Isolation of microcrystalline cellulose from nata de ganyong

Results of Characterization of microcrystalline cellulose (MCC) from nata de ganyong



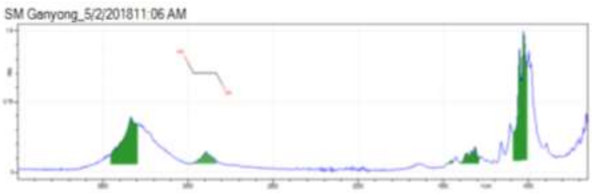
Test Parameter	Test Results: MCC from nata de ganyong	Test Results: Avicel PH 102	Requirement
Organoleptic test	–		White, odorless, tasteless, non-gritty, not felt on the tongue
Appearance	Powder	Powder	–
Color	White	White	✓
Odor	Odorless	Odorless	✓
Taste	Tasteless	Tasteless	✓
pH	6.56 ± 0.04	7.43 ± 0.04	✓
Water solubility (%)	0.2085 ± 0.0124	0.1824 ± 0.0554	✓
Moisture content (%)	11.0035 ± 0.6153	11.2736 ± 0.5355	✓
Ash content (%)	43.6698 ± 1.9864	44.3992 ± 1.8765	✓
Bulk density (g/cm³)			
Loose bulk density	0.2965 ± 0.0053	0.2853 ± 0.0082	–
Tapped bulk density	0.3555 ± 0.0029	0.3014 ± 0.0098	–
Compressibility (%)	16.2393 ± 1.4569	5.3278 ± 0.6969	✓
Water content (%)	4.3 ± 0.2166	3.4 ± 0.2438	✓
Drying shrinkage (%)	4.7286 ± 0.5411	4.4332 ± 0.6173	✓

Note: ✓ = meets the requirement; – = not specified

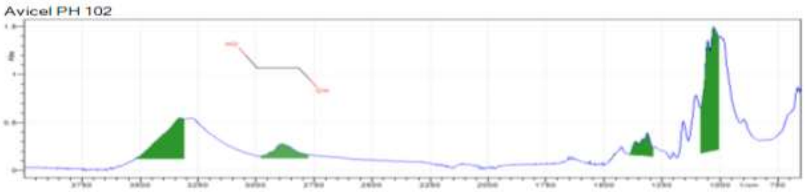
Fig 3. Characterization of microcrystalline cellulose (MCC) from nata de ganyong

Results of FTIR Analysis

FTIR analysis was conducted to detect the functional groups present in the test compounds. The IR spectra of microcrystalline cellulose derived from nata de ganyong and the reference material Avicel PH-102 exhibited various peaks, as shown in Figure 4. The observed IR spectral features included C-O stretching (1070–1020 cm^{-1}), O-H deformation (1400–1300 cm^{-1}), C-H bending of CH_2/CH_3 (1475–1445 cm^{-1}), C-H stretching of CH_2 (2975–2840 cm^{-1}), and O-H stretching (3450–3300 cm^{-1}). Other studies have reported that cellulose from nata de coco exhibits peaks at 3440 cm^{-1}, 2926 cm^{-1}, 1440 cm^{-1}, 1300 cm^{-1}, 1163 cm^{-1}, and 1040 cm^{-1} (Halib et al., 2012). The FTIR spectrum of the microcrystalline cellulose from nata de ganyong showed peaks identical to those of Avicel PH-102; thus, it can be concluded that the microcrystalline cellulose produced from nata de ganyong is pure.



(a)

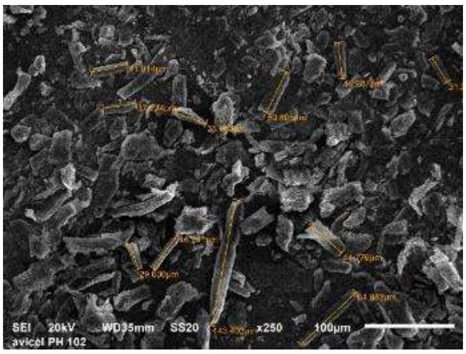


(b)

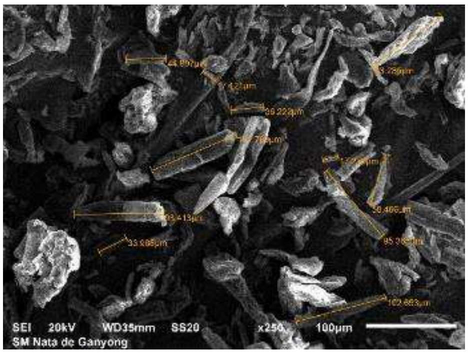
Fig 4. FTIR test results for (a) MCC nata de ganyong and (b) Avicel PH 102.

Results of Scanning Electron Microscope (SEM) Analysis

SEM analysis was conducted to determine the morphology and size of the material. SEM observations of Avicel® PH 102 at 250x magnification indicated a particle size range of 29.600 to 143.403 µm, with irregular shapes, uneven surface textures, and both sharp and blunt angles. Meanwhile, SEM results for the nata de ganyong SM showed a particle size range of 17.121 to 102.653 µm, also characterized by irregular shapes, uneven surface textures, and both sharp and blunt angles. These findings indicate that the nata de ganyong SM shares the same morphological characteristics as the standard and falls within the same particle size range—spanning from tens to approximately two hundred micrometers.



(a)

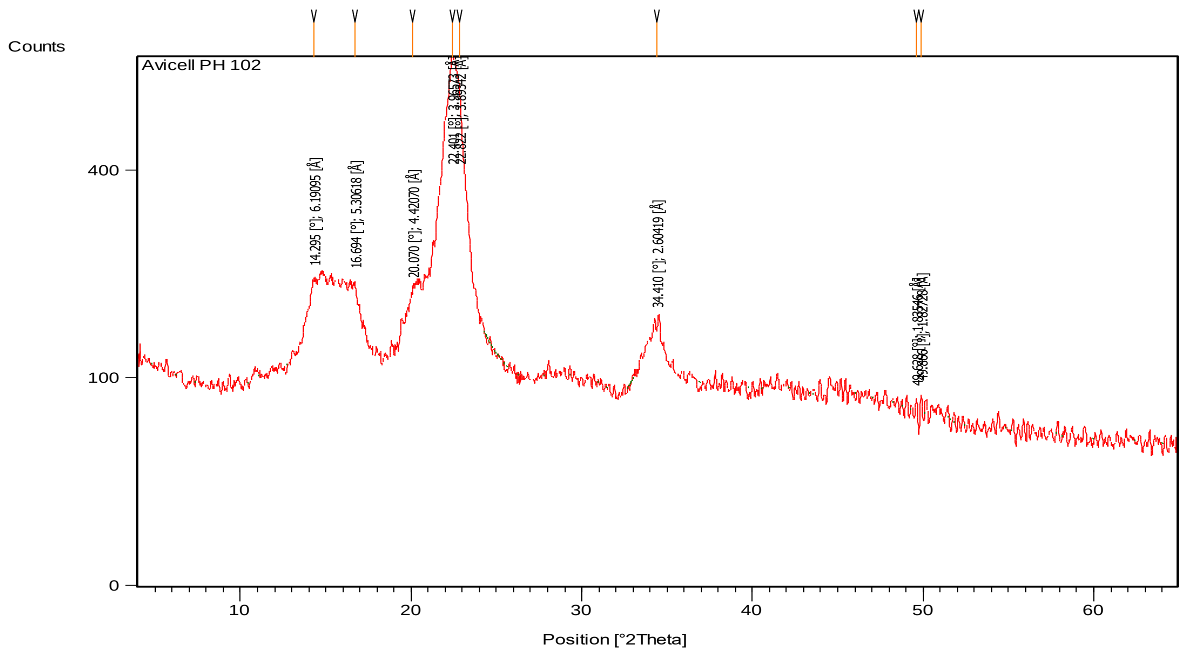


(b)

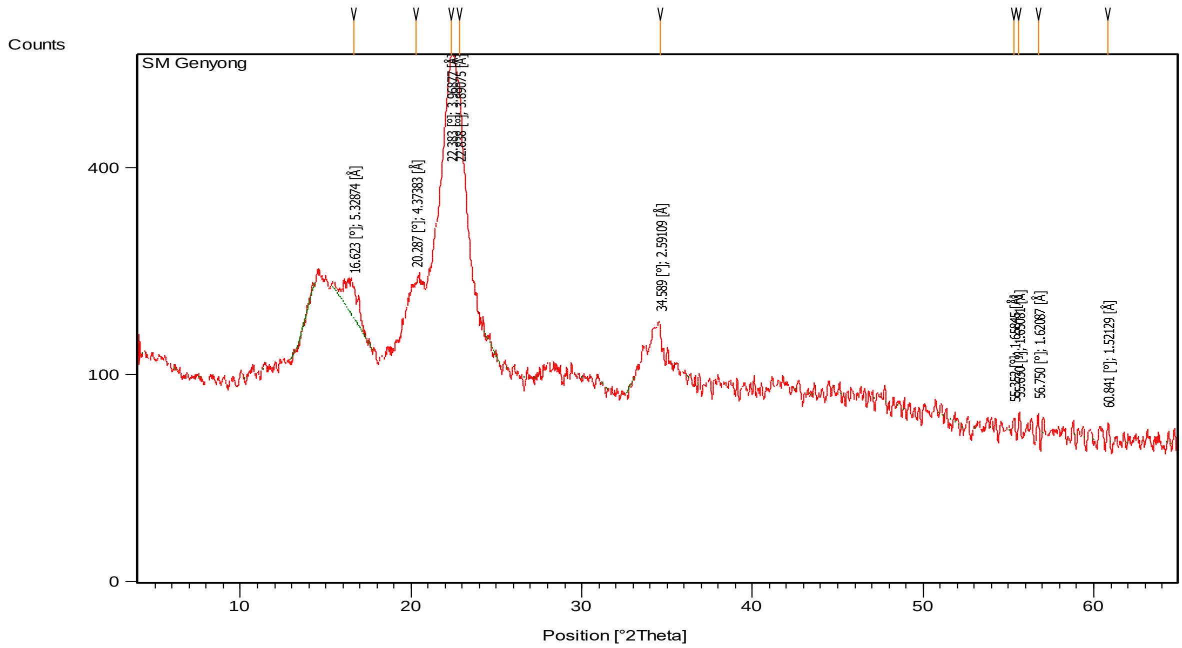
Fig 5 .SEM test results: (a) Avicel PH 102 standard, (b) MCC from Nata de Ganyong

X-Ray Diffraction (XRD) Analysis

X-Ray Diffraction (XRD) analysis was conducted to determine the degree of crystallinity and crystal structure of the microcrystalline cellulose. Based on the obtained diffraction patterns, the microcrystalline cellulose sample derived from nata de ganyong exhibited peaks at 2θ angles of approximately 16.6231°, 20.2871°, 22.3832°, 22.8380°, 34.5895°, 55.3516°, 55.6299°, 56.7495°, and 60.8414°. The peaks observed for the reference material, Avicel PH 102, occurred at 2θ angles of approximately 14.2949°, 16.6943°, 20.0698°, 22.4006°, 22.8221°, 34.4102°, 49.6284°, and 49.8657°. These results indicate that the peaks of the microcrystalline cellulose from nata de ganyong correspond to those of the Avicel PH 102 reference. Consequently, the microcrystalline cellulose from nata de ganyong is suitable for use as a tablet excipient due to the similarity in characteristics with the Avicel PH 102 reference.



(a)



(b)

Fig 6. XRD test results: (a) Avicel PH 102 standard, (b) MCC from Nata de Ganyong.

Capsulle fillling

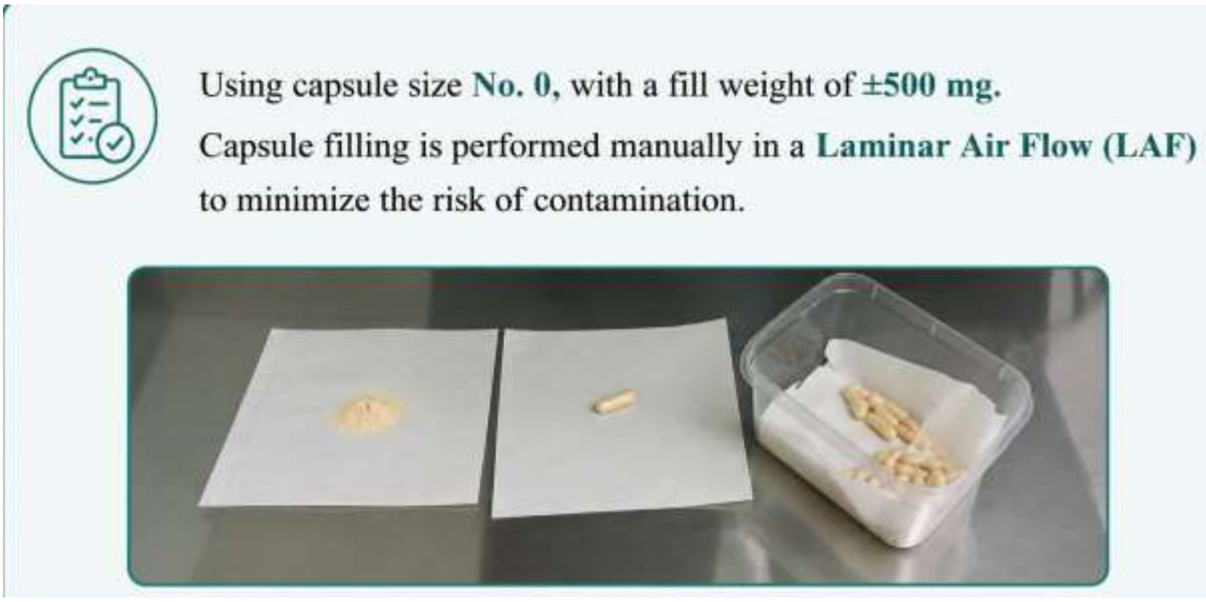


Fig 7 Capsule filling

4. Conclusions

a. Canna rhizomes can serve as a raw material for producing nata, known as nata de ganyong.
b. Microcrystalline cellulose can be isolated from nata de ganyong.
c. The characteristics of microcrystalline cellulose derived from nata de ganyong—including organoleptic properties, pH, water solubility, flow properties, angle of repose, compressibility,

moisture content, and loss on drying—are similar to the Avicel® PH 102 standard ($p > 0.05$, 95% CI), thereby meeting the evaluation criteria for microcrystalline cellulose.

d. Capsules containing the active ingredient Vitamin C and a filler made from phosphorylated nata de ganyong meet the evaluation requirements for capsules.

5. Acknowledgement

Thankyou for Ministry of Higher Education, Science and Technology Indonesia for funding this project.

6. References

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