Research Paper

# Formulation of Amylopectin Powder from Durian Peel and *Eucheuma cottonii* Carrageenan as a Potential Halal Capsule Alternative

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| Received : May 21, 2025 | Revised : June 16, 2025 | Accepted : August 27, 2025 | Online : November 21, 2025 |
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**Abstract**

Capsules are pharmaceutical preparations consisting of active compounds enclosed within water-soluble hard or soft shells. Gelatin is commonly used as a gelling agent for capsule shells. Although approximately 80% of gelatin is derived from porcine sources, this raises concerns about its permissibility for Muslim consumers. Durian peel offers a promising alternative as it contains lignin, hemicellulose, cellulose, and pectin. Combining durian peel with *Eucheuma cottonii* carrageenan is essential for producing high-quality capsule shells as a potential halal capsule alternative. This study involved an experimental approach, analyzing the amylopectin powder content in durian peel and formulating capsule shells using five variations of durian peel starch to carrageenan ratios: 0.76%:5% (F1), 0.78%:5% (F2), 0.80%:5% (F3), 0%:5% (F4), and 5%:0% (F5). The results confirmed the presence of amylopectin in durian peel, with moisture and ash content meeting the Indonesian National Standard (SNI) requirements. Halal capsule shells were successfully produced from a combination of durian peel and *Eucheuma cottonii* carrageenan, with the formulation meeting specification standards, including appropriate disintegration times.

**Keywords**: *Capsule Shells, Halal, Eucheuma Cottonii Carrageenan, Durian Peel*

## INTRODUCTION

Capsules are medicinal preparations consisting of active compounds in hard or soft shells that can dissolve in water. One of the ingredients that serves as a gelling agent to make capsules is gelatin. Gelatin is obtained from the denaturation and hydrolysis of animal bones, muscles, or muscle membranes, which include a type of macromolecular protein that can dissolve in water (Feng et al., 2022). In Indonesia, gelatin still depends on the import sector from other countries. Based on BPS data in 2023, the amount of gelatin imports until November reached 2.45 million kg with a value of 20.77 million USD (BPS, 2023).

Gelatin Manufacturers of Europe (GME) states that almost 80% of gelatin produced comes from pig peel, 15% from cattle peel, and 5% from cattle and fish bones (Rather et al., 2022). Gelatin from pigs is a polemic on the aspect of halalness, because for Muslims it is forbidden to consume pigs or parts of their bodies, including gelatin. Based on this, it is in accordance with the word of Allah in the Al-Qur'an Surah Al-Baqarah verse 173, which means, "*Verily, Allah has only forbidden to your carrion, blood, pork, and animals which (when slaughtered) are called by names other than Allah. But whoever is compelled to eat them and does not desire to do so, nor does he transgress the limits, there is no sin on him. Indeed, Allah is Forgiving and Merciful.*" (MUI, 2022)

The demand for halal capsule shells made from plant-based materials serves as an alternative to gelatin. These materials must meet essential criteria, including biodegradability and biocompatibility. Starch (amylum), a natural polymer, presents a promising option for capsule shell production due to its composition of glucose homopolymers with α-glycosidic bonds. Starch consists of two primary fractions: amylose and amylopectin (Christi A et al., 2017). While amylopectin exhibits poor flow properties and


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compressibility due to its granular, expandable nature, it demonstrates excellent binding characteristics (Kadarusman, 2021).

One of the materials that contains starch (amylum) and can be utilized to make halal capsule shells is durian peel. Durian peel is waste and can cause unpleasant odors and become a source of disease if not processed properly. Its utilization in materials to make halal capsule shells is one alternative to processing the waste. This is because durian peel contains 15.45% lignin fiber, 13.09% hemicellulose, 60.45% cellulose (Rahmawati et al., 2023), and pectin, which is quite high at 2.56% (Susanti et al., 2015). However, the amylopectin content of durian peel is still not strong enough to form a gel, so a combination polymer is needed. *Eucheuma cottonii* carrageenan is one of the alternatives chosen to be combined with durian peel amylopectin because it has a high polysaccharide content, sturdy gel content, and high gel strength (Erawati et al., 2023). With a yield of 43.42%, carrageenan is suitable for use in the formulation of edible films, while starch functions as an emulsifier, stabilizing the carrageenan during gelation (Nurshodiq et al., 2022).

In addition to serving as a halal alternative for Muslim consumers, capsule shells derived from plant-based materials offer a suitable option for individuals with allergies to animal proteins. Allergies to animal-derived proteins have been reported to trigger severe reactions, including anaphylaxis (Vervloret et al., 1983) (Yamada et al., 2002).

A study conducted by Christi et al. (2017) explored the use of amylopectin derived from cassava in combination with carrageenan for the production of hard capsule shells. However, the resulting capsules exhibited fragility, leading the authors to recommend the incorporation of additional materials in future formulations to enhance mechanical strength. In response to this recommendation, the present study incorporates sucrose as a plasticizer and titanium dioxide as a filler. Sucrose contributes to flexibility, while titanium dioxide is selected for its favorable properties, namely, high thermal stability, whiteness, amorphous nature, tastelessness, and non-hygroscopic characteristics (Mufrodi et al., 2019).

This study explores the development of halal-certified hard capsule shells using a combination of amylopectin powder extracted from durian peel and carrageenan derived from *Eucheuma cottonii*, with glycerin and sucrose serving as excipients. The goal is to produce plant-based capsule shells that meet pharmaceutical quality standards while offering a safe and acceptable alternative for Muslim consumers and individuals with allergies to animal-derived proteins.

The specific objectives of this research are to (1) identify the amylopectin content in durian peel and evaluate its potential for forming hard capsules; (2) examine the physical, mechanical, and disintegration properties of capsule shells made from a blend of durian peel starch and carrageenan; (3) assess whether the resulting capsules meet the established pharmaceutical standards for hard capsules; and (4) evaluate the compliance of the materials and production process with halal requirements.

The central research question is, to what extent can a combination of durian peel amylopectin and carrageenan produce hard capsules that fulfill both pharmaceutical and halal standards?

This study also highlights the broader relevance of this innovation for the halal pharmaceutical industry by presenting a scalable, plant-based alternative to gelatin capsules. By using durian peel and carrageenan, both free from animal derivatives. This approach addresses religious concerns associated with porcine-based gelatin and supports the increasing demand for halal pharmaceutical products, particularly in Muslim-majority regions. Additionally, this method offers a sustainable, cost-effective, and culturally appropriate solution for large-scale production of hard capsules.

## LITERATURE REVIEW

### Research on the Development of Hard Capsule Shells from Plant-Based Materials

Several studies have explored the formulation of hard capsule shells using plant-based materials in combination with various excipients. For instance, capsules have been developed from green grass jelly

(*Cyclea barbata*) leaf extract using Na-CMC and sorbitol as excipients (Amin & Alam, 2020), salak seed glucomannan with alpha-amylase enzyme excipient (Yunita et al., 2019), watermelon albedo pectin with excipient Na-CMC, HPMC, and $CaCl_2$ (Riferty et al., 2017), cassava starch and hibiscus leaves gel with excipient glycerol, glacial acetic acid, and sodium tripolyphosphate (Mardina et al., 2022), and durian seed gum extract (Zebua, 2022).

**Research on the Development of Hard Capsule Shells from Carrageenan**

Parallel studies have focused on the application of carrageenan as a primary material in capsule shell formulation. Examples include carrageenan with sorbitol and filler $TiO_2$ (Mufrodi et al., 2019), carrageenan with maltodextrin (Fauzi et al., 2020), and carrageenan with multiple disintegrants (Soraya et al., 2024).

**Research on the Combination of Plant-Based Materials and Carrageenan for Capsule Shells**

Formulations combining plant-derived components with carrageenan have also been investigated. Notable examples include cassava starch, amylopectin, and carrageenan with excipient glycerin (Christi A. et al., 2016), pectin from jackfruit peel and carrageenan (Rizal et al., 2023), arrowroot starch and *Eucheuma cottonii* with excipient sorbitol and $CaCl_2$ (Fatonah et al., 2024), cocoa pod shell amylopectin with carrageenan (Suparman, 2019), *Eucheuma cottonii* carrageenan and potato starch with excipient PEG (Erawati et al., 2023), carrageenan and potato peel with honey and sucrose (Lestari et al., 2021).

**Research on the Development of Halal Capsule Shells**

The development of halal-compliant capsule shells has also garnered attention. Studies in this domain include the use of fish bone-derived gelatin (Febriana et al., 2021), *Amorphophallus oncophillus* tubers with papaya leaf extract (Mahardika et al., 2023), *Amorphophallus oncophillus* tubers (Rosmalasari et al., 2018), *Caulerpa racemosa* (Permatasari et al., 2022), and chitosan (Tiany et al., 2019).

Despite these advancements, an optimal formulation that meets both halal requirements and pharmaceutical quality standards has yet to be identified. Therefore, the present study hypothesizes that a combination of amylopectin powder extracted from durian peel and *Eucheuma cottonii* carrageenan can yield a standardized, halal-compliant capsule shell formulation suitable for large-scale production. This formulation is expected to be safe for consumption, particularly for Muslim consumers and individuals with allergies to animal-derived proteins.

## RESEARCH METHOD

This research is an applied experiment to produce capsule shells from amylopectin powder of durian peel combined with *Euchema cottonii* carrageenan, which has a standardized evaluation as an alternative halal pharmaceutical preparation that can be consumed by the public, especially the Muslim community and people who are allergic to animal protein.

### Research Material

The tools used were a flour grinder (Miller FCT-Z100 FOMAC), oven (Memert type UN55), mesh sieve 100 (Stainlees steel), blender (Stainless steel), buchner funnel (Porcelain), test tube (Iwaki Pyrex), porcelain cup, desiccator (Glass), Muffle furnance (Faithful SX4-2-12P), analytical balance (MA 104), set of glassware (Iwaki Pyrex), laboratory scale capsule maker (Manual).

The materials needed are distilled water, $H_2SO_4$, 96% food-grade ethanol, 70% food-grade ethanol, iodine, carrageenan (Kappa carrageenan), durian peel starch, sucrose, paraffin oil, titanium dioxide, litmus paper, filter paper, and glycerin.

The capsule shell formulation developed in this study is a modification of the formulation proposed by Christi et al. (2017), which utilized amylopectin derived from cassava in combination with carrageenan.. However, the resulting capsule shells were reported to be fragile, and the authors recommended the incorporation of additional components with properties that could enhance the mechanical strength of the shells. In response to this recommendation, the present study incorporates sucrose as a plasticizer and titanium dioxide as a filler. Titanium dioxide was selected due to its high thermal stability, white color, amorphous structure, tastelessness, and non-hygroscopic nature (Mufrodi et al., 2019). Five different formulations of capsule shells were developed in this study, as detailed in the table below:

**Table 1**. Five different formulations of capsule shells

| Ingredient | Formulation (%) | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Durian peel amylopectin | 0.76 | 0.78 | 0.80 | 0.00 | 5.00 |
| Carrageenan | 5.00 | 5.00 | 5.00 | 5.00 | 0.00 |
| Glycerin | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Sucrose | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 |
| Titanium dioxide | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Distilled water | Ad 100 | Ad 100 | Ad 100 | Ad 100 | Ad 100 |

## Research Methods

### Preparation of durian peel starch

Fresh durian peel waste was randomly collected from the traditional market in Mantingan, Ngawi, Indonesia. The peels were separated into two parts: the outer layer and the inner white portion. The inner peel was cut into small pieces and sun-dried for five days. Subsequently, the dried material was sent to the Center for Research and Development of Medicinal Plants and Traditional Medicines (BP2TOOT) for milling and analysis, resulting in a fine brown powder.

### Analysis of durian peel starch

*Visual Test*

Durian peel starch was observed based on color, odor, texture, and taste (Kurniati et al., 2024).

*Analysis of amylopectin contents*

A total of 30 g of durian peel powder, added with distilled water (1:2). $H_2SO_4$ was added until the pH reached 3. Heated to 90°C for 5 hours, filtered using filter paper. Filtrate was added 96% ethanol as much as 100 ml, and precipitated for 6 hours. The precipitate was separated from the solution using filter paper. The precipitate was washed with 70% ethanol to remove the remaining acid, then dried in the oven (Hanifah et al., 2021). After drying, 3 g was taken and dripped with 10-20 drops of iodine and observed for color change. Blue color change indicates the sample contains amylum, and red color indicates amylopectin (Nurminah, 2019).

*Analysis of moisture contents*

The porcelain cup was dried at 105°C for 30 minutes. The porcelain cup was cooled in a desiccator for ± 15 minutes and then weighed. A total of 3 grams of sample was put into a porcelain cup and put in the oven at 105 °C for 3 hours, then cooled in a desiccator and weighed. The procedure is repeated until a fixed weight is obtained (Yenrina, 2015). The standard of water content must meet SNI-3451-2011 is 0%-14%.

*Analysis of ash contents*

The sample was weighed as much as 3 grams into a porcelain cup that had a known weight. Then the sample was evaporated in a water bath until dry. The samples were dried on a Muffle Furnace at a maximum temperature of 55 °C until complete ignition. Then cooled in a desiccator and weighed (Yenrina, 2015). The ash content standard must meet SNI 3451-2011, which is less than 0.6%.

**Capsule shell preparation**

Preparation of capsule shells is done by heating distilled water on a hotplate and a magnetic stirrer to a temperature of 45°C, then adding sucrose and allowing it to dissolve. After dissolving, titanium dioxide was added and left for 3 minutes to dissolve completely. The solution was added carrageenan slowly and allowed to expand and homogeneous for 20 minutes with a magnetic stirrer speed of 400 rpm. After 20 minutes, durian peel starch was added and allowed to homogenize for 1.5 hours. Then glycerin was added and left for 30 minutes.

After the solution is homogeneous, the sample is printed by first smearing the capsule printing tool (pin) with paraffin oil, which serves to facilitate the taking of capsule prints that have dried. Dipping the pin molding tool into the previously made formulation for 3 seconds with a constant temperature of 45°C. Temperature is useful to remove air bubbles that are trapped during the pin molding process. The pins were removed from the dough and placed in an inverted position for 10 minutes. Then the pins were dried in an oven at 55°C for 3 hours, and the dry dough on the pins was pulled to form the capsule shell production.

**Capsule Shell Evaluation Test**

*Specifications of Capsule Shell*

The physical specifications of the capsule shells were measured using a vernier caliper. Parameters assessed included capsule length, cap diameter, and body diameter. The measurements were compared with the specifications provided by PT Kapsulindo Nusantara: capsule length between 21.00–22.00 mm, body diameter of 7.290 mm, and cap diameter of 7.569 mm (Amalina et al., 2020). Each formulation was evaluated using two capsule shell samples.

*Moisture Content Test*

Moisture content was determined using the oven-drying method. Sample containers (crucibles) were first dried in an oven at 105°C for 30 minutes, cooled in a desiccator, and weighed. Subsequently, the capsule shell samples were placed in the containers and heated at the same temperature for 3 hours, then cooled and weighed again (Christi A et al., 2017). The moisture content results were evaluated against the PT Kapsulindo Nusantara standard, which ranges from 20% to 60% (Amalina et al., 2020). Two capsule shells from each formulation were tested.

*Disintegration Time Test*

According to the Indonesian Pharmacopoeia, 5$^{th}$ edition (2014), acceptable disintegration time for hard capsules is 15 minutes, not exceeding 30 minutes (Rizal et al., 2023). Disintegration testing was performed using a disintegration tester with distilled water maintained at 37°C, simulating human body temperature. The purpose of this test was to determine the time required for the capsule shell to break down into smaller particles, facilitating the release and absorption of the active ingredients in the gastrointestinal tract (Lestari et al., 2021). Two capsule shells from each formulation were used for this test.

**Data Analysis**

The visual characteristics of durian peel starch were analyzed using a qualitative descriptive method. Quantitative descriptive methods were employed to analysis of organoleptic, amylopectin content, moisture content, ash content, capsule shell specifications, moisture content test of capsule shells, disintegration time, and halal product. These results were then compared against established standards, including the Indonesian National Standard (SNI), the Indonesian Pharmacopoeia, and other relevant regulatory guidelines.

For quantitative comparisons, the results were presented as mean ± standard deviation (n = 2) to reflect variability within samples. Standard deviations were calculated to assess reproducibility and consistency. Furthermore, statistical methods (one-way ANOVA and Kruskal-Wallis) were used to determine whether there were significant differences ($p < 0.05$) between formulations.

## FINDINGS AND DISCUSSION

The use of durian peel starch as a potential raw material for capsule shells was analyzed through a series of analyses, including organoleptic, amylopectin content, moisture content, ash content, capsule shell specifications, moisture content test of capsule shells, disintegration time, and halal product. The results provide a comprehensive understanding of its feasibility for pharmaceutical applications.

### Organoleptic Analysis

**Table 2.** Results of Durian Peel Starch Organoleptic Analysis

| Test type | Result | Figure |
|---|---|---|
| Color | Brown |  |
| Odor | Coffee | |
| Texture | Slightly fibrous and rough | |

The organoleptic test (see Table 2) revealed that durian peel starch exhibits a brown color, attributed to prolonged sun drying. The drying process, which lasted five days, exposed the durian peel to ultraviolet (UV) radiation, causing pigmentation changes due to oxidation and water content reduction. This color alteration is common in materials exposed to such conditions and reflects the need for controlled drying to preserve aesthetic and functional qualities.

The starch also displayed a slightly fibrous and rough texture. This property arises from the high cellulose and lignin content inherent in durian peel. While these fibrous characteristics might limit flow properties, they enhance binding capabilities, a crucial attribute for capsule shell formulation. The starch emitted a coffee-like aroma, likely due to volatile compounds such as sulfur, alcohol, aldehydes, esters, and ketones. These findings emphasize the complex nature of durian peel starch, which combines unique sensory and structural properties.

### Amylopectin Content Analysis

The analysis of amylopectin content in durian peel is presented in Table 3.

**Table 3.** Analysis of Amylopectin Content of Durian Peel Starch

| Reagent | Result | Figure | Conclusion |
|---|---|---|---|
| Iodine | Brownish-red |  | (+) Positive for amylopectin content |

Durian peel presents a viable alternative material for the production of capsule shells due to its potential to be processed into starch with a relatively high pectin content, approximately 2.56%.

Pectin is a polysaccharide compound formed through the hydrolysis of amylopectin. Starch itself consists of two primary fractions, distinguishable by their solubility in hot water: approximately 20% is amylose, which is soluble in hot water, while the remaining 80% is amylopectin, which is insoluble. Amylose is composed of 250–300 glucose units linked by α-1,4-glycosidic bonds and is capable of forming helical structures, typically with eight glucose units per turn. Although amylose is generally insoluble in aqueous media, it can form micellar suspensions. When treated with iodine, amylose produces a characteristic blue-colored complex. In contrast, amylopectin contains more than 1,000 glucose units, with both α-1,4- and α-1,6-glycosidic linkages, contributing to its highly branched structure (Kàczkowski, 2003).

The presence of amylopectin in durian peel starch was confirmed through iodine testing, which resulted in a characteristic brownish-red color. Amylopectin, a branched polysaccharide with α-1,4 and α-1,6 glycosidic bonds, forms specific complexes with iodine (Nurminah, 2019). Its structural complexity makes it suitable for applications requiring flexibility and stability. Amylopectin contributes to the elasticity and durability of capsule shells, complementing the mechanical properties needed for pharmaceutical products. The findings underline the potential of durian peel starch as a plant-based polymer that meets the requirements for biodegradability and biocompatibility.

**Moisture and Ash Content Analysis**

The moisture content analysis of durian peel starch is provided in Table 4.

**Table 4.** Moisture content analysis of durian peel starch

| Standard water content According to SNI-3451-2011 | Ar content test results on starch |
|---|---|
| 0-14% | 0.29% |

The moisture content of durian peel starch (amylopectin powder) was measured at 0.29%, meeting the SNI 3451-2011 standard (0–14%). Effective sun drying played a key role in achieving this low value, reducing microbial growth risks and ensuring extended shelf life. However, excessively low moisture levels may render the starch brittle, potentially compromising its processing and performance as a capsule shell material. Future research should investigate optimal moisture levels to balance flexibility and durability.

Ash content testing is conducted to analyze the mineral components or inorganic compounds present in a material. These mineral constituents may include both inorganic and organic salts. Common examples of inorganic salts are chlorides, carbonates, phosphates, and sulfates, while organic salts may include acetates, pectates, malic acid, and oxalic acid. Minerals often form complex compounds with organic matter, making the identification of their original forms more challenging. Consequently, ash content analysis involves incinerating the organic material and quantifying the residual mineral salts, hence the term *ashing*.

This parameter is closely related to the purity and cleanliness of the tested material. A lower ash content indicates a higher degree of refinement and fewer contaminants. Moreover, the ash content provides insight into the effectiveness of the processing methods applied. In the case of durian peel starch, the ash content must comply with the Indonesian National Standard (SNI 3451-2011), which specifies a maximum threshold of 0.6%. The low ash content observed in durian peel-derived amylopectin in this study suggests that the starch is of high purity and free from significant impurities.

**Capsule Shell Specifications**

The results of the capsule shell specification test for formulations combining durian peel-derived amylopectin powder and carrageenan are summarized in table 5.

**Table 5.** Capsule shell specifications

| Standard Parameters (PT. Kapsulindo Nusantara) | | Formulation Result | | | | |
|---|---|---|---|---|---|---|
| | | F1 | F2 | F3 | F4 | F5 |
| Total Capsule Length (mm) ± SD | **21-22** | 21.00±0.3 | 22.00±0.6 | 22.00±0.7 | 21.00±0.9 | 21.00±0.4 |
| Body diameter (mm) ± SD | **7.290** | 7.153±0.2 | 7.259±1.4 | 7.259±1.2 | 7.254±0.2 | 7.012±1.4 |
| Cap diameter (mm) ± SD | **7.479** | 7.325±1.1 | 7.325±1.4 | 7.469±0.7 | 7.320±0.03 | 7.215±1.1 |
| Thickness of capsule shell (mm) ± SD | **18.44** | 6.05±0.04 | 10.12±0.2 | 18.23±1.1 | 12.06±0.08 | 0.00±0.00 |

Description:

F1: Capsule shell formulation containing 76 grams of amylopectin powder from durian peel.

F2: Capsule shell formulation containing 78 grams of amylopectin powder from durian peel.

F3: Capsule shell formulation containing 80 grams of amylopectin powder from durian peel.

F4: Capsule shell formulation containing 5 grams of carrageenan, without the addition of amylopectin powder from durian peel.

F5: Capsule shell formulation containing 5 grams of amylopectin powder from durian peel, without carrageenan.

In this research, a hard capsule shell was made. Hard capsules are designed to consist of 2 parts (2-piece shell), consisting of a top cover (cap) and a capsule body (body). Capsules have a variety of molded sizes; each size has its own standard volume in preparation and has several characteristics of each size. Capsule shells were made for size 0 with a volume of 0.68 ml.

| Capsule size | 000 | 00 | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|---|
| Volume of contents (ml) | 1.37 | 0.95 | 0.68 | 0.50 | 0.37 | 0.30 | 0.21 | 0.13 |

The measurement results for the length of the capsule body and cap were in accordance with the specifications set by PT Kapsulindo Nusantara, which range from 21.00 mm to 22.00 mm. However, the diameter measurements of the capsule cap across all formulations did not meet the company's standards, which specify 7.290 mm for the body and 7.479 mm for the cap. Additionally, the thickness measurements of the capsule shells varied across formulations and did not conform to the standard thickness specification of 18.44 mm. Based on the data obtained, an increase in the concentration of durian peel starch was associated with a corresponding rise in the total length of the capsule shell, body diameter, and cap diameter. However, statistical analysis revealed that these effects were not significant for total length ($p = 0.328$), body diameter ($p = 0.999$), and cap diameter ($p = 0.997$).

The data indicate that increasing the concentration of starch leads to a corresponding increase in capsule shell thickness, and this difference was statistically significant ($p = 0.000$). However, when durian peel starch was used without the addition of carrageenan (F5), the resultant capsule shell lacked sufficient structural integrity, thereby failing to form a measurable diameter. This can be attributed to the water-absorbing properties of starch, which contribute to the formation of a thicker film during capsule formation. The deviation from standard specifications may be due to the manual manufacturing method employed in this study, which can result in inconsistent shell thickness. Variability in viscosity, immersion technique, and operator skill also likely contributed to the observed inconsistencies.

**Moisture Content Test**

The results of the water content analysis of capsule shells formulated with durian peel-derived amylopectin powder and carrageenan are presented in Table 6.

**Table 6.** Table of capsule shell moisture content test results

| Formulation | Moisture Content (%) ± SD |
|---|---|
| F1 | 81 ± 0.7 |
| F2 | 83 ± 1.4 |
| F3 | 111 ± 1.3 |
| F4 | 101 ± 0.4 |
| F5 | 84 ± 1.1 |

Description:
F1: Capsule shell formulation containing 76 grams of amylopectin powder from durian peel.
F2: Capsule shell formulation containing 78 grams of amylopectin powder from durian peel.
F3: Capsule shell formulation containing 80 grams of amylopectin powder from durian peel.
F4: Capsule shell formulation containing 5 grams of carrageenan, without the addition of amylopectin powder from durian peel.
F5: Capsule shell formulation containing 5 grams of amylopectin powder from durian peel, without carrageenan.

Moisture content refers to the ratio of water to solid material in a substance. In both food and pharmaceutical preparations, high moisture content increases the risk of microbial growth, which can compromise product stability and safety. Moisture content testing in capsule shells is essential to assess the quality and integrity of the final product. Excessive moisture can result in a soft and pliable shell, while insufficient moisture may lead to brittleness. Therefore, controlling moisture levels is critical to ensuring the mechanical and functional properties of the capsule shells.

Based on the data from the test results, the water content of each capsule shell is higher than the standard of PT Kapsulindo Nusantara, which is from 20- 60%. This result is due to the raw materials used in this research, using two vegetable raw materials that have high water content, namely carrageenan and durian peel. Carrageenan is produced from red seaweed extract (Rhodophyceae) as a hydrocolloid with the ability to bind large amounts of water. Carrageenan has OH- free ions that can bind with water so that the bond becomes strong (Erawati et al., 2023) (Nurshodiq, 2022). The moisture content of carrageenan can be influenced by several things, such as harvest age and extraction time. While starch itself has hydroxyl group molecules that bind with hydrogen, so that it has good water absorbent properties (Rahmawati et al., 2023). Thus, in this research, it was found that the moisture content of the capsule shell was still high, due to the combination of durian peel starch and carrageenan.

The high moisture content may also be attributed to the manual capsule-forming process, which produces shells with uneven thickness. This inconsistency can hinder uniform drying, leading to suboptimal moisture reduction and elevated residual water content. Furthermore, the presence of glycerin in the formulation plays a crucial role in retaining moisture due to its hygroscopic properties. Glycerin readily attracts and retains water molecules, which contributes to the stabilization of the capsule shell by absorbing environmental humidity and reducing water evaporation. Nevertheless, this characteristic may also interfere with the drying efficiency of the shells, ultimately resulting in residual high moisture content.

The data indicate that increasing the concentration of durian peel starch results in higher moisture content in the capsule shells, although statistically insignificant (p=0.078). This indicates that durian peel starch possesses strong water-absorbing properties. As the proportion of durian peel starch increases in the formulation, a greater volume of distilled water is required to maintain a final concentration of 100%. This adjustment results in a higher overall water content within the formulation. These findings are consistent with those reported by Christi et al. (2017), who observed that greater amylopectin concentrations, when combined with a fixed amount of carrageenan, led to increased moisture content in capsule shells. However, their study utilized amylopectin derived from cassava.

**Disintegration Test**

The results of the capsule shell disintegration time test for the combination of durian peel starch and carrageenan are shown in the table below.

**Table 7.** Table of capsule shell disintegration test results

| Formulation | Disintegration Test Result (minutes) ± SD |
|---|---|
| F1 | 13.35 ± 1.4 |
| F2 | 17.24 ± 1.4 |
| F3 | 22.12 ± 0.7 |
| F4 | 19.35 ± 1.4 |
| F5 | 1.45 ± 1.4 |

Description:
F1: Capsule shell formulation containing 76 grams of amylopectin powder from durian peel.
F2: Capsule shell formulation containing 78 grams of amylopectin powder from durian peel.
F3: Capsule shell formulation containing 80 grams of amylopectin powder from durian peel.
F4: Capsule shell formulation containing 5 grams of carrageenan, without the addition of amylopectin powder from durian peel.
F5: Capsule shell formulation containing 5 grams of amylopectin powder from durian peel, without carrageenan.

The disintegration test is performed to evaluate the time required for the capsule shell to disintegrate, thereby facilitating the gradual release of the active pharmaceutical ingredient over a defined period. Disintegration time serves as a critical quality parameter, particularly for oral dosage forms, as it ensures that the drug is released within the gastrointestinal tract before systemic absorption. Complete disintegration of the capsule shell is essential to enable the onset of the drug's therapeutic action. In accordance with the Indonesian Pharmacopoeia (Third Edition), the acceptable disintegration time is less than 15 minutes for gelatin-based capsules and less than 30 minutes for non-gelatin capsules.

A trend of increasing disintegration time with higher starch concentrations was observed. For example, Formulation 1, containing 76 grams of starch, disintegrated in 13 minutes and 35 seconds, while Formulation 3, with 80 grams, required 22 minutes and 12 seconds. This correlation is attributed to increased shell thickness with higher starch content, which prolongs the time required for the shell to dissolve. Statistically, the difference in starch concentration had a significant effect on increasing the disintegration time (p=0.000).

Thicker capsule shells offer enhanced mechanical strength but may delay drug release, impacting bioavailability. Carrageenan's contribution to the disintegration time was also noted. Its hydrophilic properties facilitate water absorption, accelerating disintegration. The balance between shell thickness, mechanical integrity, and dissolution rates is critical for achieving desired therapeutic outcomes.

**Halal Product Analysis**

Halal products must be processed following halal-compliant methods, utilizing raw materials, additives, and auxiliary substances that are certified or recognized as halal. Plant-derived materials are generally considered halal unless they have intoxicating or harmful properties. Animal-derived materials are halal except for those explicitly prohibited by syar'i law.

In this study, halal analysis did not employ advanced analytical techniques such as PCR or GC-MS because all raw materials and equipment were sourced and controlled directly by the researchers, ensuring full traceability. Instead, halal compliance was verified by confirming that all materials and tools used were certified halal or classified as halal according to the Indonesian Ulema Council (MUI) Fatwa or authoritative literature. literature. Halal evaluation in this study included:

a. Durian Peel Starch: A plant-derived raw material, free from intoxicating or harmful effects upon consumption.
b. Alcohol (70% and 96%): According to MUI Fatwa No. 11 (2009), alcohol/ethanol derived from the alcohol industry for food, cosmetics, and pharmaceuticals is haram. However, non-khamr alcohol/ethanol, synthesized chemically or produced by non-khamr fermentation and used in production processes, is considered mubah (permissible) provided it is not medically harmful (MUI, 2009).
c. Aquadest, $H_2SO_4$, and Iodine: These reagents were used solely for amylopectin identification during testing and did not participate in the capsule formulation or production. Their use aligns with the Indonesian Ministry of Religious Affairs Regulation No. 20 of 2021, which prohibits hazardous materials in halal-certified micro and small businesses (BPJPH, 2021).
d. Carrageenan: Used carrageenan holds a valid halal certification until 2025 (Certification ID: 35310000756351239).
e. Titanium Dioxide, Glycerin, and Sucrose: These excipients are halal and safe as per the Indonesian Food and Drug Authority (BPOM) Regulation No. 32 of 2019 (BPOM, 2019).
f. Production Process: Manufacturing was conducted using clean equipment and safe procedures consistent with Regulation No. 20 of 2021. The process involved simple, manual, or semi-automatic technology without irradiation, genetic engineering, or harmful treatments, and was performed in an appropriate environment ensuring product safety and halal compliance (BPJPH, 2021).

**CONCLUSIONS**

The results of this study demonstrate that the combination of durian peel amylopectin with *Eucheuma cottonii* carrageenan represents a viable alternative for halal capsule shells. The capsule shells produced met the specifications outlined by PT Kapsulindo Nusantara, and their disintegration times complied with the Indonesian Pharmacopoeia Edition III standard, being under 30 minutes, despite moisture content exceeding the standard threshold (>60%). Among the tested formulations, the optimal composition was determined to be 0.80% durian peel starch combined with 5% carrageenan. This formulation exhibited desirable properties, including a capsule length of 22 mm, body diameter of 7.259 mm, cap diameter of 7.469 mm, thickness of 18.23 mm, water content of 111%, and a disintegration time of 22 minutes and 12 seconds, effectively fulfilling critical quality criteria. Halal compliance analysis confirmed that all raw materials and equipment used in the manufacturing process were certified halal or classified as halal according to the MUI Fatwa and other authoritative sources.

These findings contribute to the advancement of halal pharmaceutical preparations derived from plant-based polymers, supporting the Indonesian Ulema Council's (MUI) halal program, particularly within the pharmaceutical sector. Furthermore, this research offers a practical recommendation for the industry to develop halal pharmaceutical products catering to the Muslim population, which constitutes the majority in Indonesia and globally, as well as individuals with allergies to animal proteins. This work also addresses ongoing debates regarding the halal status of capsule shells, traditionally produced from non-halal sources such as pork gelatin, by providing a credible plant-based alternative.

## LIMITATION & FURTHER RESEARCH

Further research on the use of powder amylopectin from durian peel combined with *Eucheuma cottonii* carrageenan as a halal capsule shell alternative is necessary. This should include formulation optimization, comprehensive biocompatibility and safety assessments, and evaluation of the functional properties of the materials involved. Optimization efforts should be integrated with an automated capsule shell printing process to enhance the standardization of capsule specifications, including moisture content.

Biocompatibility and safety evaluations are essential, given that this study did not address these aspects, despite the intended human consumption of the capsules. Additionally, a thorough investigation of the functional characteristics of each formulation component is required to develop a capsule shell that consistently meets established standards.

To support potential commercialization, future studies should also consider scalability and cost-effectiveness. Such analyses are critical for accurately predicting production costs and determining viable pricing strategies, thereby facilitating the practical application and market introduction of these halal capsule shells.

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