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Extraction and characterization: starch, protein, and oil of durian seeds

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ABSTRACT: Durian is a seasonal fruit widely consumed in Indonesia, with its seeds often left unutilized. This study explores the physicochemical characteristics of flour, starch, protein, and oil extracted from durian seeds sourced from West Sumatra. Conducted in two stages - extraction and characterization - the study applied a descriptive quantitative method. Durian seed starch yielded 9.42% with round and irregular granules, 18.17 % amylose, 81.83 % amylopectin, water absorption of 2.11 mL g^{-1}, oil absorption of 2.91 mL g^{-1}, and exhibited a type C gelatinization profile with a peak viscosity of 3059.5 ± 1496.55 cP. Thermal properties showed an initial gelatinization temperature of 65.17°C and degradation at 297.55 °C. The starch had a °Hue value of 267.40 and whiteness of 89.85%. Protein concentrate yielded 0.16% with 72.30 % protein, containing six amino acids suitable for food applications like crackers, noodles, and complementary foods. Oil yield was 0.25%, containing unsaturated fatty acids such as linoleic (19.77 %), stearic (11.78 %), and conjugated linoleic acid (11.27 %), alongside saturated fatty acids like hexadecanoic acid (30.38 %). Durian seed flour yielded 28.60%, with moisture (9.33%), ash (2.67 %), protein (4.91 %), °Hue (101.03), whiteness (87.59 %), and sulfite residue (58.05 ppm), complying with Indonesian health standards. These findings suggest durian seeds' high potential for food industry applications.
Keywords: *Durio zhybethinus* Murr.; physicochemical characteristics; complementary foods.

Extração e caracterização: amido, proteína e óleo das sementes de durian

RESUMO: O durião é uma fruta sazonal amplamente consumida na Indonésia, cujas sementes frequentemente ficam subutilizadas. Este estudo explora as características físico-químicas da farinha, do amido, da proteína e do óleo extraídos de sementes de durião provenientes de Sumatra Ocidental. Realizado em duas etapas: extração e caracterização. O estudo adotou um método quantitativo descritivo. O amido de semente de durião rendeu 9,42% com grânulos redondos e irregulares, 18,17% de amilose, 81,83% de amiolopectina, absorção de água de 2,11 mL g^{-1} e absorção de óleo de 2,91 mL g^{-1} e apresentou um perfil de gelatinização do tipo C, com uma viscosidade de pico de 3059,5 ± 1496,55 cP. As propriedades térmicas indicaram uma temperatura inicial de gelatinização de 65,17 °C e uma temperatura de degradação de 297,55 °C. O amido apresentou valor de °Hue de 267,40 e branquidão de 89,85%. O concentrado de proteína rendeu 0,16% de proteína, com teor proteico de 72,30%, e contém seis aminoácidos adequados para aplicações alimentares, como salgadinhos, noodles e alimentos complementares. O rendimento de óleo foi de 0,25%, contendo ácidos graxos insaturados, como o ácido linoleico (19,77%), o ácido esteárico (11,78%) e o ácido linoleico conjugado (11,27%), além de ácidos graxos saturados, como o ácido hexadecanoico (30,38%). A farinha de semente de durião apresentou 28,60% de teor de farinha, 9,33% de umidade, 2,67% de cinzas, 4,91% de proteína, °Hue de 101,03, branquidão de 87,59% e resíduo de sulfito de 58,05 ppm, em conformidade com os padrões de saúde indonésios. Essas descobertas sugerem o elevado potencial das sementes de durião para aplicações na indústria alimentícia.
Palavras-chave: *Durio zhybethinus* Murr.; características físico-químicas; alimentos complementares.

1. INTRODUCTION

Durian (*Durio zibethinus* Murr.) is a seasonal fruit that is quite popular in Indonesia and grows widely in the forests of Sumatra, Java, Kalimantan, and Sulawesi (REDIYONO, 2020). This fruit, which has a unique taste and aroma, is very popular among some people (HAMID et al., 2018). In general, people consume durian because it has a sweet taste and provides a special appeal for durian lovers. Durian fruit consists of three parts, namely the skin, flesh, and seeds, with the durian skin accounting for 69.16%, the flesh for 22%, and the seeds for 8.84% (HERNAMAN et al., 2021). In 2022, durian production in Indonesia reached 1.58 million tons with 93 national superior varieties (BPS, 2022) and a seed availability of 139,672 tons/year.

West Sumatra Province is one of the provinces on the island of Sumatra that produces a lot of durian fruit. According to the West Sumatra Province Food Crops and Horticulture Service (2022), durian production in 19 districts/cities reached 219,638 tons, with 19,416 tons of seeds produced. The five districts/cities with the highest durian production in West Sumatra are Agam District (75,224 tons), Lima Puluh Kota District (28,704 tons), Tanah

Datar District (22,798 tons), Padang Pariaman Regency (20,294 tons), and Pesisir Selatan Regency (18,482 tons), with the varieties produced being Takada, Tambago, Montong, Talantam, Kaum Koto, Kunik Tandikek, and Ciliang (IHSAN; INDRIYANI, 2019).

Durian produces waste, such as seeds that have not been fully utilized. Every 100 grams of durian seeds contains 51 grams of water, 46.2 grams of carbohydrates, 2.5 grams of protein, and 0.2 grams of fat. Durian seeds are not consumed raw because they contain cyclopropene fatty acids, which are toxic to the body (MISRAH, 2020). This compound can be reduced by boiling or burning (NDRURU, 2022). According to Amir; Saleh (2014), durian seeds contain secondary metabolites, namely alkaloids, phenolics, flavonoids, and triterpenoids, and show antioxidant activity in ethanol extracts of durian seeds. The utilization of durian seeds has the potential to produce flour, starch, protein, and oil through extraction processes, thereby adding value and enabling their use as raw materials in various food and non-food products.

Durian seeds contain odorless and tasteless mucilage that is soluble in both cold and hot water, with its main components being phospholipids, proteins, carbohydrates, and water. Durian seeds also contain water-soluble polysaccharides that have hydrocolloid properties and are widely used as alternative food ingredients (WULANDARI, 2014). According to Amin; Arsad (2009), durian seeds have great potential as a new source that can be used in the food industry because of their high dietary fiber content, low fat content, and suitability as a dough thickener. Durian seeds also contain gum that has a higher water-binding capacity, so that they can be used as a potential source of dietary fiber. Durian seeds are also used as a low-cost source of hydrocolloids (compounds that can form gels) in various types of food.

The starch content of durian seeds can be utilized in various non-food products and has been proven by several studies, such as the use of durian seed starch as a raw material for bioplastics (Nur et al., 2020), maltodextrin production (Satmah et al., 2021), and biodegradable plastic from durian seed starch (HAMZAH, 2020). The protein contained in durian seeds (lectin), as studied by Sari (2019), affects fungal growth. The study explains that lectin protein functions as an antimicrobial protein and that a 100% lectin concentration is most effective in inhibiting *Candida albicans* fungi. In addition to carbohydrates and proteins, durian seeds also contain oils with 38.8% oleic acid, 5.9% linoleic acid, and 3% α-linoleic acid (FEBRIANTY et al., 2020). In the study by Febrianty et al. (2020), the oil needed as a skin moisturizer is oil that contains linoleic acid and oleic acid. This is because these acids are the main components of ceramides that adhere to the stratum corneum. This oil content has the potential to be used in the manufacture of beauty products such as lotions.

The high carbohydrate content in durian seeds can also be used in the production of flour as a raw material for food processing. Durian seed flour contains 22.48% fiber, which is a type of carbohydrate that cannot be digested in the upper digestive system (ROSAHDI et al., 2022). This allows the fiber to reach the large intestine intact, making it a potential prebiotic (SIGIRO et al., 2020). Several studies have utilized the carbohydrate content in durian seeds in various ways, such as in dried foods like chips (Djaeni; Prasetyaningrum, 2010), ice cream stabilizers (Sistanto et al., 2017), bread making (Nathanael, 2016), biscuit making (Verawati; Nopri, 2019), and beef sausage fillers (APRIANTINI et al., 2021). Based on this description, this research was conducted to determine the characteristics of starch, protein, and oil from durian seeds from West Sumatra.

2. MATERIAL AND METHODS

2.1. Materials and Tools

The raw material used in this study was durian seeds from the Pesisir Selatan, West Sumatra. Other materials used were lime, ethanol, acetone, n-hexane, sodium metabisulfite, H_2SO_4, NaOH, mm:mb indicator, boric acid, HCl, Kjedhal tablets, alpha amylase enzyme, distilled water, pepsin enzyme, beta amylase enzyme, vegetable oil, CH3COOH, iodine solution, ethanol, chloroform, HPLC hexane, and sodium thiosulfate.

The tools used in this study were knives, digital scales, blenders, filter cloths, ovens, containers, 80 mesh sieve, pH meter, grinder, vacuum filter, 47 mm membrane filter, Sokhlet, desiccator, dish, food dehydrator, colorimeter, SEM microscope, centrifuge tube, vortex, centrifuge, RVA canister, test tube, water bath, 100 mL measuring flask, UV-Vis spectrophotometer, Kjeldahl flask, destruction apparatus, dropper pipette, Wattman paper, Erlenmeyer flask, measuring cup, beaker, pH meter, GC-MS, Ultrasonic Assisted Extraction, DSC 4000 Perkin Elmer, rotary evaporator, and LC-MS.

The research was conducted using descriptive methods, and the data will be presented in quantitative form in the form of numbers, graphs, and images.

2.2. Sampling techniques

The durian seed samples were peeled, cut into small pieces 2 cm thick using a knife, then soaked in lime for 12 hours to remove the mucilage, washed thoroughly until free of mucilage, and weighed.

The process of extracting starch from durian seeds in this study refers to the method developed by Rozhikin et al. (2020) with several modifications. Durian seeds were weighed at 100 g with the addition of 500 g of water and ground using a blender. The material was squeezed using a filter cloth. The filtered suspension was then left to settle for 1-2 days. The sediment was collected and dried in an oven at 50 ℃ for 6 hours. The dried starch sediment was ground using a blender and then sieved using an 80-mesh sieve.

The protein extraction process from durian seeds in this study refers to a modified method from Adhibuana et al. (2018). Durian seeds were dried in a food dehydrator at 50℃ for 2 hours. Next, the durian seeds were ground using a grinder. The durian seed powder was soaked in 50% ethanol at a ratio of 1:5 (w/v) and then shaken for 3 hours. It was centrifuged at a speed of 8000 rpm for 15 minutes. The supernatant was collected in a beaker, then acetone was added at a ratio of 1:1 (v/v). It was left to stand for 5 hours until a precipitate formed. The precipitate was separated using a vacuum filter.

Next, the process of extracting oil from durian seeds in this study refers to the method of Djamaludin; Anies (2021) with several modifications. A total of 100 g of durian seed powder was placed in an Erlenmeyer flask, and n-hexane solvent was added at a ratio of 1:3 (w/v). The sample was placed in a sonicator for extraction for 45 minutes at a wavelength of 33 kHz at room temperature. The sample was macerated for 12 hours at 50°C. After the extraction process

was complete, the sample was centrifuged for 15 minutes at a speed of 4000 rpm. Next, the extraction results were filtered using filter paper to separate them from the resulting residue. The filtered results were then separated using a rotary evaporator.

The process of processing flour from durian seeds in this stage refers to a modified method from Ryan (2016). Durian seeds are sorted, washed, and boiled at a temperature of 80°C for 30 minutes. Next, the durian seeds that have had their skins removed are sliced to a thickness of 3 mm. The seeds are washed with water, then soaked in 0.6% sodium metabisulfite for 80 minutes and rewashed with water. The durian seeds are dried in a food dehydrator at a temperature of 50°C for 17 hours. The dried durian seeds are then ground using a blender and sifted using an 80-mesh sieve.

In this study, several analytical observations were made on the characteristics and yields of starch, oil, protein, and flour in local durian seeds. The observations on flour characteristics included analysis of moisture content, ash content, protein content, whiteness, water absorption, and sulfite residue. Observations on starch characteristics included whiteness, starch granule shape, water absorption, oil absorption, amylographic properties of starch, amylose and amylopectin content, and thermal property measurements. Observations on durian seed protein characteristics included protein content and amino acid analysis using the LC-MS method. Observations on oil characteristics included FFA number and fatty acid analysis using the GC-MS method.

3. RESULTS

3.1. Yield

Yield is an important parameter used to determine the efficiency of extracting or isolating a component from raw materials. In this study, the yields analyzed included the yields of starch, flour, oil, and protein isolated from durian seeds. Each component had a different yield value, depending on the characteristics of the material, the processing method, and the extraction technique used. The yield results can be seen in Table 1.

Table 1. Yield of flour, starch, protein, and oil from durian seeds.
Tabela 1. Rendimento de farinha, amido, proteína e óleo a partir de sementes de durião.

Rendemen	(%)
Flour	38,50
Starch	9,42
Protein	0,16
Oil	0,25

3.2. Chemical and functional analysis of durian seed starch

The analysis of the chemical and functional properties of durian seed starch aims to evaluate its characteristics and potential for use in various applications, both in the food and non-food sectors. The chemical properties analysis includes amylose and amylopectin content. The functional properties analysis includes whiteness, color, water absorption, oil absorption, and granule shape and size. The results of the chemical and functional properties analysis can be seen in Table 2. Starch granules can be observed under a microscope due to the presence of birefringence. The briefrigence effect on starch granules is indicated by the presence of cross sections or black and white colors on the granules. Briefrigence is a property of starch granules that can reflect polarized light so that, under a polarizing microscope, it forms blue and yellow or black and white fields. The results of observing the shape and size of durian seed starch granules using a SEM microscope can be seen in Figure 1.

Table 2. Chemical and functional properties of durian seed starch.
Tabela 2. Propriedades químicas e funcionais do amido da semente de durião.

Analysis	Mean±SD
Degree of Whiteness (%)	89,85 ± 0,53
Color (°Hue)	267,40 ± 2,01
Water Absorption Capacity (mL g^{-1})	2,11 ± 0,36
Oil Absorption Capacity (mL g^{-1})	2,91 ± 0,10
Amylose content (%)	18,17 ± 1,23
Amylopectin Content (%)	81,83 ± 1,23

Note: SD = standard deviation.
Nota: DP = desvio padrão.

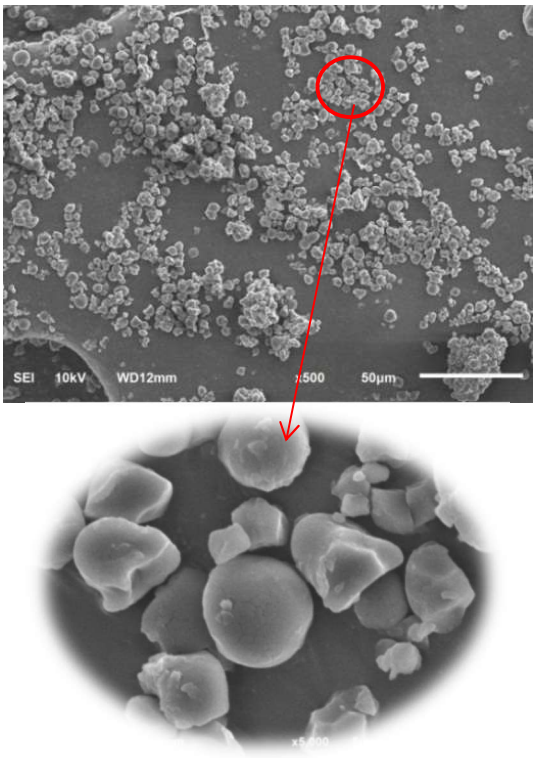

Figure 1. Shape and size of starch granules (500x and 5000x magnification).
Figura 1. Forma e tamanho dos grânulos de amido (ampliações de 500x e 5000x).

To determine the amylographic characteristics of the starch produced, testing using a Rapid Visco Analyzer (RVA) is required. This test is important because amylographic parameters, such as gelatinization temperature, maximum viscosity, viscosity during holding, and final viscosity, provide an overview of the thermal and functional behavior of starch during the heating and cooling process. RVA can be used to measure the dynamic viscosity of materials and provide information about changes in starch structure during heating. In addition, this tool can also help in studying the ability of starch to form a paste, which is important in determining its applicability in various food products. The results of amylographic measurements using RVA can be seen in Table 3.

Table 3. Pasting properties of durian seed starch.
Tabela 3. Propriedades de gelatinização do amido da semente de durião.

Pasting properties	Durian seed cake
Peak (cP)	3059,5 ± 1496,55
Trough (cP)	2335 ± 84,85
Breakdown (cP)	724,5 ± 143,54
Final Visc (cP)	3347,5 ± 195,87
Setback (cP)	1012,5 ± 280,72
Peak Time (min)	6,05 ± 0,35
Pasting Temperature (^{0}C)	83,55 ± 1,13

The paste curve properties of durian seed starch can be seen in Figure 2. In addition to the RVA test, thermal analysis is also needed to examine the characteristics of durian seed starch thoroughly. Thermal testing provides important information about physical changes that occur in starch during the heating and cooling processes, such as gelatinization, retrogradation, and thermal degradation. By conducting thermal testing, we can gain a deeper understanding of the thermal stability and critical temperatures that affect the functional properties of the starch. Thermal analysis is a term used to analyze the time and temperature at which physical changes occur when a substance is heated or cooled. Measurements of the thermal properties of durian seed starch can be seen in Table 4, and the DSC curve of durian seed starch can be seen in Figure 3.

Table 4. Thermal properties of durian seed starch.
Tabela 4. Propriedades térmicas do amido da semente de durião.

Variable	Gelatinization	Degradation
T_0 (^{0}C)	65.17	297.55
T_P (^{0}C)	108.81	312.96
T_C (^{0}C)	147.95	334.97
ΔH (J/g)	281.04	-28.03
Area Size (mJ)	4609.20	-459.72

Explanation: T0 = Initial temperature, TP = Peak temperature, TC = Final temperature, ΔT = Transition temperature, ΔH = Enthalpy.
Explicação: T0 = Temperatura inicial, TP = Temperatura máxima, TC = Temperatura final, ΔT = Temperatura de transição, ΔH = Entalpia.

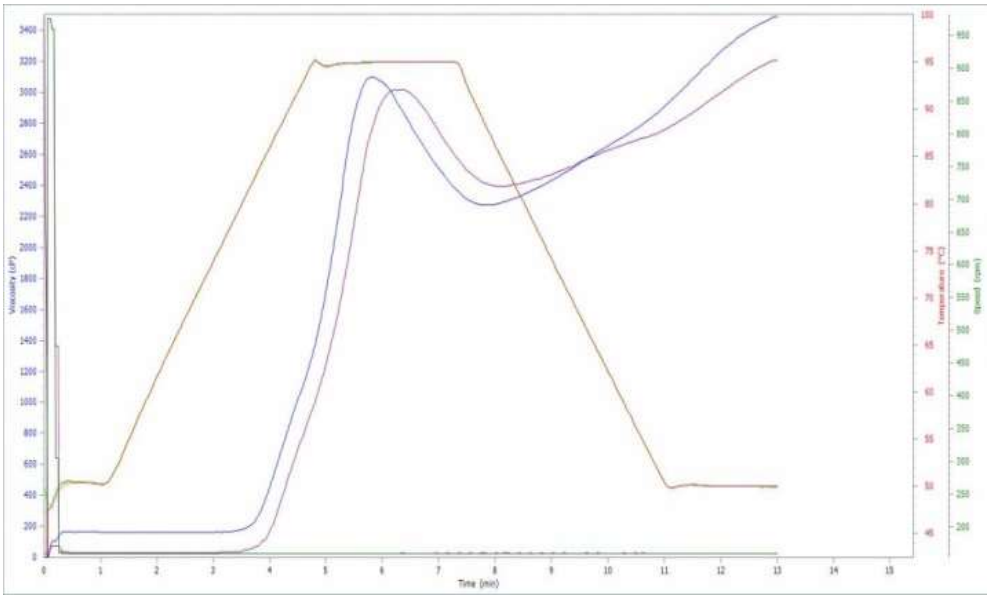

Figure 2. RVA curve of durian seed starch.
Figura 2. Curva RVA do amido da semente de durião.

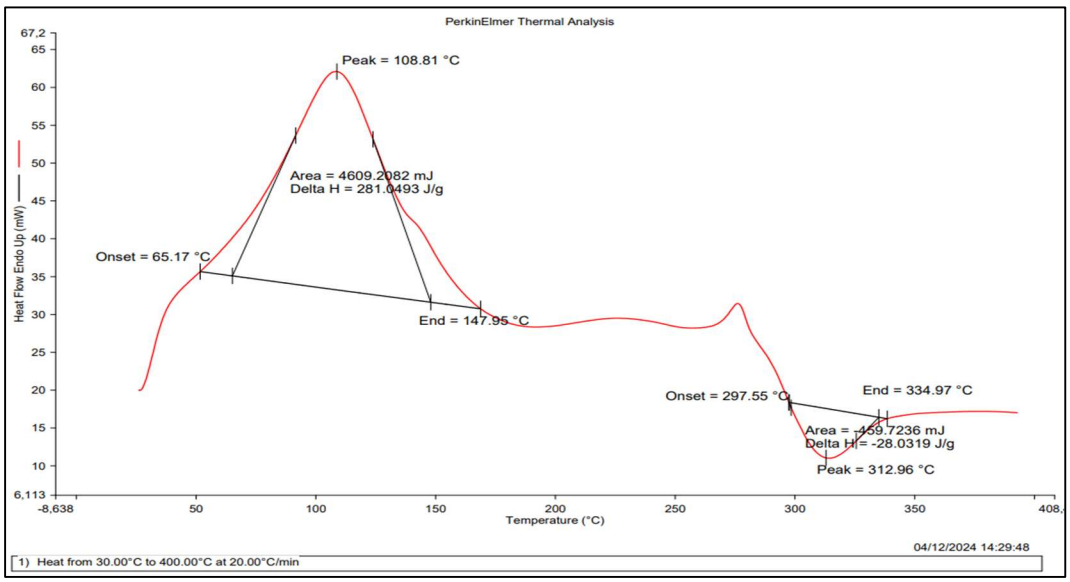

Figure 3. DSC curve of durian seed starch.
Figura 3. Curva de DSC do amido da semente de durião.

3.3. Protein Analysis of Durian Seeds

The protein content of the extracted durian seeds was analyzed. This analysis aimed to determine the protein content of the extracted durian seeds and to confirm whether the product was pure protein or protein concentrate. The results showed that the protein content obtained from the extraction was 72.30%. On the other hand, amino acid profile analysis was also performed on the extracted durian seed protein. This analysis aimed to determine the amino acid content in the sample.

Amino acid profile analysis using LC-MS showed the presence of various amino acids that were successfully identified in the sample. The LC-MS method provided accurate information about the presence, type, and concentration of amino acids based on retention time and peak intensity. The LC-MS results data in the form of a chromatogram can be seen in Figure 4. Table 5 shows the data from the amino acid composition analysis of durian seed protein concentrate using LC MS chromatography can be seen in Table 5.

Table 5. Amino acid composition of durian seed protein.
Tabela 5. Composição de aminoácidos da proteína da semente de durião.

Types of Amino Acids	Compound Name	%
Non-Essential Amino Acids	Tyrosine	2,27
Essential Amino Acids	Valine	2,12
	Isoleucine/Leucine	52,86
	Phenylalanine	32,98
	Threonine	6,07
	Tryptophan	3,70

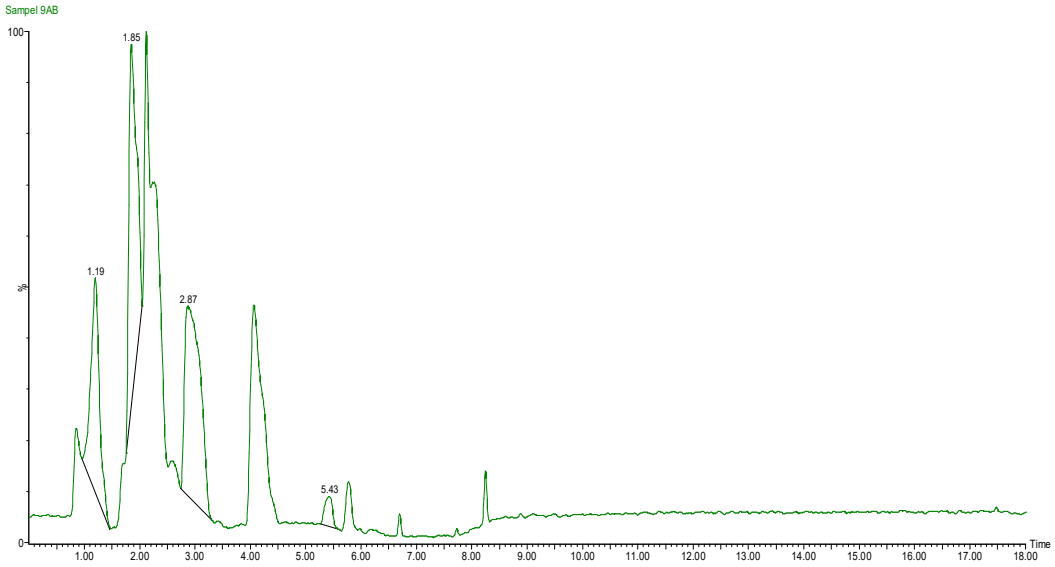

Figure 4. LC-MS chromatogram of amino acid components in durian seed protein concentrate.
Figura 4. Cromatograma LC-MS dos componentes de aminoácidos no concentrado de proteína da semente de durião.

3.4. Durian Seed Oil Analysis

Free fatty acids (FFAs) are an important parameter in assessing the quality of oil or lipids in food ingredients. High FFA levels indicate triglyceride degradation due to hydrolysis, which is generally triggered by enzymatic activity or chemical reactions during storage and processing. In this study, the FFA content in durian seed oil was found to be 1.53%, indicating the occurrence of lipid hydrolysis during the extraction or storage stages.

Fatty acids are part of fat molecules that can function as components of body fat or can also be used as energy producers. Fatty acids can be divided into two groups based on chemical bonds, namely saturated fatty acids and unsaturated fatty acids. To determine the types of fatty acids contained in oil, an analysis is carried out using the Gas Chromatography-Mass Spectrometry (GC-MS) method. GC-MS analysis aims to determine the profile and content of fatty acids found in durian seed oil. The GC-MS chromatogram of fatty acid components in durian seed oil can be seen in Figure 5.

The data from the fatty acid composition analysis of durian seed oil using GC-MS chromatography can be seen in Table 6.

Table 6. Fatty acid composition of durian seed oil.
Tabela 6. Composição de ácidos graxos do óleo de semente de durião.

Types of Fatty Acids	Systematic Name	Retention Time	%
Saturated Fatty Acids	n-Hexadecanoic Acid	12.986	30.38
	9,12-Octadecadienoic acid (Z,Z)-	14.653	12.71
	Octadecanoic acid	15.334	1.7
	Hexadecanoic acid, methyl ester	12.625	1.21
Unsaturated Fatty Acids	9,12,15-Octadecatrienoic acid, (Z,Z,Z)-	15.118	19,77
	9-Octadecynoic acid	16.208	11.78
	9(E),11(E)-Conjugated linoleic acid	14.998	11.27

3.5 Analysis of Durian Seed Flour

In the analysis of durian seed flour, physical and chemical property tests were conducted to understand the characteristics of the material comprehensively. Physical analysis is a testing method that evaluates the physical and mechanical characteristics of a material or product. This analysis can observe physical changes or appearances of a

material, namely, durian seed flour. The physical analysis of durian seed flour includes color and degree of whiteness. The results of the color and degree of whiteness tests can be seen in Table 7.

Table 7. Color and degree of whiteness of durian seed flour.
Tabela 7. Cor e grau de brancura da farinha de semente de durião.

Analysis	Mean ± SD
Color (°Hue)	101,03±1,30
Degree of Whiteness (%)	87,59±0,48

Note: SD = Standard Deviation.
Nota: DP = Desvio Padrão.

Chemical analysis is a process of measuring or observing the chemical properties of a substance after a chemical change related to its ability to react or undergo specific changes. The chemical analysis conducted includes moisture content, ash content, protein content, and sulfite residue. The results of the analysis can be seen in Table 8.

Table 8. Moisture Content, ash content, protein content, and sulfite residue of durian seed flour.
Tabela 8. Teor de umidade, teor de cinzas, teor de proteína e teor de resíduo de sulfito da farinha de semente de durião.

Analisis	Mean ± SD
Moisture Content (%)	9,33 ± 0,94
Ash Content (%)	2,67 ± 0,47
Protein Content (%)	4,91 ± 0,49
Sulfite Residue (ppm)	58,05 ± 0,55

Note: SD = Standard Deviation.
Nota: DP = Desvio Padrão.

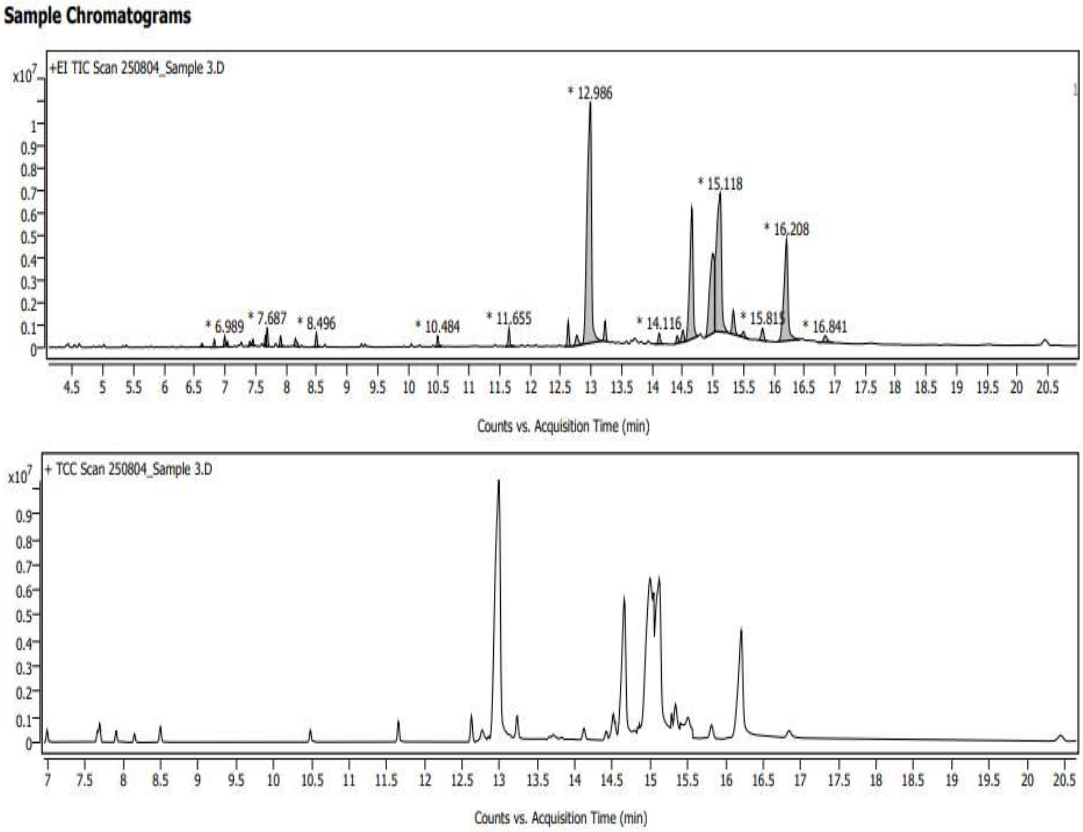

Figure 5. GC-MS chromatogram of fatty acid components in durian seed oil.
Figura 5. Cromatograma GC-MS dos componentes de ácidos graxos no óleo de semente de durião.

4. DISCUSSION

4.1. Yield

One of the quality parameters of the extract is the yield of the extract produced. Yield is the percentage of product obtained by comparing the final weight of the material with its initial weight. Yield is expressed as a percentage (%), and the higher the yield value, the greater the value of the extract produced (WIJAYA et al., 2018). This study calculated the yield of flour, starch, protein, and oil extracts from durian seeds.

The yield of durian seed flour was 38.50%. This result is higher than that obtained in Ryan (2016) study, which was 21.22% - 24.37%. Several factors, such as processing methods, drying levels, particle size, and extraction process efficiency, influence this yield value. This is in line with Widya (2003) statement that, overall, low yield values are caused by weight loss due to water loss during heating. Durian seeds also have the potential to be used as an alternative food ingredient due to their high carbohydrate content. With a carbohydrate content of 46.2 g per 100 g of seeds, durian seed flour can be used in various food products, such as dodol, or as a substitute in the manufacture of bread and noodles. The process of processing durian seeds into flour not only increases nutritional value but also provides economic opportunities for the community by utilizing durian seed waste. Based on Table 1, it can be seen that the analysis results show a durian seed starch yield of 9.42%. The results obtained in this study are lower than those of Nur et al. (2020), which were 12.84%. The yield obtained is influenced by the extraction method. An optimal process will produce maximum yield. Yield is determined based on the percentage of starch weight produced relative to the weight of the raw

material. Factors that influence yield include the extraction method, type of solvent, temperature, and extraction time.

Protein concentrate yield is influenced by the isolation method used, such as precipitation, centrifugation, and drying processes. In this study, the use of the precipitation method with ethanol solvent and acetone precipitation resulted in a yield of 0.16%. This figure shows that the protein content of durian seeds is still lower than that of several other protein sources. The main factors that affect protein concentrate yield include temperature, extraction time, and the type of solvent used.

In addition, the precipitation method used may not be efficient enough to precipitate most of the protein contained in the material. The low protein concentrate yield indicates that durian seeds may not be suitable as a primary source of protein when compared to other materials. However, added value can be increased by combining this material with other protein sources and improving the extraction method. Low yield indicates the need for further research to optimize the isolation process, such as using solvents or enzymes that are more specific to durian seed protein, as well as considering additional purification techniques to improve efficiency.

Based on Table 1, the yield of durian seed oil was 0.25%. This result is lower than the yield of other seed oils. This is because the fat content in durian seeds is very low, at 0.2 g. The low-fat content in durian seeds results in a low oil yield. The yield is also influenced by the extraction method and the type of solvent used. The properties of the solvent influence solvent extraction, the particle size of the material, the solvent-solid ratio, the extraction temperature, and the extraction time (FAJRI; YOSAPHAT, 2022). Oil extraction from durian seeds uses an ultrasonic device with n-hexane as the solvent. The use of n-hexane as a solvent is due to the nonpolar nature of the oil to be extracted from durian seed powder, which requires a nonpolar solvent such as n-hexane (SALIMI et al., 2019).

With the help of ultrasound, the process of extracting organic compounds from plants and grains using n-hexane solvent can take place more quickly. The cell walls of the material are broken down by ultrasonic vibrations so that the contents can be easily extracted (FARIHA; HARDJONO, 2023). Thus, durian seeds have the potential as a source of raw material for oil products, but further research is needed to determine the most efficient extraction method and achievable yield.

4.2. Chemical and Functional Analysis of Durian Seed Starch

The degree of whiteness is one of the test parameters for starch characteristics. The results of the study showed that the degree of whiteness of durian seed starch obtained was 89.85%. The degree of whiteness is the ability of a material to reflect light against the light that hits its surface. This value reflects that the isolated starch has a relatively high level of brightness, indicating good starch purity. The results obtained in this study are higher than those obtained by Jufri et al. (2006), who obtained a whiteness degree of durian seed starch of 71.23% in the form of brownish-white powder. In this study, the starch was in the form of a reddish-white powder. The high whiteness value may be influenced by an effective isolation process that removes pigments, phenolic compounds, or other impurities, resulting in starch with a visual quality suitable for industrial food and pharmaceutical applications.

The Hunter system can be used to determine the color of flour in this study. In the Hunter system, there are three parameters, namely L*, a*, and b*. The notation L* indicates the reflected light that produces white, gray, and black colors. The notation a* indicates the chromatic value of red (positive value) and green (negative value). The notation b* indicates the chromatic color yellow (positive value) and blue (negative value). Meanwhile, croma indicates color intensity, and °Hue indicates the proportion of color contained in the material.

Based on Table 2, the °Hue value of starch obtained was 267.40 with a blue color category. Although the starch appears reddish-white, it has a blue color proportion. This is due to the high amylopectin content in starch, which can affect the °Hue value to become blue, as well as the influence of light reflection from the Hunter Color device, such as its ability to absorb low wavelengths.

Water absorption is the ability of a material to absorb water. Water absorption indicates the extent to which a material can attract water from its surroundings to bond with the material's particles (NUR et al., 2020). Water absorption needs to be determined in order to establish the physicochemical characteristics of starch, particularly in its application in food and non-food products. The water absorption capacity obtained was 2.11 mL g^{-1}. This may be due to the molecular structure of starch, which consists of amylose and amylopectin chains, both of which affect water retention capacity. Water absorption capacity is also influenced by the presence of hydrophilic groups that interact with water through hydrogen bonds. Other factors contributing to water absorption are the size of the starch granules and their porosity. In durian seed starch, smaller granules tend to have a larger surface area, facilitating interaction with water molecules. In addition, the presence of protein or lipid content bound to starch granules can also affect the hydrophobic or hydrophilic properties of starch.

Oil absorption capacity is the ability of a material to absorb oil. Oil absorption capacity is the physical ability of starch to absorb and retain oil through capillary attraction into the material, which is very important as oil acts as a flavor enhancer and also improves mouth feel in food (DINIYAH et al., 2018). The result obtained was 2.91 mL g^{-1}, where each 1 g of starch was able to absorb 2.91 mL of oil. This shows that starch has a granular structure with microporosity that plays an important role in oil absorption. Starch has hydrophobic properties where oil sticks to the surface of the starch granules and then enters the pores of the granules through diffusion. The surface area of starch depends on the size of the starch obtained; finely ground starch has a larger surface area, thereby increasing oil absorption capacity. Thus, durian seed starch has excellent potential as an oil absorbent and opportunities for utilizing natural materials in the food, pharmaceutical, or other industries as absorbents, thickeners, or emulsifiers.

The shape and size of durian seed starch granules were also observed using an SEM microscope. The results showed that durian seed starch granules were round or oval with a smooth surface and irregular shapes with magnifications of 50 μm and 5 μm. These granules varied in shape and size depending on the starch source. The physical form of starch grains is semi-crystalline, consisting of crystalline and amorphous units (MARYAM et al., 2016). According to Belitz; Grosch (1999), the arrangement and structure of amylose and amylopectin molecules in starch granules are specific to each starch source, which determines the shape

and size of the granules. The mostly straight amylose structure is found in the amorphous part of the starch granule, with a small portion forming the crystalline part of the starch.

Meanwhile, amylopectin molecules play a significant role in forming the crystalline part of the starch. This round or oval shape generally indicates an even distribution of pressure on the granule structure, which can affect the mechanical and thermal properties of starch. There is no clear relationship between gelatinization and the shape of starch granules, but the gelatinization temperature is related to granule compactness, amylose content, and amylopectin content.

The amylose content is one of the important parameters in starch characterization, as it affects functional properties such as gel-forming ability, water absorption, and resistance to retrogradation. Based on the results of the analysis, the amylose content obtained was 18.17% and the amylopectin content was 81.83%. The amylopectin content was calculated based on the difference between the total starch and amylose contents. The purpose of analyzing the amylose and amylopectin contents was to determine the amount of soluble and insoluble fractions in durian seed starch. The results obtained were lower than those of Nur et al. (2020), who obtained a result of 28.49%. In this study, the amylose content in durian seed starch was classified as moderate, ranging from 15% to 20%. The amylose content also varied between varieties and was influenced by genetic factors, the environmental conditions in which the durian grew, and the starch isolation method used. Lower amylose content can increase starch development and gel strength. The amylose content in starch provides strength to the plastic matrix, while amylopectin provides elastic plastic properties (ROZIKHIN et al., 2020). Thus, durian seed starch has the potential to be used in various industrial applications, including as a binding agent in pharmaceutical formulations and edible film manufacturing. Variations in amylose content indicate that extraction methods and growth conditions can influence the chemical composition of this starch.

The amylographic properties of starch describe its viscosity characteristics during heating and cooling, which are closely related to the gelatinization and retrogradation of starch. The gelatinization pattern shows changes in starch viscosity during processing at high temperatures and when the temperature is lowered. This can be used as a way to predict how the functional characteristics of starch and its application in food products will be optimized. Pasting temperature is the initial temperature at which gelatinization occurs. Peak viscosity is the peak viscosity when the starch is gelatinized. Hold viscosity is the viscosity when the heating temperature is maintained for several minutes. Final viscosity is the viscosity value of the starch paste after the cooling stage. Breakdown is the value obtained at the holding stage, where the heating temperature is maintained to determine the stability of the starch paste during the heating process. Viscosity setback is the change in viscosity value during the cooling process. A low setback value indicates a low tendency for retrogradation and syneresis.

The gelatinization process has several stages. In the first stage, starch in cold water absorbs water, which is a reversible process. In the second stage, due to the heat applied, the hydrogen bonds between amylose and amylopectin in the starch granules begin to break, while the kinetic energy of the water molecules increases and becomes stronger than the attractive force between the amylose and amylopectin molecules, allowing water to enter the starch granules and causing them to expand. This process of water absorption into the starch granules is irreversible. In this second stage, the starch granules swell, causing a significant increase in the viscosity of the starch paste until it reaches its maximum viscosity, or peak viscosity. Measurements using RVA show that the peak viscosity of durian seed starch paste is 3059.5 ± 1496.55 cP. Peak viscosity indicates the ability of starch granules to bind water and maintain swelling during heating. The third stage of gelatinization involves further expansion of the granules, reaching maximum expansion until the granules break and cause the amylose and a small amount of amylopectin to diffuse out of the granules and disperse into the solution. The breakdown of starch granules causes a decrease in the viscosity of the starch paste. This occurs when the heating temperature of the starch paste is maintained at 95 °C for 150 seconds, causing the viscosity to decrease to 2335 ± 84.85 cP, which is called Hold/Through Viscosity. This sharp decrease indicates that durian seed starch granules are less resistant and less stable to the heating process. The difference between the peak viscosity and hold viscosity values is the breakdown viscosity value. RVA measurements showed that the breakdown value of durian seed starch paste was 724.5 ± 143.54 cP. The breakdown viscosity value indicates stability in high-temperature paste. The higher the breakdown viscosity value, the more unstable it is in high-temperature processing (MAULANI et al., 2016). When the temperature was lowered after being maintained at 95℃,, the RVA measurement results showed that the viscosity of the starch paste increased to 3347.5 ± 195.87 cP, which is called the final viscosity. This increase in viscosity was caused by the reformation of hydrogen bonds between amylose and amylopectin. Final viscosity indicates the ability of starch to form a thick paste or gel after heating and cooling. The change in viscosity during the cooling process is called setback, with a value of 1012.5 ± 280.72 cP. This setback value indicates the ability of the starch paste to undergo retrogradation, which is the process of reforming the starch matrix that has undergone gelatinization. Amylose molecules will rebind to each other with amylopectin branches outside the granules after the paste is cooled.

From the results of the RVA analysis of durian seed starch above, the gelatinization profile type can be determined. Based on the viscosity pattern of the paste, the gelatinization profile of starch can be classified into four types, namely type A with high peak viscosity followed by a considerable breakdown viscosity value, type B with moderate expansion ability as indicated by a lower peak viscosity compared to the final viscosity, and type C with low to moderate peak viscosity and a small breakdown viscosity value. Therefore, the gelatinization profile of durian seed starch can be classified as type C, as indicated by a high peak viscosity of 3059.5 ± 1496.55 cP and a low breakdown viscosity of 724.5 ± 143.54 cP. Type C starch exhibits excellent thermal and mechanical stability. These properties make type C starch ideal for products requiring stability, such as baby food, canned sauces, or products processed with extensive heating and stirring.

The thermal properties of durian seed starch were analyzed to determine the gelatinization characteristics that reflect the stability and strength of the starch granule structure against heating. Thermal testing can be observed using differential scanning calorimetry (DSC). The basic principle of DSC testing is that when a sample undergoes

physical changes, such as phase transitions, changes in heat flow between the reference and the sample are required to keep their temperatures the same. This process can be exothermic or endothermic, depending on whether more or less heat enters the sample. For example, when a solid sample transitions to a liquid, more heat is required because the energy entering the sample is absorbed to increase its temperature to that of the reference, making the process endothermic because it requires much heat. Conversely, exothermic processes involve the release of heat energy from the sample.

In starch, endothermic processes can be said to involve gelatinization, while exothermic processes may indicate retrogradation or degradation. Wang; Copeland (2013) explain that the temperature at which starch granules begin to lose their polarization properties is called the initial change temperature (T0), the state at which starch reaches its maximum temperature (Tp), and the point at which 98% of the polarization of starch granules is lost is called the final temperature (TC). In the gelatinization process, the initial temperature represents the temperature at which the initial structural changes, indicating gelatinization, begin to occur in starch. This is where the sample begins to show significant thermal effects. It marks the point at which water molecules first penetrate the amorphous region of the starch granules, initiating disruption of the crystal structure. Tp indicates the temperature at which starch gelatinization reaches its maximum rate, signifying the most active phase of the gelatinization process. Knowledge of Tp is essential for optimizing processing conditions to achieve desired product characteristics such as texture, viscosity, and stability. Tc indicates the temperature at which the gelatinization process is essentially complete, at which point the thermal effects of the sample cease (ZENG et al., 2015). In starch gelatinization, the enthalpy value indicates the energy requirement of starch during gelatinization, reflecting the loss of molecular order. The area value and ΔH are directly proportional; the larger the area, the greater the ΔH value.

Figure 3 shows that the starch curve of durian seeds exhibits endothermic behavior at the first peak and exothermic behavior at the second peak. The endothermic peak is associated with the melting of amylopectin crystals. The curve shows the initial gelatinization temperature of durian seed starch at 65.17 °C, with a peak temperature of 108.81 °C and a final temperature of 147.95 °C. The enthalpy value is the energy requirement of starch during the gelatinization process, with an enthalpy value of 281.04 J/g. The amylose content is directly proportional to the gelatinization temperature. A higher initial gelatinization temperature indicates a higher amylose content in the starch. This may be due to the presence of longer double helices in amylose, possibly formed by elongated amylose-amylase, amylose-lipid, and amylopectin chains, resulting in a higher melting temperature (ALONSO et al., 2016).

At the second peak, an exothermic process occurs, namely thermal degradation, which begins at an initial temperature of 297.55 °C, with a peak temperature of 312.96 °C and a final temperature of 334.97 °C. This process involves the release of energy from the sample, marked by the breakdown of the starch structure into simpler compounds. Starch consists of two main polymers, namely amylose (straight chain) and amylopectin (branched chain). At high temperatures, these chains begin to degrade through a depolymerization process, producing molecules with lower molecular weights. Therefore, from the results of the thermal property measurements, it can be concluded that durian seed starch undergoes two thermal processes during heating: heat energy absorption through gelatinization at a temperature of 65.17 °C and, at a higher temperature of 297.55 °C, degradation begins to occur.

4.3. Protein Analysis of Durian Seeds

The results of the study show that the protein content obtained from protein extraction was 72.30%. This value indicates that the extraction results obtained are classified as protein concentrate. An isolated protein is pure protein from extraction with a minimum protein content of 90%. In this study, the protein content was found to be below 90%, which is classified as a protein concentrate. This is due to the extraction process, which also extracts other compounds such as flavonoids, carbohydrates, and fats. Although the protein content of durian seeds is relatively low compared to other protein sources such as soybeans or nuts, their potential use in the food industry remains significant. With further processing, durian seeds can be used as an additive in food products to increase nutritional value and provide health benefits. Further research is needed to explore optimal processing methods and practical applications of durian seed protein concentrate in various food products.

LC-MS can detect the presence of amino acids in samples. In LC (chromatography), a mobile phase is used to carry the sample through a column containing a solid support and coated with a liquid as a stationary phase. The analyte is then partitioned between the mobile phase and the stationary phase, resulting in separation due to differences in partition coefficients. Based on Table 4, 6 amino acid compounds were detected by LC-MS. To determine the protein quality of durian seeds, the essential amino acid composition is compared with the 2013 FAO/WHO standard. This comparison aims to determine whether the protein from durian seeds can meet human nutritional needs or has limiting amino acids. This data is expressed as a percentage of total protein, so that when comparing it with the FAO standard, the value is converted into units of mg amino acid/g protein. The results of the analysis of the essential amino acid composition of durian seeds and their comparison with FAO standards can be seen in Table 8.

Table 8. Comparison of essential amino acid content in durian seeds with FAO standards.
Tabela 8. Comparação do teor de aminoácidos essenciais em sementes de durião com os padrões da FAO.

Essential Amino Acids	(%)	(mg/g protein)	FAO standards (mg/g protein)	LAA (Limiting Amino Acid Score)
Isoleucine/Leucine	52,86	528,6	91	5,81
Fenilalanin	32,98	329,8	41	8,04
Threonine	6,07	60,7	25	2,43
Triptofan	3,70	37,0	6,6	5,61
Valine	2,12	21,2	40	0,53

Several identified amino acids have dominant values, such as Isoleucine/Leucine with a value of 528.6 mg/g of protein, indicating a higher relative concentration compared to other amino acids and FAO standards. Isoleucine/Leucine are two different essential amino acids, but they have the same molecular formula and molecular weight (NURYANTO et al., 2023). These amino acids must be obtained through food in sufficient quantities to meet human needs. Isoleucine/leucine is found in high-protein foods such as meat, fish, milk, eggs, and nuts (RONDANELLI et al., 2021). Isoleucine deficiency can cause symptoms similar to hypoglycemia, such as fatigue, depression, and dizziness. Leucine is necessary for child development, as it helps regulate protein formation and breakdown, provides energy for muscles, and prevents muscle damage (NURYANTO et al., 2023).

Amino acids are divided into two types: essential amino acids and non-essential amino acids. Essential amino acids are amino acids that the human body cannot produce, while non-essential amino acids are amino acids that can be produced by the human body (NURYANTO et al., 2023). This study found six amino acids (5 essential amino acids and one non-essential amino acid). The essential amino acids found in this study are valine, isoleucine, leucine, phenylalanine, threonine, and tryptophan. Valine, leucine, and isoleucine are included in BCAA (Branched-Chain Amino Acids), which are amino acids that have a branched chemical structure and constitute almost 50% of the essential amino acids found in food and 35% of the essential amino acids in muscle protein (SOLICHAH, 2022). These amino acids are used in sports supplement products for muscle recovery, improving athletic performance, and reducing fatigue (FEDEWA et al., 2019).

The amino acid valine has the lowest content at 21.2 mg g^{-1} of protein, while the FAO standard for valine is 40 mg g^{-1} of protein. Valine is a branched-chain amino acid that functions as a glucogenic precursor. Valine is essential for muscle tissue growth and maintenance. Valine can also boost mental ability, improve muscle coordination, help repair damaged tissue, and maintain nitrogen balance (ABDULLAH et al., 2013). The amino acid phenylalanine has a value of 329.8 mg g^{-1} protein, far above the FAO standard of only 41 mg g^{-1} protein. Phenylalanine can be applied in low-calorie food and beverage products because phenylalanine is one of the components of aspartame, an artificial sweetener that provides sweetness without adding calories (MAGNUSON et al., 2007).

The amino acid threonine has a content of about 60,7 mg g^{-1} protein, which is also higher than the FAO standard of 25 mg g^{-1} protein. Threonine plays an important role in nutrition and health in protein synthesis, digestive health, and immune system support, and can be applied in livestock feed products (QAISRANI et al., 2018). The amino acid tryptophan is found in an amount of 37,0 mg g^{-1} protein, which is more than sufficient compared to the FAO standard of 6,6 mg g^{-1} protein.

Tryptophan plays a role in maintaining mood and mental health. This is because tryptophan functions as a precursor for the synthesis of serotonin, which is known as the happiness hormone in regulating mood and emotions (YOUNG, 2013). Tyrosine is a non-essential amino acid that has a phenolic group and is weakly acidic. Tyrosine has several benefits, including reducing stress, acting as an antidepressant, and detoxifying substances from opiates and cocaine (LALOPUA et al., 2022).

In the assessment of protein quality, amino acids with the lowest content compared to FAO standards are referred to as limiting amino acids. From this comparison, valine becomes the limiting amino acid in durian seeds, as its content is much lower than the FAO standard. Suppose a protein has a limiting amino acid content. In that case, the body cannot utilize that protein optimally, as protein synthesis in the body requires a balance between all essential amino acids. To improve the protein quality of durian seeds, it is recommended to consume them alongside protein sources that are rich in valine, such as legumes (soybeans, almonds), grains, fish, chicken, and meat. Thus, the amino acid content in durian seed protein concentrate has the potential to be an additional raw material for food products such as complementary foods, noodles, and crackers, and can be used as an alternative vegetable milk and for fermentation for functional food products.

4.4. Durian Seed Oil Analysis

In this study, the Free Fatty Acid (FFA) content found in durian seed oil was obtained at 1.53%. This value indicates the percentage of free fatty acids present in the oil as a result of triglyceride hydrolysis, which can occur during storage, processing, or due to enzymatic activity. The FFA level is an important parameter in assessing oil quality. The higher the FFA content, the more the oil quality declines because it indicates fat degradation. According to plant oil quality standards, a good FFA level is generally below 2%. Therefore, an FFA value of 1.53% is still within an acceptable range and indicates that the durian seed oil obtained has pretty good quality and is still suitable for use, both for consumption and industrial purposes.

However, the FFA levels can also be influenced by several factors, such as the condition of the raw materials, extraction methods, and storage time and temperature. Therefore, controlling the production and storage processes is very important to maintain the quality of the oil produced.

In this study, an analysis was conducted on the composition of fatty acids contained in durian seed oil. Fatty acids can be divided into two categories based on chemical bonds, namely saturated fatty acids and unsaturated fatty acids. Saturated fatty acids have higher boiling points compared to unsaturated fatty acids with the same chain length. Unsaturated fatty acids with a greater number of double bonds have a lower boiling point; thus, unsaturated fatty acids have lower viscosity and boiling points compared to saturated fatty acids with the same chain length (WINARNO, 2008).

This type of fatty acid provides unique characteristics compared to other fatty acids that typically have straight or branched carbon chains without a ring structure. To obtain information about the composition of these fatty acids, a Gas Chromatography-Mass Spectrometry (GC-MS) instrument was used, which is capable of accurately identifying and quantifying compounds based on their molecular mass and fragmentation patterns.

Based on Table 6, the results obtained show the fatty acid content of durian seed oil. This study shows that the highest fatty acid content in durian seed oil is saturated fatty acid (hexadecanoic acid) at 30.38% and unsaturated fatty acid (linoleic acid) at 19.77%, which is different from the findings

in the research by Febrianty et al. (2020) that emphasized oleic acid content at 38.8%, linoleic acid at 5.9%, and α-linolenic acid at 3% as the main components supporting the potential of the oil as a skin moisturizer. The results indicate variations in the fatty acid composition of durian seed oil. These differences may occur due to several factors, including the source of the material (durian seeds) coming from various varieties and different regions. The technique used in extracting durian seed oil can also influence the fatty acid profile produced.

Saturated fatty acids give oils a solid characteristic at room temperature, like coconut oil, because they have a higher melting point than unsaturated fatty acids. Hexadecanoic acid is a saturated fatty acid composed of 16 carbon atoms. Compounds of both saturated and unsaturated fatty acids with long chains in fatty acids consisting of C12-C22 have antimicrobial activity compared to fatty acids with less than 12 carbon atoms. Hexadecanoic acid is the most commonly encountered fatty acid, as it can be found in the human body and is also present in food or is an early product of endogenous biosynthesis from fatty acids, carbohydrates, and amino acids. Hexadecanoic acid compounds are derivatives of carboxylic acids that have antibacterial and antifungal properties.

Durian seed oil also contains unsaturated fatty acids, namely linoleic acid. Linoleic acid is an essential nutrient that has two double bonds at the ninth and twelfth carbon atoms in the carbonyl functional group structure. It is called an essential fatty acid because the body cannot produce it on its own (AUSI; BARLIANA, 2016). Linoleic acid is obtained from candlenut seeds, avocado seeds, dragon fruit, and walnut nuts (SOFIANA et al., 2024). Linoleic acid is metabolized through the lipoxygenase and cyclooxygenase pathways. Various types of these metabolites are essential in regulating inflammatory responses and the immune system. Linoleic acid has several benefits in the pharmaceutical field. One of them is an anti-inflammatory and antioxidant that can protect the skin from damage caused by free radicals and promote cell regeneration. In previous studies, linoleic acid has been shown to address various skin issues, which is why linoleic acid is widely formulated into cosmetic products (SOFIANA et al., 2024). On the other hand, oils with high unsaturated fatty acid content can also be applied to food products, one of which is shortening. Shortening products use vegetable oils that contain high unsaturated fatty acids, which require a hydrogenation process to convert the oil into a semi-solid or solid form (HASIBUAN, 2021).

4.5. Analysis of Durian Seed Flour

In Table 7, the °Hue value of durian seed flour is shown to be 101.03. The °Hue value indicates the type of color present in the flour. The resulting °Hue values will be categorized into the °Hue parameter, thus obtaining objective color data. Based on the °Hue values, the color of the flour obtained is yellow. Meanwhile, the visible color of the flour is a whitish-yellow. Although the flour appears to be whitish-yellow, it has a proportion of yellow color, influenced by the natural color of the durian seed cotyledons, which are whitish-yellow.

The whiteness degree of durian seed flour is one of the important parameters in assessing the quality of the produced flour. Based on the study conducted, durian seed flour has a whiteness value of 87.59%. The whiteness produced is also influenced by the soaking of sodium metabisulfite on durian seeds. Sodium metabisulfite can inhibit the browning reaction during the processing of durian seed flour. According to Prabasini (2013), soaking with sodium metabisulfite solution can prevent non-enzymatic browning reactions because the sulfite group in sodium metabisulfite bonds with the carbonyl group in the flour's sugar, preventing the formation of melanoidin compounds that cause brown coloration. In the research by Ryan (2016), it was proven that the treatment of soaking durian seeds in sodium metabisulfite resulted in a brighter color in the flour compared to durian seeds without the sodium metabisulfite soaking treatment. Durian seed flour is still below the brightness standard according to SNI 3751:2018, which has the color standard of typical white wheat flour. Therefore, further sample modifications are needed to produce a good color of durian seed flour with food additives that do not exceed the threshold, so that durian seed flour can become an indicator of quality and its potential use in various food industry applications.

Table 8 presents the results of the chemical analysis of durian seed flour. One of the parameters analyzed is water content, which is an important aspect in food materials because it affects quality, shelf life, and product stability. The water content of a material influences the shelf life of the food. The lower the water content of a material, the longer it will last. The result obtained in this study is 9.33%. The result is almost the same as the research by Ryan (2016), which ranged from 8.28% to 11.12%. The results obtained are influenced by the concentration of sodium metabisulfite, where the higher the concentration of sodium metabisulfite, the lower the moisture content. The low moisture content is due to sodium metabisulfite being able to damage the tissue of the material. According to Rahman; Penera (1999), in Herudiyanto (2007), the sulfitation process can cause the tissue cells in the material to become porous, thus accelerating the drying process. With this rapid drying, the moisture content of the material evaporates quickly. According to SNI standards, the moisture content for wheat flour (SNI 01-03751-2009) is a maximum of 14.5% (w/w), cassava flour (SNI 01-2397-1992) is a maximum of 12% (w/w), rice flour (SNI 3549-2009) is 13% (w/w), and corn flour (SNI 01-3727-1995) is 10% (w/w) (CHRISANDY, 2013). When compared to the moisture content standards of these flours, the moisture content in this durian seed flour is still within the SNI standard range.

The ash content of durian seed flour is one of the important parameters in analyzing the quality of this flour. The ash content indicates the amount of minerals and inorganic elements contained in the flour, which can affect the nutritional value and functionality of the product. Based on the research, it was found to be 2.67%. The result is higher than that of the research by Ryan (2016), which found it to be between 1.07% and 2.02%. A low ash content value indicates good flour quality, while a high ash content may indicate contamination or suboptimal purification processes. For comparison, the ash content of commercial wheat flour typically ranges from 0.6%, indicating that durian seed flour has a higher ash content. However, it is still acceptable for specific uses in food products. This value is also influenced by the soaking of sodium metabisulfite concentration on the durian seed, which affects the ash content of the resulting durian seed flour, where the higher the concentration of sodium metabisulfite, the lower the ash content will be. The higher the concentration of sodium metabisulfite, the more

damaged the cell tissue will be (more holes), resulting in more minerals diffusing out of the cells (PRABASINI et al., 2013). Determining the ash content is also important for evaluating the potential of durian seed flour in food applications or other industries.

Protein is an important nutrient for the body because it functions as a building and regulating substance within the body. Protein is also a source of amino acids. Based on the results in Table 8, the protein content of durian seed flour is 4.91%. In Ryan's (2016) study, the protein content of durian seed flour was found to be 2.22%-2.61%, which is lower than the obtained result. The protein content of durian seed flour is lower compared to raw durian seeds due to several factors related to the processing and composition of the materials. Protein may be damaged, and its quantity may be reduced during food processing. The decrease in protein quantity depends on the processing method used. Factors affecting the reduction of protein quantity include temperature, which causes protein denaturation, and water, which leads to the loss of soluble protein (SETYANINGSIH, 2010). In the production of durian seed flour, the seeds undergo boiling and drying stages to eliminate the cyclopropene fatty acid compounds that contain toxins. This stage causes the protein content in durian seeds to undergo denaturation, which reduces the availability of protein in the form of flour.

Sulfites in food can act as both a preservative and a bleaching agent. As a preservative, sulfites will damage the cell walls of microbes, causing them to lose their cell permeability and eventually die. As a bleaching agent, sulfites can make food products whiter by inactivating the enzyme polyphenoloxidase, which is responsible for browning reactions. The result obtained in this study was 58.05 ppm. This value is still below the threshold established in the regulation of the Minister of Health of the Republic of Indonesia regarding food additives, where the residue limit for sulfites in flour, calculated as SO_2, is 500 mg kg^{-1} (500 ppm). Specifically, the Codex General Standard for Food Additives has set the maximum allowable limit for sulfites in starch and flour as food ingredients at 200 mg/kg (FONSECA et al., 2015). Sulfites that remain in food products are sulfites that have reacted with enzymes, intermediate compounds resulting from the oxidation of polyphenolase enzymes, intermediate compounds from Maillard reactions, and also sulfites that are trapped within the food matrix. Some sulfites that are trapped may remain in slices of durian seeds after the drying process. According to the research results, the sulfite residue in the oxidation process of durian seed flour is still below the threshold value. Therefore, the processing of durian seed slices to produce durian seed flour using sodium metabisulfite solution is said to be safe, and durian seed flour can be used as an ingredient in bread and cake products.

5. CONCLUSIONS AND SUGGESTIONS

5.1. Conclusions

Based on the research and analysis that have been conducted, it can be concluded that:

1. Durian seeds produce starch with a yield value of 9.42% with the characteristics: round and irregular granule shape at magnifications of 50 μm and 5 μm, amylose content (18.17%), amylopectin content (81.83%), water absorption capacity (2.11 mL g^{-1}), oil absorption capacity (2.91 mL g^{-1}), the gelatinization profile of durian seed starch is classified as type C with peak viscosity (3059.5 ± 1496.55), thermal property test of starch with initial gelatinization temperature (65.17 ℃), and initial degradation temperature (297.55 ℃), °Hue value (267.40), and whiteness degree (89.85%).
2. Durian seeds produce a protein concentrate with a yield value of 0.16% and a protein content of 72.30%, and contain six amino acid compounds that have the potential to be used as raw materials or additives in food products such as complementary food for infants, crackers, and noodles.
3. Durian seeds produce oil with a yield of 0.25% that contains unsaturated fatty acid compounds such as linoleic acid (19.77%), stearoleic acid (11.78%), and conjugated linoleic acid (11.27%), as well as saturated fatty acid compounds such as hexadecanoic acid (30.38%), linoelaidic acid (12.71%), octadecanoic acid (1.7%), and methyl palmitate (1.21%).
4. Durian seed flour produces a yield of 28.60% with characteristics of moisture content (9.33%), ash content (2.67%), protein content (4.91%), °Hue value (101.03), whiteness degree (87.59%), and sulfite residue (58.05 ppm) meets the requirements of the Indonesian Ministry of Health regulations (500 ppm) and can be used as a raw material for composites in cakes, biscuits, or bread.

5.2 Suggestions

Based on the research results that have been conducted on the utilization of durian seeds through the extraction and characterization of starch, protein, oil, and flour, it is recommended for future researchers:

1. Further research on the formulation, safety, and effectiveness of its application in various food and non-food products to enhance the added value of durian seeds as an alternative raw material.
2. Further investigate the methods of protein and oil extraction from durian seeds to achieve high yield values.

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