

Research article

Enhancement of the Functional Characteristics of Jack Bean (*Canavalia ensiformis* (L.) D.C.) Sprouts by Tempeh Fermentation in Different Packaging Types

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Received: 15 August 2025, Revised: 15 January 2026, Accepted: 15 January 2026, Published: 10 April 2026

Abstract

Tempeh is one example of a food that contains significant amounts of resistant starch and dietary fiber. The quality of manufactured tempeh is affected by the raw materials and packaging employed. Variations in packaging influence the fermentation conditions accessible for *Rhizopus* sp. Jack bean sprouts are regarded for their abundant functional characteristics. However, no research has examined the starch profile and dietary fiber properties of jack bean sprout tempeh prepared in various packaging types. This study aimed to assess the effects of variations in packaging style on the starch profile and dietary fiber properties of tempeh derived from jack bean sprouts. This research used a non-factorial randomized block design. The treatment variables comprised three packaging types: teak leaves, banana leaves, and plastic packaging with nine repetitions for each. Starch and dietary fiber compositions were examined with ANOVA, followed by DMRT with significance determined at $p < 0.05$. The results indicated that tempeh in plastic packaging contained the highest total starch (54.54%), but tempeh wrapped in banana leaves exhibited the most resistant starch concentration (14.54%). Conversely, tempeh encased in teak leaves possesses the highest dietary fiber level (28.1%) in comparison to tempeh wrapped in other materials. Applying appropriate tempeh packaging can optimize the starch profile and dietary fiber properties of tempeh.

Keywords: tempeh; resistance starch; dietary fiber; packaging type, germinated jack bean

1. Introduction

Degenerative diseases are health conditions that are extensively targeted for prevention. The onset of degenerative diseases results from imbalanced dietary practices and

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<https://doi.org/10.55003/cast.2026.268808>

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insufficient physical activity. Consequently, researchers and nutrition specialists have employed diverse methodologies to identify alternative food elements that may aid in the prevention of degenerative diseases. Degenerative diseases are the primary cause of mortality worldwide. Data from the World Health Organization (WHO) indicates that degenerative diseases accounted for 36 million, or two-thirds, of the 57 million global deaths in 2008 (Herlina, 2023). A prevalent degenerative disease affecting individuals globally is diabetes. The World Health Organization reports that 537 million people aged 20 to 79 are affected by diabetes. The figure is projected to rise to 643 million by 2030 and 783 million by 2045. Diabetes resulted in about 6.7 million fatalities in 2021.

Diabetes prevention can be achieved through the consumption of foods abundant in resistant starch, dietary fiber (Wolever, 2003; Fuentes-Zaragoza et al., 2010; Yovani et al., 2022), and antioxidants (Triandita et al., 2016). These three elements are present in tempeh. Tempeh, a quintessential Indonesian fermented food product (Rizal et al., 2022), has been extensively researched for its potential to mitigate diabetes mellitus (Triandita et al., 2016; Su et al., 2023; Yoshari et al., 2023). Historically, soybeans serve as the primary component in tempeh manufacture. With advancements in science, tempeh may be manufactured from diverse varieties of beans, grains, and legumes (Ahnman-Winarno et al., 2021). Nonetheless, non-soy tempeh continues to be comparatively unpopular. To increase consumer interest, it is necessary to investigate the functional qualities of non-soy tempeh.

In Indonesia, jack beans (*Canavalia ensiformis* (L.) DC.) have been grown as a potential protein substitute for soybeans. Agustia et al. (2023) report that jack beans germinated for 60 h exhibited a protein content of 33.60% (dry basis), a dietary fiber content of 18.60% (dry basis), and a hydrogen cyanide (HCN) value of 9.62 ppm. Additionally, it has been found that jack bean sprouts can lower blood sugar levels by inhibiting the DPP-IV enzyme (Agustia et al., 2024). According to Astawan et al. (2024), the germination process followed by fermentation influences the sensory profiles and physicochemical properties of soybean tempeh and velvet bean (*Mucuna pruriens*). Therefore, using jack bean sprouts as a substitute for soybeans in tempeh preparation may improve its nutritional value.

Several factors influence the nutritional value of tempeh, including source of raw materials, fermentation time, humidity, temperature, and packaging (Munir et al., 2023). Common materials utilized in tempeh packaging include banana leaves, plastic, teak leaves (Ahnman-Winarno et al., 2021), and hibiscus leaves (Puspasari et al., 2023). The type of packaging is a factor influencing mold growth during fermentation. Mold proliferation is enhanced in leaf packaging due to its light-proof characteristics and effective aeration, which help maintain humidity levels during fermentation (Agustia et al., 2025). The proliferation process is more effective under these conditions. A study carried out by Puspasari et al. (2023) indicates that variations in tempeh packaging significantly influence the resultant antioxidant activity, fat, and ash content. Banana and teak leaves exhibit more porous and semi-permeable structures compared to plastic packaging, which improves aeration and moisture balance, thus promoting optimal *Rhizopus* activity and increasing fermentation efficiency. Ingredient availability and regional sociocultural factors influence the tempeh packaging material. Consumers favor plastic packaging due to its greater practicality. However, due to its low heat, vapor, and air permeability, plastic packaging needs perforations (Agustia et al., 2025).

The dietary fiber concentration in tempeh is affected by the raw ingredients utilized (Ahnman-Winarno et al., 2021) and the preparation procedure (Drabo et al., 2023). A study performed by Drabo et al. (2023) indicates an enhancement in soluble dietary fiber in tempeh derived from zamne beans. Nonetheless, no information has been discovered

concerning the starch profile and dietary fiber in tempeh produced with various packaging techniques. This study was intended to examine the effect of packaging variation on the starch profile and dietary fiber in jack bean sprout tempeh.

2. Materials and Methods

Jack bean seeds (*Canavalia ensiformis*) were purchased from Wonogiri, Central Java, Indonesia. "Raprima", the commercial tempeh inoculum which contains *Rhizopus oligosporus*, was procured from a traditional market. The packaging materials used were teak leaves (*Tectona grandis* L.f), banana leaves (*Musa balbisiana* Colla), and plastic (polypropylene 0.1 mm). All chemical reagents utilized in this research were of analytical quality. The tempeh utilised underwent a 48-h fermentation process. This study utilized a non-factorial randomized block design. The treatment factors consisted of three packaging types: teak leaves, banana leaves, and plastic packaging, with nine repetitions for each type.

2.1 Jack bean sprout tempeh production

2.1.1 Germination of jack bean

The jack bean sprouts production in this investigation was done following the procedure of Fitriani et al. (2022) and Agustia et al. (2023). The seeds were sorted, cleaned, and soaked in warm water (50°C) with 1% w/w NaHCO₃ for 24 h at a seed-to-water ratio of 1:5 w/v to start the jack bean germination process. The seeds were cleaned and drained prior to germination, and tap water was added every six h to replace the water. At a temperature range of 25°C to 28°C and a relative humidity of approximately 100%, the seeds were permitted to grow. The sprouts were collected after 60 h.

2.1.2 Tempeh fermentation

Jack bean sprout tempeh was prepared using the procedure provided by Puspitojati et al. (2019), with minor alterations (Figure 1). The jack bean sprouts were prepared by peeling, washing, and boiling them for 30 min. The jack bean sprout: water ratio = 1:4 (w/v). The sprouts were then sliced into 5-6 pieces and submerged in water for 24 h, maintaining a jack bean sprout: water ratio of 1:4 (w/v). The sprouts were subsequently boiled for 30 min. The beans were drained and left to cool at 30°C. A 0.2% concentration of tempeh inoculum (10⁶ CFU/g) was applied to the jack beans sprouts, and then properly mixed and wrapped. The utilized packing materials were teak leaves, banana leaves, and plastic (polypropylene). Each packaging contained 100 g of jack bean sprouts inoculated with Raprima yeast. The plastic was perforated at approximately 2 cm intervals before being employed as packaging, followed by sealing with a sealer. In the packaging of leaves, jack bean sprouts inoculated with instant yeast were wrapped in banana and teak leaves, which were subsequently secured with a hook stick and punctured at intervals of approximately 2 cm. The incubation was conducted at a constant temperature of 30°C for 48 h. All tempeh samples were subsequently dried in an oven at 50-55°C for 24 h, ground, sieved through a 60 mesh, and stored at -18°C for future analysis.

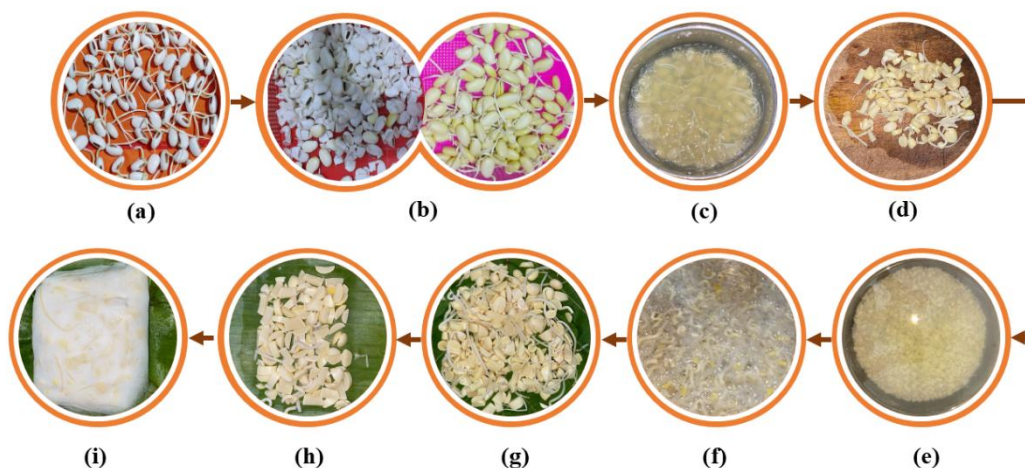


Figure 1. The step-by-step jack bean sprout tempeh process. (a) germination, (b) shelling, (c) first boiling, (d) chopping, (e) soaking, (f) 2nd boiling, (g) inoculation, (h) packaging, (i) tempeh product

2.2 Resistant starch analysis

The RS content analysis method had multiple phases and was performed according to McCleary and Monaghan (2002). The non-RS starch in each sample was initially dispersed and hydrolyzed with α -amylase and amyloglucosidase (AMG for 16 h) at 37°C. Next, the hydrolysis process was terminated (enzyme inactivation) by the addition of 99% ethanol. Following inactivation, the sample was subjected to centrifugation, and the resultant pellet (RS) was collected and subsequently washed twice with 50% ethanol to eliminate glucose from the hydrolysis. In the following step, RS was dissolved by submerging the cleaned pellet in 2 M KOH for 20 min in an ice water bath. Following neutralization with acetate buffer, the RS solution was hydrolyzed into glucose using AMG for 30 min at 50°C. The final stage involved the quantification of glucose derived from RS hydrolysis using glucose oxidase-peroxidase (GOPD) reagent. The quantified glucose concentration was transformed into the RS content of the sample by multiplying the glucose concentration by 0.9.

2.3 Amylose and amylopectin content analysis

The iodine binding method was used to determine the amount of amylose in the starch (Juliano, 1971). A test tube containing about 100 mg of starch sample was filled with 1 mL of 95% ethanol and 9 mL of 1 N NaOH. For around 10 min, the test tube was heated in boiling water until a gel developed. After cooling the test tube, the solution was quantitatively transferred into a 100 mL volumetric flask and made up to volume with water. A 5 mL (aliquot) of the solution was pipetted into a 100 mL volumetric flask, and then 1 mL of 1 N acetic acid and 2 mL of iodine solution (0.2% I₂ in 2% KI) were added. The flask was then made up to volume with water. After 20 min, a spectrophotometer was used to measure the absorbance at a wavelength of 625 nm. The amylose content of the sample was calculated using a regression equation derived from the standard curve. The

amylopectin content was then determined from the difference between the total starch and amylose contents.

2.4 Sample preparation and digestion

Two blank tests were performed to determine whether the reagents contributed anything to the measurement. Fifty mg samples were weighed precisely and transferred into 600 mL tall-form beakers. An aliquot of 40 mL of pH 8.2 MES-TRIS buffer solution was added to each beaker. Each sample was agitate using a magnetic stirrer, until it was evenly mixed. With slow stirring, 50 μ L of heat-stable α -amylase solution were added to each beaker. The beakers were then covered with aluminum foil and let to sit in a water bath at temperature between 95°C and 100°C for 15 min with constant stirring. Timing started as soon as the bath temperature reached 95°C.

After removing every beaker from the bath, the temperature of the bath was lower to 60°C. Meanwhile, the foil coverings were removed from the beakers, and a spatula was used to distribute any gels that had been accumulated at the bottom of the beaker and scrape away any debris from the inside. Ten mL of water was used to clean the spatula and the walls of the beaker. Each beaker was then filled with 100 μ L of the protease solution. All beakers were covered again with aluminum foil and incubated for 30 min at 60°C with continuous stirring. Timing started as soon as the bath temperature reached 60°C.

At the end of the 30 min period, the foil was removed from the beakers, and 5 mL of 0.561 N HCl was added and stirred. Next, 1 N NaOH solution was added to bring the pH down to 4 at 60°C. Then, 300 μ L of the amyloglucosidase solution was added, and with constant stirring the beaker contents were incubated for 30 min at 60°C while covered by aluminum foil. Timing started as soon as the bath temperature reached 60°C.

2.5 Dietary fiber analysis

Total dietary fiber (TDF), insoluble dietary fiber (IDF) and soluble dietary fiber (SDF) were determined according to the AOAC method (AOAC, 1995). Each digested sample (225 mL) was added to hot 95% ethanol (60°C) in a beaker at an ethanol-to-sample volume ratio of 4:1. Each beaker was removed from the bath, covered in aluminum foil, and kept at room temperature to encourage protein precipitation. A crucible that had previously been tared was prepared by moistening its filter paper with 15 mL of 78% ethanol. In addition, Celite was evenly spread onto the fritted glass surface under suction. Next, the alcohol-treated enzyme digestate was filtered through the crucible, and any remaining particles in the beaker were quantitatively transferred into the crucible using a rubber spatula and 78% ethanol. The residue was washed twice with 95% ethanol and acetone. The crucible was dried in a desiccator for 1 h, and then the combined weights of the crucible, Celite and dietary fiber residue was weighed to the nearest 0.1 mg. Then, TDF, IDF and SDF of each sample were determined. The protein and ash content of the residue was also determined according to AOAC method (1995).

Calculation

Blank (B) calculation:

$$B \text{ (mg)} = [BR_1 + BR_2/2] - P_B - A_B$$

Where

BR₁ and BR₂ = weights of residue for duplicate blank determination (mg)
 P_B = weights of protein for duplicate blank determination (mg)
 A_B = weights of ash for duplicate blank determination (mg)

Dietary fiber (DF) calculation below is the same calculation used for TDF and SDF:

$$\text{TDF or SDF (g/100 g)} = \{[(R_1+R_2)/2] - P - A - B\} / [(M_1+M_2)/2] \times 100$$

Where

R₁ and R₂ = weight of residue for duplicate samples (mg)
 P = weight of protein for duplicate blank determination (mg)
 A = weight of ash for duplicate blank determination (mg)
 B = blank weight (mg)
 M = weight (mg) for samples (duplo → M1 and M2)

2.6 Statistical analysis

All the data analysis (starch profile and dietary fiber properties) was carried out using IBM SPSS Statistics 26, which was created by IBM Corp. Analysis of variance was employed to analyze the data. Statistical significance was defined as $p < 0.05$. Duncan's Multiple Range Test was used to examine the average difference between treatments.

3. Results and Discussion

3.1 Starch profile of germinated jack bean tempeh

Tempeh is a typical Indonesian fermented food product that is generally produced from soybeans (Irvan et al., 2021). However, tempeh is starting to be produced from various types of beans and cereals (Romulo & Surya, 2021). Tempeh production is greatly influenced by raw materials, inoculum composition, and packaging type (Sudaryantingsih & Pambudi, 2024). Variations in packaging affect the resulting tempeh because the surface structures of the packaging types are different, thus affecting the growth of fungi that play a role in tempeh fermentation. Banana and teak leaves possess porous and semi-permeable structures that enhance aeration and moisture balance, thereby facilitating optimal *Rhizopus* activity. Plastic packaging, due to its non-porous nature, limits oxygen exchange and retains moisture, resulting in reduced fungal growth and diminished fermentation efficiency (Agustia et al., 2025). The packaging of tempeh with plastic and leaves meets the essential criteria, including moisture retention of soybeans during fermentation, adequate aeration for mold growth without excessive air exposure, and preservation of the cleanliness and aesthetic quality of the produced tempeh (Puspasari et al., 2023).

The presence of microorganisms on the leaf packaging surface is known to affect the tempeh fermentation process. According to Lindow and Brandl (2003), the majority of microorganisms found on plant leaves are bacteria, with an average of 10^6 - 10^7 per cm² of leaf surface. Thus, the use of leaves as food wraps may enhance the food microbiome, particularly LAB (Erdiansyah et al., 2022). However, other studies have shown that paper and plastic wraps do not have a significant impact on the microbiological quality of tempeh, especially LAB (Santhirasegaram et al. 2016). In addition, Wicaksono et al. (2024) reported that when compared to tempeh covered in plastic, tempeh wrapped in banana leaves had more enterobacteria and also tended to have more lactobacilli and total bacteria.

Table 1 shows that the differences in tempeh fermentation packaging produced different starch profiles for each tempeh product produced. A significant difference ($p < 0.05$) was observed in the starch profile (amylose, amylopectin, and total starch) among the three tempeh samples with different packaging. Fermentation for 48 h showed that the levels of amylose, amylopectin and total starch in tempeh with plastic packaging had the highest values, namely 12.46%, 42.08%, and 54.54%, respectively. Tempe packaged in plastic exhibited elevated starch levels due to the airtight environment, which limited oxygen and moisture exchange, thereby inhibiting microbial enzyme activity and decelerating starch hydrolysis in contrast to the more permeable natural leaf packaging. The three profiles (amylose, amylopectin, and total starch) were found to be the lowest in tempeh packed with banana leaf. Tempeh with banana leaf packaging had amylose, amylopectin and total starch values of 9.16%, 40.69%, and 49.85%, respectively. The tempeh packaged with teak leaves had a higher amylose, amylopectin, and total starch content than that packaged with banana leaves because the banana leaves had higher permeability level that enhanced starch hydrolysis than teak leaf (Indreswari et al., 2021). Higher permeability in banana leaves favors more extensive starch hydrolysis and retrogradation, resulting in lower total starch content.

Table 1. Starch profile of jack bean sprout tempeh in different packaging materials

Starch Properties	Jack Bean Seed	Jack Bean Sprout Tempeh		
		Teak Leaf	Banana Leaf	Plastic
	20.2*			
Amylose (%)		12.23±0.05 ^b	9.16±0.03 ^c	12.46±0.03 ^a
	79.8*			
Amylopectin (%)		41.67±0.03 ^b	40.69±0.06 ^c	42.08±0.06 ^a
	36.9**			
Total Starch (%)		53.96±0.09 ^b	49.85±0.03 ^c	54.54±0.09 ^a

*Akinyemi et al. (2020); **Sridhar and Seena (2006). Significant differences are indicated by different superscript letters in the same row (Duncan's test, $p < 0.05$).

There was no literature found that directly discussed the relationship between differences in tempeh packaging and its starch profile. However, based on several reference literatures, differences in the starch profiles in tempeh packaged in different packaging types were related to the characteristics of the packaging and mold growth during tempeh fermentation. Tempeh packed with banana leaves had the highest permeability level among the three packages (Indreswari et al., 2021). Therefore, tempeh mold is thought to be easier to reproduce and grow well in tempeh with banana leaves packaging. Effective mold proliferation during tempeh fermentation, facilitated by banana leaf packing, enabled the efficient utilization of organic components in jack bean sprouts by tempeh mold as a nutritional source (Agustia et al., 2025). One of the compounds needed in high amounts by mold during tempeh fermentation is starch (Sudaryantingsih & Pambudi, 2024). Increased starch hydrolysis correlates with a decreased starch content. So, the total starch content in tempeh packaged in banana leaves was the lowest. According to this analysis, the concentration of starch in tempeh is inversely correlated with the growth of mold populations during fermentation.

The same results were also found in research on jack bean tempeh by Purwandari et al. (2024). The starch profile in cooked tempeh diminished relative to that of the cooked beans. The increase in fungal biomass necessitates the use of starch as a carbon source, potentially accounting for the reduced total starch concentration in leaves packaging relative to plastic packaging. Fermented grains exhibited reduced starch content as a result of microbial activity by enzymes such as amylases, glucoamylases, and maltases (Purwandari et al., 2024). Enzymatic hydrolysis decreases the total starch content in grains. The released simple sugars are subsequently used by fermenting microorganisms as an energy source, resulting in the production of metabolites including organic acids, ethanol, and carbon dioxide. The biochemical composition of the grains varies depended upon testing; specifically, starch levels decrease, while levels of reducing sugars, organic acids, and other bioactive compounds frequently increase.

The highest resistant starch percentage, measured at 14.54%, was observed in tempeh packaged with banana leaves (Figure 2). Banana leaves allow higher aeration, supporting continued fungal activity and promoting partial starch hydrolysis and retrogradation, which increase resistant starch formation. Shu et al. (2009) reported that the augmentation of amylose in a sample directly correlates with an increase in resistant starch. Accelerated mold proliferation and the synthesis of hydrolytic enzymes, especially amylase, facilitate the hydrolysis of amylose into monosaccharides. However, the residual amylose contributes to the development of resistant starch post-fermentation due to its compact, linear shape, which hinders the action of digestive enzymes. The rise in resistant starch may also be affected by the utilization of complex starch by *Rhizopus oligosporus* during fermentation (Sorenson & Hesseltine, 1966).

3.2 Dietary fiber content of germinated jack bean tempeh

The variation of tempeh packaging influences the dietary fiber properties of jack bean sprout tempeh. A significant difference ($p < 0.05$) was observed among the three tempeh samples in different packaging in terms of all dietary fiber properties including soluble dietary fiber, insoluble dietary fiber, and total dietary fiber. Table 2 presents the dietary fiber profile values for three distinct forms of tempeh packaging. Table 2 indicates that the use of teak leaf or banana leaf produced negligible differences in soluble dietary fiber. The soluble dietary fiber content in jack bean sprout tempeh with plastic packaging was significantly the lowest at 2.93%. The insoluble dietary fiber concentration of teak leaf tempeh was significantly the highest at 24.51%, followed by banana leaf tempeh at 22.16%. Tempeh packaged in plastic exhibited the lowest insoluble dietary fiber content at 19.99%. The highest total dietary fiber content was seen in the teak leaf tempeh (28.01%), followed by banana leaf (25.53%), and plastic (22.92%). In contrast to the starch profile data, tempeh wrapped in plastic exhibited the lowest values for all dietary fiber properties. This was probably due to insufficient aeration in plastic packing, which restricted oxygen exchange and prevented microbial enzymes from turning insoluble fiber into soluble fiber (Drabo et al., 2023).

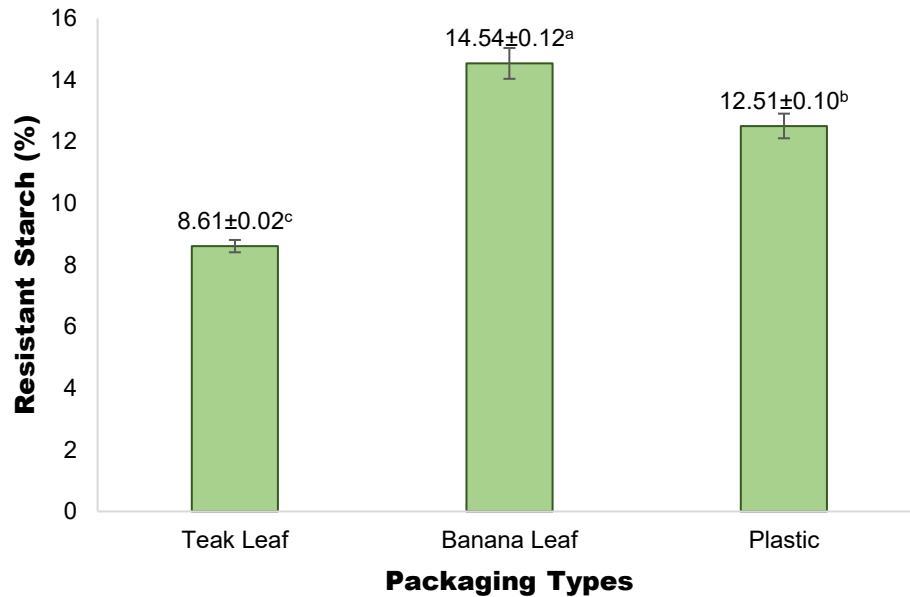


Figure 2. Resistant starch concentration of each germinated jack bean tempeh. Significant differences are indicated by different superscript (Duncan's test, $p < 0.05$).

Table 2. Dietary fiber profile of jack bean sprout tempeh in different packaging materials

Dietary Fiber Properties	Jack Bean Seed*	Jack Bean Sprout Tempeh		
		Teak Leaf	Banana Leaf	Plastic
Soluble Dietary Fiber (%)	8.20 g/kg	3.49±0.05 ^a	3.37±0.02 ^a	2.93±0.06 ^b
Insoluble Dietary Fiber (%)	167.59 g/kg	24.51±0.06 ^a	22.16±0.03 ^b	19.99±0.03 ^c
Total Dietary Fiber (%)	175.79 g/kg	28.01±0.11 ^a	25.53±0.04 ^b	22.92±0.10 ^c

*Sridhar and Seena (2006). Significant differences are indicated by different superscript letters in the same row (Duncan's test, $p < 0.05$).

The elevated concentrations of soluble dietary fiber in tempeh packed with teak and banana leaves were believed to be associated with the continuous fermentation process. The fermentation of tempeh utilizing teak and banana leaves yielded a higher population of *Rhizopus* than fermentation in plastic (Figure 1). This phenomenon was attributed to the elevated permeability of teak and banana leaf packaging (Indreswari et al., 2021). The porous structures of teak and banana leaves facilitate enhanced oxygen diffusion into the tempeh matrix compared to plastic packaging. The improved aeration facilitates optimal aerobic growth of *Rhizopus* sp., enabling continuous enzyme production that degrades complex fibers including cellulose and hemicellulose into more soluble forms. During fermentation, soluble fiber arises as *Rhizopus* converts insoluble fiber into soluble fiber (Drabo et al., 2023).

Compared to the cooked bean, the cooked tempeh had a lower total fiber content. Pectinase and xylanase are examples of fungal enzymes that can partially hydrolyze insoluble fiber into soluble fiber during fermentation, causing it to leak out during the cooking procedure (Purwandari et al., 2024). A plausible explanation for the reduced fiber concentration in tempeh could be the utilization of certain fibers for fungal growth (Fitriani et al., 2024). Fungal carbohydrases degrade the fiber polymer, liberating sugar monomers. Fructose, glucose, maltose, galactose, and xylose are acknowledged as optimal carbon sources for the proliferation of *Rhizopus oligosporus* (Sorenson & Hesseltine, 1966).

During tempeh fermentation, the degradation of amylose and amylopectin decreases total starch while facilitating the development of resistant starch and fiber-like compounds. Resistant starch primarily contributes to insoluble dietary fiber, whereas microbial activity enhances the components of soluble fiber. Consequently, the overall dietary fiber content increases, whereas total starch decreases throughout fermentation. Tempeh packaged with teak leaves demonstrated greater characteristics especially in fiber composition and starch properties compared to those packaged in banana leaves and plastic. Teak leaves provide higher oxygen exchange and support sustained fungal growth and enzyme production, resulting in higher fiber composition and a more favorable starch profile than the others packaging types. The selection of packaging for tempeh is essential as it affects its nutritional composition, particularly the starch and fiber profiles of the tempeh.

4. Conclusions

Tempeh bean sprouts packaged in teak and banana leaves exhibited reduced levels of amylose and amylopectin relative to those packaged in plastic, suggesting that the choice of packaging material exerts a measurable influence on starch composition. This finding is likely because of the characteristics of the packaging and mold growth during tempeh fermentation. Leaf packaging possesses high permeability, allowing oxygen to circulate, hence promoting the reproduction and growth of tempeh mold, thereby increasing starch hydrolysis. Nonetheless, tempeh packaged in banana leaves exhibited elevated levels of resistant starch, while teak leaf packing resulted in increased total dietary fiber. Collectively, these results underscore the dual role of traditional leaf-based packaging as it not only preserves tempeh products but also modulates the functional and nutritional properties of tempeh, offering potential benefits for the development of tempeh with enhanced health-promoting attributes.

5. Acknowledgements

The authors wish to thank the Directorate of Research and Community Service (DPPM) of the Directorate General of Higher Education, Research, and Technology, Ministry of Education, Culture, Research, and Technology, Republic of Indonesia, for provided funding for this project under the Fundamental Regular (FR) Research Scheme (Grant Number: 545/UN23/PT.01.05/2025).

6. Authors' Contributions

Friska Citra Agustia designed and coordinated research and wrote the paper; Aprilia Fitriani performed research, analyzed data, and wrote the paper.

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7. Conflicts of Interest

The authors declare no conflict of interest regarding this publication.

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