

# Effect of mung bean sprout (*Vigna radiata*) germination phases on the physical and sensory quality of nata de coco

ANDRIANSYAH\*, AKHMAD FATHIR, LINDA TRI ANTIKA

Department of Biology Education, Faculty of Teacher Training and Education, Universitas Islam Madura. Jl. Pondok Pesantren Miftahul Ulum Bettet, Pamekasan 69351, East Java, Indonesia. Tel.: +62-324-32178, \*email: ryanandriansyah720@gmail.com

Manuscript received: 21 September 2025. Revision accepted: 19 November 2025.

**Abstract.** *Andriansyah, Fathir A, Antika LT. 2025. Effect of mung bean sprout (Vigna radiata) germination phases on the physical and sensory quality of nata de coco. Asian J Agric 9: 787-799.* The use of natural nitrogen sources in nata de coco production is essential to enhance food safety and promote sustainable fermentation practices. This study evaluated the effect of mung bean sprout (*Vigna radiata*) germination phases 24 hours (F1), 48 hours (F2), and 72 hours (F3) as natural nitrogen sources on the physical and sensory properties of nata de coco. Sprout extracts were mixed with coconut water and sugar, inoculated with *Acetobacter xylinum* at a density of  $1 \times 10^8$  CFU/mL, and fermented for 15 days. The observed parameters included thickness, weight, total soluble solids, and sensory attributes (aroma and taste) assessed using a three-point hedonic scale. Statistical analysis revealed no significant differences ( $p > 0.05$ ) among germination phases in all measured parameters, although the 48-hour treatment tended to produce nata with slightly better physical and more balanced sensory characteristics. These findings indicate that within the 24-72-hour window, sprout physiological maturity only modestly affects nitrogen availability, suggesting that the use of sprout extract itself as a natural nitrogen source is more influential than germination duration. Overall, this study reinforces the potential of mung bean sprout extract as a safe, eco-friendly, and sustainable alternative to synthetic nitrogen sources in microbial cellulose production, supporting the development of environmentally responsible food biotechnology.

**Keywords:** Food fermentation, germination stage, mung bean sprouts, nata de coco, natural nitrogen source

## INTRODUCTION

Nata de coco is a high fiber food derived from coconut water, characterized by its chewy texture, white color, and soft taste (Santosa et al. 2021; Sarifudin et al. 2024). It is produced through fermentation by *Acetobacter xylinum*, which secretes extracellular enzymes that polymerize glucose into cellulose, forming nata sheets. This process generates a white cellulose layer, containing some entrapped bacterial cells, that develops on the surface of the medium (Santosa et al. 2021; Sine et al. 2021; Potočnik et al. 2023; Indraningtyas et al. 2024). The cellulose-producing capacity of *A. xylinum* is shaped by several factors, particularly the availability of essential nutrients such as carbon and nitrogen (Ningsih et al. 2021; Biran et al. 2023). Inorganic nitrogen sources such as urea and ammonium sulfate (ZA) are commonly used. However, ammonium sulfate has been linked to increased levels of heavy metals such as Cu, Pb, and Zn in nata products, which may pose health risks with long-term consumption (Akni et al. 2024; Alifani et al. 2024). Therefore, mung bean sprouts (*Vigna radiata* L.) have been proposed as a natural nitrogen source alternative in nata production (Murtius et al. 2021; Darmawati et al. 2022).

Mung bean sprouts are young seedlings that develop from germinated mung bean seeds. Their early growth relies primarily on the nutrient reserves stored within the seeds and generally requires several days until the sprouts reach the vegetative stage. Nutritionally, 100 g of mung bean sprouts

contain approximately 3.04 g of protein, 0.18 g of fat, 5.94 g of carbohydrates, 1.8 g of fiber, 13 mg of calcium, 54 mg of phosphorus, 1 mg of iron, and provide about 30 kcal of energy (NutriVals 2025). Previous research demonstrated that germination periods of 0, 12, 24, 36, and 48 hours significantly affect the protein content of mung bean sprouts (Puspitasari et al. 2024). Synthetic nitrogen sources such as urea, ammonium sulfate, and sodium nitrate are widely used in microbial fermentation to support bacterial growth. However, prolonged use increases production costs and poses environmental risks due to chemical waste that may contaminate soil and water (Yi-Shen et al. 2018; Wang et al. 2024).

Therefore, natural nitrogen alternatives are needed that are eco-friendly, low-cost, and easily obtainable. Germinated mung bean sprouts contain abundant amino acids and soluble proteins produced through enzymatic hydrolysis during germination (Yu et al. 2020). These organic nitrogen compounds are readily assimilated by *A. xylinum*, supporting enzyme synthesis and microbial cellulose formation (Płoska et al. 2025). Therefore, mung bean sprout extract offers a sustainable natural nitrogen source to replace synthetic fertilizers in nata de coco production. Several studies have examined nitrogen sources in nata processing, including work assessing sugar variations and their effects on nata de coco quality (Attaqy et al. 2023). Examined different volumes of sprout extract (5, 10, and 15 mL) and their effects on the physical properties of nata de coco (Junardi and Febrina 2022). Tested sprout extract

concentrations of 10%, 20%, and 30% in the production of nata de *Annona montana* (Fidyasari and Ula 2021). In addition, studied various nitrogen sources, including tofu wastewater, sprouts, and *Azolla microphylla*, to determine the most effective natural nitrogen source for high quality nata de coco production (Santosa et al. 2021).

Various studies have assessed alternative nitrogen sources to replace urea or ammonium sulfate, such as mung bean sprouts, tofu wastewater, and *A. microphylla* (Santosa et al. 2021). However, most studies emphasize extract concentrations or comparisons among nitrogen sources, while the physiological changes occurring during sprout germination remain largely overlooked. Yet germination modifies protein, amino acid, reducing sugar, and enzyme levels that directly affect nata de coco quality. This gap highlights the need to link germination physiology with fermentation outcomes. Therefore, this study investigates how three germination durations (24, 48, and 72 hours) influence the physical and sensory properties of nata de coco, clarifying the role of sprout physiology in supporting fermentation performance.

## MATERIALS AND METHODS

### Study area

The experimental design used was a Completely Randomized Design (CRD) with three treatments, namely F1 (mung bean sprouts soaked for 24 h), F2 (48 h), and F3 (72 h) (Figure 1). Each treatment was carried out in three replications, with one fermentation vessel in the form of a glass jar (250 mL capacity, 7 cm mouth diameter, 10 cm height) containing the fermentation medium defined as a single experimental unit ( $n=1$ ). Thus, the number of replications for each treatment was  $n=3$ . All vessels were incubated under in vitro laboratory conditions to ensure uniform cellulose formation by *A. xylinum*. The selection of germination time of 24 h, 48 h, and 72 h was based on biological considerations and previous studies. Research on mung bean reported a significant increase in amylase activity during 24-48 h of germination (Wintersohle et al. 2024). In contrast, studies on *Phaseolus lunatus*, indicated that the degradation of the storage protein phaseolin begins within 12-24 h, with more pronounced structural changes observed at 48-72 h (Wu and Shin 2025). Furthermore, investigations on demonstrated that antioxidant activity and bioactive compounds increase during 24-48 h but tend to decline after 72 h (Cele et al. 2025). Therefore, this time range was selected to capture the early, peak, and late phases of nutrient composition changes that may influence substrate availability for *A. xylinum*. This study did not include a control treatment without sprout extract or with conventional nitrogen sources (such as ammonium sulfate or urea). The main objective was to compare the physiological effects of different germination stages (24 h, 48 h, and 72 h) of mung bean sprouts as natural nitrogen sources rather than to benchmark against synthetic nitrogen controls. Therefore, the 48-hour germination stage (F2), which is most commonly used in previous nata fermentation studies,

served as the internal reference within the experimental design (Santosa et al. 2021; Junardi and Febrina 2022).

### Procedures

The preparation of mung bean sprouts was carried out by soaking  $\frac{3}{4}$  kg of mung beans, which were divided into three containers, each containing  $\frac{1}{4}$  kg, and labeled according to the soaking duration: 24 h (F1), 48 h (F2), and 72 h (F3). Each container was filled with clean water for soaking, and for soaking durations longer than 24 h, the soaking water was replaced every 24 h to minimize the risk of spoilage. All containers were stored at room temperature (30°C) under the same laboratory conditions and tightly closed to minimize contamination. To standardize the experiment, mung beans from the same batch, identical soaking vessels, and the same water source were used, and all treatments were conducted simultaneously. This study did not include a control treatment without sprout extract, as the primary objective was to compare the effects of different soaking durations.

After germination, each type of sprout (F1, F2, F3) was weighed (100 g), mixed with 100 mL of distilled water, and homogenized using a sterile blender. The extract was filtered using filter paper to separate the residue, and only the liquid filtrate was used. The filtrate was then combined with 400 g of fresh coconut water and supplemented with 40 g of sugar, followed by homogenization until evenly mixed. The mixture was boiled for 10 minutes with continuous stirring until reaching a rolling boil, and then filtered again to remove foam. The resulting solution was transferred into sterilized plastic containers for cooling. During cooling, 10 mL of acetic acid was added, and the pH was adjusted with a calibrated pH meter to a specific value of 4.3, which is considered the optimum condition for the growth of *A. xylinum* (Yamin et al. 2022). The concentrations of sugar and acetic acid were determined based on the amount of material weighed and the volume of solution used, ensuring consistency across treatments.

Once the solution reached room temperature, 100 mL of *A. xylinum* starter culture was added. The starter was obtained commercially with a cell density of  $1 \times 10^8$  CFU/mL as specified by the supplier; no independent cell count was performed in this study. Each treatment was prepared in triplicate, with one jar defined as a single experimental unit ( $n=1$  per jar;  $n=3$  per treatment). The jars were covered with sterilized wooden paper secured with rubber bands to prevent contamination and incubated statically for 15 days at 30°C. According to Iguchi et al. (2000) the optimal temperature for the growth of *A. xylinum* ranges from 28-31°C.



Figure 1. Types of mung bean sprouts

## Data analysis

Data collection in this study included the measurement of nata de coco thickness using a caliper and weight determination using an analytical balance. Before weighing, each nata pellicle was gently blotted with sterile tissue paper to remove free surface water, ensuring that the measured mass represented the actual gel weight rather than adhering surface moisture (Dey et al. 2024). The total soluble solids were expressed as total soluble solids ( $^{\circ}$ Brix), which were measured using a digital refractometer to determine the sweetness level of each treatment. In addition, sensory evaluation was conducted for the aroma and taste attributes involving 12 untrained panelists. The limited number of panelists was due to the small amount of product obtained during the experiment. Considering the preliminary nature of this study and the restricted sample size, this number was deemed sufficient to provide indicative sensory responses and to describe general preference trends among panelists (Lawless and Heymann 2010; Stefanowicz 2013). The panelists were asked to provide ratings using a three-point hedonic scale consisting of 1=Disagree (TS), 2=Neutral (N), and 3=Agree (S), so that each attribute of aroma and taste was assessed separately based on individual perception. The use of hedonic scales is a common method in consumer sensory evaluation, although the nine-point scale is most widely applied (Cardello 2017). However, variations with fewer categories, such as three- or five-point scales, are also frequently employed in studies with a limited number of panelists or when researchers prioritize simplicity in evaluation (Triandini and Wangiyana 2022; Addo-Preko et al. 2023). A three-point hedonic scale was applied in this study to simplify evaluation for untrained panelists, ensuring better consistency and reducing cognitive load. Although less detailed than 5- or 9-point scales, this approach has been adopted in preliminary studies with limited panelists (Triandini and Wangiyana 2022). In addition, the use of a simplified scale was intended to minimize confusion, shorten evaluation time, and reduce variability among panelists' responses, which is important when using untrained assessors.

The data obtained from physical parameters were analyzed using one-way ANOVA to determine significant differences among treatments (F1, F2, and F3). When significant differences were found, post hoc Tukey tests were performed to identify which treatments differed significantly. Meanwhile, the sensory evaluation data were analyzed using the non-parametric Kruskal–Wallis test because the distribution of the data was not normal. If the Kruskal–Wallis test indicated potential differences among treatments, the Dwass–Steel–Critchlow–Fligner (DSCF) test was employed as a non-parametric post hoc method to conduct pairwise comparisons. The DSCF test was selected because it is appropriate for ordinal or non-normally distributed data with relatively small sample sizes and provides pairwise comparisons comparable to Tukey's test in parametric conditions. All inferential statistical analyses were performed at a significance level of  $\alpha=0.05$  using Jamovi version 2.3.28, while data presentation in tabular form was carried out using Microsoft Excel.

## RESULTS AND DISCUSSION

Overall, the physical parameters (thickness, weight, and total soluble solids) and sensory attributes (aroma and taste) showed a consistent descriptive trend. The 48-hour germination phase (F2) generally produced nata with slightly higher physical quality and more balanced sensory perception, although differences were not statistically significant ( $p>0.05$ ). These results suggest that the mid-germination stage provides an optimal balance of carbon and nitrogen compounds for *A. xylinum* growth, supporting more stable cellulose formation. The similarity among treatments further indicates that within the 24–72 h range, mung bean sprout extracts maintain relatively stable nutrient composition, allowing uniform nata quality regardless of minor physiological variations. Thus, the overall observation confirms that sprout extracts can serve as consistent, eco-friendly nitrogen sources for bacterial cellulose production.

### Thickness

The thickness produced by *A. xylinum* reflects its ability to convert nutrients into cellulose (Santosa et al. 2021). Based on the results presented in Table 1, the greatest thickness mean was observed in nata produced using mung bean sprouts germinated for 48 hours (F2), which reached 4.7 mm. In comparison, nata produced using sprouts germinated for 24 hours (F1) and 72 hours (F3), both showed a thickness of 4.3 mm. This finding is likely associated with the higher availability of nitrogen at 48 hours, which enables *A. xylinum* to synthesize cellulose that is denser and has greater mass (Putri et al. 2021). At 24 hours of germination (F1), the germination process is still in its initial phase; thus, the concentrations of nutrients such as proteins, sugars, and enzymes have not yet developed substantially. Following seed imbibition, metabolic activity begins to increase, as indicated by the activation of enzymes, enhanced respiration, and various biochemical changes. However, the mobilization of stored nutrients such as starch and proteins remains in the early stages and has not yet reached its maximum potential (Dong et al. 2015; Živković et al. 2025). At 48 hours (F2), the sprouts have reached an optimal growth phase. The concentrations of nutrients such as amino acids, B vitamins, and minerals have increased significantly, and the pH level of the extract also contributes to the greater thickness of the resulting nata (Mandey et al. 2020). At 72 hours (F3), although the sprouts are physically longer, a substantial portion of the nutrients produced during the earlier stages of germination has been utilized to support sprout growth. Consequently, the nitrogen content is reduced, leading to lower nata thickness. Germination influences the chemical composition and structural development of proteins within the seeds (Wintersohle et al. 2024). However, the descriptive trend indicating greater thickness at the 48-hour germination phase (F2) was not supported by statistical analysis. The ANOVA results showed no significant differences among treatments ( $F=0.620$ ,  $p=0.589$ ), and the Tukey post hoc test further confirmed that pairwise comparisons between F1 and F2 ( $p=0.915$ ), F1 and F3 ( $p=1.000$ ), and F2 and F3 ( $p=0.915$ )

were all non-significant. Thus, although F2 tended to produce slightly greater thickness on average, the variability among replicates, particularly the extreme value observed in F3, obscured statistical significance. That suggests that the effect of germination duration on nata de coco thickness is not consistent enough to be considered statistically significant.

The thickness of the nata de coco pellicle reflects the growth rate and metabolic activity of *A. xylinum* during fermentation. This process is strongly influenced by the availability of carbon and nitrogen sources that can be utilized by the microorganism to synthesize cellulose (Wintersohle et al. 2024). At the 48-hour germination phase, mung bean sprouts generally contain higher levels of simple sugars and soluble proteins compared to the 24-hour or 72-hour phases. These nutrients are more easily assimilated by bacteria, supporting the formation of thicker nata layers. This finding is consistent with previous reports indicating that increased nutrient availability during germination enhances microbial activity and cellulose production (Ramana et al. 2000; Wintersohle et al. 2024). Beyond this mechanism, the presence of heterogeneous replication results (e.g., extreme values observed in one F3 replicate) suggests that the composition of the extract, such as reducing sugar concentration, pH, or the presence of inhibitory compounds, fluctuated among replicates. Such variability may have increased the variance and masked statistical significance, even when descriptive trends favored F2.

Cellulose formation by *A. xylinum* is influenced by the availability of carbon sources used during fermentation. Glucose derived from starch hydrolysis plays a crucial role as the primary substrate for cellulose synthesis, and sufficient availability of this carbon source supports bacterial growth and optimal nata formation. Several studies have also reported that cellulose biosynthesis activity is highly dependent on the accessible glucose available during fermentation (McManus et al. 2018; Li et al. 2022). Furthermore, easily assimilable nitrogen sources such as peptides and free amino acids play a key role in supporting cellular protein biosynthesis, enzyme production (including those facilitating glucose metabolism in the cellulose pathway), and microbial biomass growth. Studies on the effect of nitrogen sources on bacterial cellulose production have shown that the type and concentration of nitrogen, such as peptone, yeast extract, and amino acids, can increase cellulose yield when maintained within an optimal range. Conversely, excessive or inappropriate nitrogen sources may reduce cellulose production due to metabolic burden or potential toxicity (e.g., accumulation of metabolic by-products) (Molina-Ramírez et al. 2017; Avirasdya et al. 2022). This relationship is particularly relevant in the context of mung bean germination as a nutrient source. During the 48-hour germination phase, mung bean sprouts undergo increased physiological activity, resulting in the breakdown of stored starch and proteins into simpler compounds such as sugars and free amino acids, which can be readily utilized by microbes during fermentation. Previous studies have reported that this phase is associated with higher levels of soluble sugars and hydrolyzed proteins compared to the ungerminated state (Wintersohle et al.

2024). In addition, germination can reduce the content of antinutritional factors such as phytate, thereby enhancing the availability of minerals and essential nutrients in the extract (Tuncel et al. 2025). The combination of increased reducing sugars and readily assimilable nitrogen during this period provides an optimal nutritional environment for *A. xylinum* to sustain intensive metabolic activity, including cellulose synthase expression and other supporting pathways. Therefore, the 48-hour phase may represent an “optimal point,” where nutrient availability is high but not yet depleted by the sprout’s own growth, allowing for optimal cellulose production.

### Weight

Based on the results presented in Tabel 2, the highest average weight was observed in nata produced from mung bean sprouts germinated for 48 hours (F2), with an average weight of 28.7 gr. This can be attributed to the fact that F2 represents the optimal stage of organic compound availability in sprouts, during which a substantial amount of proteins has already been hydrolyzed into amino acids and peptides, making them more readily assimilated by microorganisms. At this stage, nutrient quality and bioavailability in the seeds increase, while antinutritional factors such as phytic acid, trypsin inhibitors, and polyphenols decrease, thereby enhancing nutrient utilization by microorganisms during fermentation (Prasad and Sahu 2025). The second-highest weight was recorded in nata from sprouts germinated for 24 hours (F1), with an average of 27.1 gr. Although F1 ranked below F2, the nitrogen content at this stage was still predominantly in the form of complex proteins rather than readily available amino acids. Nevertheless, protein content can increase by approximately 9-12% after 24 hours of soaking at 25°C (Devi et al. 2015). The lowest weight was obtained in nata from sprouts germinated for 72 hours (F3), with an average of only 16.7 gr. This stage exhibited inconsistency in nutrient content due to advanced sprout growth, where nutrients are re-utilized for leaf or shoot formation. According to Ikram et al. (2021) the progressive activation of hydrolytic enzymes during germination leads to the mobilization of stored macronutrients proteins, carbohydrates, and lipids toward growing embryonic organs, resulting in fluctuating nutrient levels in late germination stages. Nevertheless, statistical analysis indicated that the differences in nata weight among treatments were not significant. ANOVA yielded  $F=2.09$  with  $p=0.257$ , while the Tukey post hoc test revealed that the comparisons between F1 and F2 (mean difference=-1.60 g;  $p=0.935$ ), F1 and F3 (mean difference=5.73 g;  $p=0.465$ ), and F2 and F3 (mean difference=7.33 g;  $p=0.312$ ) were all non-significant ( $p>0.05$ ). This suggests that although descriptively F2 produced a higher weight compared to F1 and F3, the considerable variability in the data, particularly in F3, masked statistical significance among treatments.

For nata weight in Table 2, it is important to note that this parameter does not merely reflect the amount of cellulose synthesized, but also the physical properties of the network formed, particularly water-holding capacity, tissue density, and gel porosity. Bacterial cellulose structure is organized as a network of nanometer-scale microfibrils

interconnected through hydrogen bonding. Variations in cellulose chain length, degree of crystallinity, and fibril orientation can result in significant differences in water retention capacity. Recent studies have confirmed that the nanoribbon network of bacterial cellulose is highly porous and capable of retaining large amounts of water, thereby markedly increasing wet weight without substantial changes in dry mass (Portela et al. 2019; Ammar et al. 2022). Thus, wet weight not only serves as an indicator of cellulose production but also reflects the structural properties of the pellicle produced. At the 48-hour germination phase, the sprout extract is generally rich in simple sugars and free amino acids, which provide essential nutrients for microbial growth and cellulose formation by *A. xylinum*. These nutrients not only support bacterial activity but may also contribute to the overall pellicle mass through the formation of cellular components and other organic matter. Previous studies have reported that under favorable nutritional conditions, bacteria can produce additional extracellular materials that enhance water retention capacity and increase the total wet mass of the pellicle (Oliva et al. 2025). Therefore, the higher pellicle weight observed in F2 can be explained as a combination of more intensive cellulose production and greater microbial biomass accumulation.

Organic nitrogen (peptone, free amino acids) indeed promotes cell growth and enzyme biosynthesis, but excess nitrogen can stimulate increased respiratory metabolism, which in some cases reduces carbon allocation to the cellulose pathway. Singh et al. (2017) reported that the balance between carbon and nitrogen supply determines the efficiency of cellulose polymerization, where excess nitrogen may shift metabolism toward biomass formation without proportionally enhancing cellulose production. In other words, the nutritional conditions in F2 may represent a balanced state in which carbon is sufficient for cellulose polymerization and nitrogen is adequate to support microbial growth, without diverting metabolism to competing pathways.

### Total soluble solids

Based on the results of total soluble solids testing (Table 3), a clear difference was observed among the treatments. The highest total soluble solids were recorded in F2 (48 h) at 11.7°Brix. This is attributed to the fact that after 48 hours, germination reaches its active phase, during which enzymatic activity peaks. Enzymes such as amylase, protease, and lipase function at maximum intensity, resulting in greater hydrolysis of starch into simple sugars, thereby yielding a higher total soluble solid. Elevated sugar levels also contribute to an increase in nata elasticity and a reduction in firmness, as looser fiber bonding allows the gel to retain more water (Putri et al. 2021; Tambunan et al. 2021). The second-highest total soluble solids was observed in F1 (24 h), with a mean value of 10.7°Brix. At this stage, mung bean seeds initiate the breakdown of stored starch into simple sugars such as glucose and maltose (Gumelar and Fariyanto 2020). However, because this process has only recently begun, enzymatic activity remains relatively low. In contrast, F3 (72 h) exhibited the lowest total soluble solids, averaging 10.4°Brix. This reduction is due to significant changes in nutrient utilization dynamics during advanced sprout growth. At this stage, sprouts undergo further development, producing elongated shoots that consume a substantial portion of the available nutrients, leaving less starch to be converted into simple sugars. Furthermore, total protein content tends to decline with longer soaking durations (Agume et al. 2017; Rahman et al. 2021). However, the Tukey test indicated that the differences among treatments were not significant. The comparison between F1 and F2 showed a mean difference of -1.00 ( $p=0.159$ ), F1 and F3 showed 0.30 ( $p=0.801$ ), and F2 and F3 showed 1.30 ( $p=0.070$ ). The  $p$ -value in the F2 vs F3 comparison was relatively close to 0.05, suggesting a tendency toward difference, but not strong enough to be statistically significant. This highlights that variability among replicates substantially influenced the consistency of results, meaning that the higher total soluble solids in F2 should be considered a trend rather than a statistically confirmed difference.

**Table 1.** Thickness data of nata de coco and Tukey post hoc comparisons

Growth Phase	Replicate 1 (mm)	Replicate 2 (mm)	Replicate 3 (mm)	Mean (mm)	Comparison	Mean Difference	p-value
F1 (24 h)	4.7	4.2	4.1	4.3	F1 (24 h) vs F2 (48 h)	-0.400	0.915
F2 (48 h)	4.9	5.1	4.2	4.7	F1 (24 h) vs F3 (72 h)	0.000	1.000
F3 (72 h)	4.6	2.2	6.2	4.3	F2 (48 h) vs F3 (72 h)	0.400	0.915

Note: \*: Replicate 1-3 represent raw measurement values obtained from three repetitions of the same treatment

**Table 2.** Weight data of nata de coco and Tukey post hoc comparisons

Growth Phase	Replicate 1 (gr)	Replicate 2 (gr)	Replicate 3 (gr)	Mean (gr)	Comparison	Mean Difference	p-value
F1 (24 h)	26.4	28.6	26.4	27.1	F1 (24 h) vs F2 (48 h)	-1.60	0.935
F2 (48 h)	28.1	28.5	29.6	28.7	F1 (24 h) vs F3 (72 h)	5.73	0.465
F3 (72 h)	17.3	14.6	32.3	16.7	F2 (48 h) vs F3 (72 h)	7.33	0.312

Note: \*: Replicate 1-3 represent raw measurement values obtained from three repetitions of the same treatment

The total soluble solids (Table 3) showed the highest average value in F2 (48 hours). Biologically, this phenomenon aligns with the active germination phase, during which starch reserves and complex polysaccharides in mung bean seeds are broken down into simple sugars such as glucose and maltose. The increase in soluble sugar content at this stage provides a readily available carbon source for *A. xylinum* during the fermentation process. Several international studies have confirmed that the 48-hour germination phase often represents an optimum point for the accumulation of simple sugars, prior to their decline as the sprout's own growth consumes sugars. Gunathunga et al. (2024) reported that during germination, the level of reducing sugars significantly increases in the mid-germination phase (around 48-72 hours), accompanied by a decrease in antinutritional compounds such as raffinose and stachyose. Similar findings were also reported by Gu et al. (2023), showing that germination enhances soluble carbohydrate content and nutrient availability while reducing antinutritional compounds in the seeds.

From a fermentation perspective, a higher initial sugar concentration provides *A. xylinum* with a sufficient substrate supply to support cellulose formation. Montenegro-Silva et al. (2024) reported that an increase in glucose concentration at the initial stage of fermentation is positively correlated with the cellulose synthesis rate. However, two important aspects should be noted. First, part of the available sugars is consumed during the fermentation process; therefore, the final total soluble solids value reflects not only the initial sugar content but also the balance between microbial consumption rate and substrate availability throughout fermentation. Rezzazadeh et al. (2020) found that glucose consumption by *A. xylinum* results not only in cellulose formation but also in by-products such as acetic acid and ethanol. Second, higher initial sugar levels can accelerate the accumulation of these secondary metabolites, thereby influencing medium pH, pellicle texture, and even organoleptic attributes. For instance, García-Sánchez et al. (2020) reported that increasing glucose concentration above a certain threshold led to greater production of organic acids, which, while supporting initial cellulose growth, could reduce the organoleptic quality of the product. Therefore, the increase in total soluble solids observed in F2 reflects both an optimum biological phase of germination and a fermentation condition enriched with substrates for *A. xylinum*. Nevertheless, its long-term implications are not always linear: excessively high sugar supply may stimulate the formation of larger amounts of acidic metabolites, ultimately affecting the sensory quality of nata de coco. Thus, the interpretation of total soluble solids must take into account the dynamics of substrate consumption and secondary metabolite formation, rather than relying solely on the initial concentration.

### Aroma

After conducting a sensory evaluation involving 12 respondents to assess the aroma of nata, the results are presented in Table 4. Descriptively, the highest proportion of agreement responses was recorded in the F1 (24 hours) sample, with 41.2% of respondents indicating a favorable

aroma. However, statistical analysis using the Kruskal–Wallis test showed no significant differences among treatments ( $\chi^2=0.795$ ,  $p=0.672$ ), and pairwise comparisons further confirmed that all p-values were above 0.05 (Table 6). This suggests that although F1 appeared to have the highest preference rate, this tendency should be interpreted only as a descriptive trend rather than a statistically significant difference.

Based on the results presented in Table 4, respondents expressed the highest preference for the aroma of nata produced from sprouts subjected to 24 hours of soaking (F1). A total of 41.2% of respondents agreed that the aroma was favorable, indicating that nata from F1 exhibited a fresher and lighter aroma. However, post hoc pairwise comparisons revealed that the differences among treatments were not statistically significant (F1 vs F2:  $W=-1.0404$ ,  $p=0.743$ ; F1 vs F3:  $W=-0.0433$ ,  $p=1.000$ ; F2 vs F3:  $W=1.1414$ ,  $p=0.699$ ). This indicates that although F1 descriptively appeared to be the most preferred, the variation should be interpreted as a descriptive trend rather than a statistically confirmed difference. This is likely due to the relatively short soaking period of mung beans, during which sprouts have not yet produced secondary metabolites (such as ammonia or volatile organic acids) that could negatively affect the aroma of nata (Pradana et al. 2022; Fajari et al. 2025). In the case of F2 (48 hours), the highest percentage of responses was neutral (45.8%), with only 21.9% of respondents agreeing, suggesting that the aroma was less preferred. For F3 (72 h), 35.9% of respondents agreed with the aroma quality, which was higher than F2 but lower than F1. This suggests that the aroma of F3 was more complex and somewhat more acceptable than that of F2. Previous studies have shown that a slightly acidic aroma in nata de coco after 14 days of fermentation may be attributed to the persistence of volatile acids produced during fermentation, which are not fully eliminated during the boiling process (Nurdin et al. 2023).

Furthermore, the differences in aroma preference among F1, F2, and F3 can be further understood from the perspective of substrate changes, microbial dynamics, and the volatile compounds produced. The germination process of mung beans during soaking is known to increase reducing sugars and free amino acids as a result of amyolytic and proteolytic enzyme activity, meaning that the longer the soaking time, the more complex the substrates available for *A. xylinum* as well as accompanying microflora (Chen et al. 2019; Wang et al. 2020). Under substrate-rich conditions, such as in F2, in addition to the increase in nata cellulose, microbial metabolism also generates a higher amount of Microbial Volatile Organic Compounds (MVOCs), including organic acids, aldehydes, ketones, and amines, which can reduce the fresh impression of nata's aroma (Han et al. 2024). Volatile profiling studies on coconut-based products have demonstrated that key compounds such as acetic acid, acetaldehyde, ethyl acetate, and alcohols play major roles in shaping aroma characteristics, with volatile acids and bases often imparting sharp or fermentative notes that consumers less favor (Zhang et al. 2020; Li et al. 2024; Hu et al. 2025). From a flavoromics perspective, the increase in substrate concentration does not necessarily correlate positively with sensory acceptance, since excessive

metabolite production may lead to aroma deviations from the neutral profile expected by consumers (van Wyk 2024). This is consistent with the finding that panelists preferred the lighter and fresher aroma of F1 (24 h), whereas F2 received a higher proportion of neutral responses due to the dominance of volatile acids. In F3 (72 h), part of the acidic compounds may be converted into volatile esters that impart fruity notes, making its aroma more acceptable than F2, though still less fresh compared to F1. These findings are in line with the study of Rodriguez-Campos et al. (2012) on cocoa fermentation, where variations in fermentation duration were shown to shift volatile profiles with direct implications for sensory preferences.

### Taste

Based on the organoleptic test on the taste aspect conducted with 12 respondents, the assessment data of nata taste were obtained as follows (Table 5). Based on the hedonic evaluation of taste, the distribution of panelists' responses indicated that the differences among treatments were relatively small. The nata produced from the 24-hour germination phase (F1) received the highest proportion of "agree" responses (39.4%), followed by "neutral" (34.7%) and "disagree" (25.8%). This result suggests that nata from F1 (24 h) was relatively the most preferred descriptively. In the 48-hour treatment (F2), the responses were more balanced across the three categories, with 33.2% "agree," 35.2% "neutral," and 31.7% "disagree," indicating that the taste of nata from F2 was perceived as moderate without a strong tendency toward liking or disliking. Meanwhile, in the 72-hour treatment (F3), most panelists (45.4%) gave "neutral" responses, with liking (29%) and disliking (25.6%) proportions being nearly equal. However, the post hoc pairwise comparison confirmed that these differences were not statistically significant (F1 vs F2:  $W=-0.694$ ,  $p=0.876$ ; F1 vs F3:  $W=-0.392$ ,  $p=0.959$ ; F2 vs F3:  $W=0.347$ ,  $p=0.967$ ). This indicates that although F1 (24 h) appeared to be more preferred descriptively than F2 (48 h) and F3 (72

h), the variation in taste preference should be interpreted as a trend rather than a statistically significant difference.

This tendency can be explained by the changes occurring during germination and fermentation. In F1 (24 h), the balance between simple sugars and free amino acids remains relatively stable, resulting in a more neutral and acceptable taste (Yu et al. 2020). In F2 (48 h), the increased availability of reducing sugars and amino acids during germination enhances microbial metabolism, which may lead to the formation of small amounts of organic acids and hydrophobic peptides associated with slightly bitter notes (Chugh and Kamal-Eldin 2020; Wu et al. 2021). The imbalance between sugars and acids strengthens the perception of sour-bitter taste and reduces acceptability, consistent with the findings of Ningsih et al. (2021), who reported that the sour taste of nata arises from bacterial glucose degradation. In F3 (72 h), most panelists gave neutral ratings, which can be associated with the increased complexity of taste due to prolonged fermentation. This process may promote partial conversion of acids into esters, adding subtle flavor nuances. However, the simultaneous decrease in total soluble solids, residual acids and peptides, and the formation of a denser bacterial cellulose matrix contributed to a less fresh taste and a noticeable aftertaste (Park et al. 2022; Wang et al. 2023). Sugar concentration also plays an important role, as nata with a bland and neutral taste is generally considered ideal (Ratnasari et al. 2020; Zaura et al. 2023), whereas limited nitrogen availability can result in a flat taste due to the insufficient binding between nitrogen and polysaccharide precursors (Latumahina et al. 2017). Therefore, although nata produced with the 48-hour germination phase showed the most optimal physical thickness, the best descriptive taste profile was observed in F1 (24 h). This finding highlights that microbial dynamics, metabolite accumulation, and the balance between sugar and acid play substantial roles in determining the sensory quality of nata de coco derived from mung bean sprout extracts.

**Table 3.** Total soluble solids data of nata de coco and Tukey post hoc comparisons

Growth phase	Replicate 1 (°Brix)	Replicate 2 (°Brix)	Replicate 3 (°Brix)	Mean (°Brix)	Comparison	Mean difference	p-value
F1 (24 h)	11	10	11	10.7	F1 (24 h) vs F2 (48 h)	-1.00	0.159
F2 (48 h)	12	12	11	11.7	F1 (24 h) vs F3 (72 h)	0.30	0.801
F3 (72 h)	10	11	10.1	10.4	F2 (48 h) vs F3 (72 h)	1.30	0.070

Note: \*Replicate 1-3 represent raw measurement values obtained from three repetitions of the same treatment

**Table 4.** Hedonic test results for aroma of nata de coco with DSCF pairwise

Growth phase	Disagree (TS)	Neutral (N)	Agree (S)	Comparison	W	p-value
F1 (24 h)	30.4%	28.4%	41.2%	F1 (24 h) vs F2 (48 h)	-1.0404	0.743
F2 (48 h)	32.3%	45.8%	21.9%	F1 (24 h) vs F3 (72 h)	-0.0433	1.000
F3 (72 h)	25.8%	38.3%	35.9%	F2 (48 h) vs F3 (72 h)	1.1414	0.699

**Table 5.** Hedonic test results for taste of nata de coco with DSCF pairwise

Growth phase	Disagree (TS)	Neutral (N)	Agree (S)	Comparison	W	p-value
F1 (24 h)	25.8%	34.7%	39.4%	F1 (24 h) vs F2 (48 h)	-0.694	0.876
F2 (48 h)	31.7%	35.2%	33.2%	F1 (24 h) vs F3 (72 h)	-0.392	0.959
F3 (72 h)	25.6%	45.4%	29%	F2 (48 h) vs F3 (72 h)	0.347	0.967

### Statistical analysis

To determine the significant differences among treatments, an ANOVA test was conducted, and the results are presented in Table 6. Based on the statistical test results presented in Table 6, it can be seen that all research parameters showed p-values greater than 0.05. This indicates that differences in the sprout growth phases used as nitrogen sources did not cause significant variations in either the physical or organoleptic parameters of nata de coco. For the thickness variable, the ANOVA test produced an F-value of 0.620 with a p-value of 0.589. This value is far above the significance threshold of 0.05, meaning that although the 48-hour phase descriptively showed the highest thickness, the difference cannot be considered statistically meaningful. In other words, the observed variation in thickness is more likely influenced by natural data variability rather than by the treatment of sprout growth phases itself. A similar result was observed in the weight variable, where ANOVA produced an F-value of 2.09 with a p-value of 0.257. This again shows that differences among treatments were not significant. Although F2 appeared heavier than F1 and F3, mathematically, the probability that this difference was due to chance remains very high. Interestingly, in this variable, the homogeneity test indicated non-homogeneous data, which suggests considerable variation in value distribution among groups. This condition further reinforces the reason why, despite differences in mean values, the results could not reach statistical significance. For total soluble solids, the F-value obtained was 3.68 with a p-value of 0.124. This value is closer to the significance threshold compared to the other variables, but still above 0.05, and therefore cannot be considered significantly different. This result illustrates that the sprout growth phase does influence the tendency of total soluble solids, with the 48-hour phase producing the highest value. However, the variation among replicates was still considerable, making it statistically insufficient to confirm a difference. In other words, this result shows a strong trend, but not enough to prove a difference scientifically.

In contrast to the three physical parameters, the organoleptic evaluation of aroma and taste using the Kruskal-Wallis test also showed similar results, with p-values of 0.672 and 0.880, respectively. Both values are far above 0.05, indicating no significant differences in panelist preferences among sprout growth phases. This means that even though panelists tended to prefer the aroma and taste at the 24-hour phase, such preferences were subjective and not statistically consistent across individuals. This shows that the sensory aspects of nata de coco are more influenced by the diverse perceptions of the panelists rather than by the treatment differences. Overall, the high p-values across all

variables demonstrate that the treatment factor was not strong enough to produce significant differences. In other words, the data reveal a tendency of variation among phases, but the natural variability among replicates was more dominant than the treatment effect. This emphasizes that the results of this study should not only be interpreted from the statistical side, but also from the descriptive patterns that emerged. To further understand the data distribution patterns underlying these test results, the following section will present the plots of data spread and distribution to provide clearer insights into how the data were distributed in each treatment and why the p-values obtained were relatively high.

Although the statistical results indicated no significant differences among treatments ( $p > 0.05$ ), descriptive patterns revealed consistent tendencies, particularly in the 48-hour germination treatment (F2). This treatment produced nata de coco with higher average values for thickness, weight, and total soluble solids compared to the 24-hour (F1) and 72-hour (F3) sprouts. Biologically, this pattern can be linked to the metabolic dynamics of sprouting. In the early phase of germination (24 h), enzyme activity such as  $\alpha$ -amylase and proteases has only begun to increase, resulting in limited hydrolysis of storage proteins and starch into free amino acids and reducing sugars. By 48 h, enzyme activity reaches a peak, leading to a sharp rise in glucose, maltose, and amino acid availability, which *A. xylinum* can directly assimilate to support cellulose synthesis (Gu et al. 2023; Gunathunga et al. 2024). At the later stage (72 h), many of these compounds are re-utilized for sprout growth, resulting in reduced substrate availability and higher variability among replicates.

From a practical perspective, the observed trends in F2 suggest that mung bean sprouts at mid-germination provide more accessible nitrogen and carbon sources for microbial fermentation. Recent studies emphasize that germination enhances the nutritional quality of legumes by increasing the digestibility of proteins and the content of bioavailable sugars, while reducing antinutritional factors (Gu et al. 2023). This is in line with findings showing that bacterial cellulose yield is strongly affected by the balance between available sugars and nitrogen sources (Montenegro-Silva et al. 2024). Moreover, the use of sprout extracts as natural nitrogen sources resonates with current efforts in sustainable food production. Instead of relying on synthetic nitrogen fertilizers, which may introduce heavy metal residues or environmental burdens, natural alternatives such as mung bean sprouts or agro-industrial by-products have been shown to maintain high bacterial cellulose productivity while reducing ecological impact (Hasanin et al. 2023; Taokaew 2024).

**Table 6.** ANOVA test data results

Variable	Test Type	Statistic (F/ $\chi^2$ )	df	p-value	Normality (Shapiro-Wilk)	Homogeneity (Levene)
Thickness	ANOVA (param.)	F=0.620	2, 3.44	0.589	W=0.897, p=0.236	F=3.57, p=0.095
Weight	ANOVA (param.)	F=2.09	2, 3.34	0.257	W=0.851, p=0.076	F=10.6, p=0.011
Total Soluble Solids	ANOVA (param.)	F=3.68	2, 4.00	0.124	W=0.852, p=0.078	F=0.0135, p=0.987
Aroma	Kruskal-Wallis	$\chi^2=0.795$	2	0.672	—	—
Taste	Kruskal-Wallis	$\chi^2=0.255$	2	0.880	—	—

These tendencies correspond with previous investigations on alternative nitrogen sources for bacterial cellulose fermentation. For instance, mango peel waste hydrolysates have successfully replaced conventional nutrient supplements without compromising cellulose yield (Hasanin et al. 2023), while organic nitrogen from legumes has demonstrated enhanced microbial growth and enzyme biosynthesis compared to inorganic sources (Zheng et al. 2023). Taken together, the present results support the interpretation that the physiological stage of germination, especially around 48 hours, plays a decisive role in shaping the nutrient profile of mung bean sprouts, thereby influencing the physical quality of nata de coco.

Normality test analysis using Q-Q plots revealed a marked contrast between physical and sensory parameters. For the thickness variable (Figure 2), the data points closely followed the theoretical diagonal line with minimal deviation, particularly around the central quantiles. This pattern indicates that the residuals were relatively symmetric and did not exhibit substantial skewness. Thus, the assumption of normality was satisfied, and the thickness of nata de coco could be further analyzed using parametric methods. A similar trend was observed for the weight variable (Figure 3), although its distribution appeared slightly more complex. The Q-Q plot showed deviations in the upper tail, suggesting the presence of one or two extreme values from replicates in the 72-hour phase. Nevertheless, the majority of data points maintained a fairly linear pattern consistent with the theoretical line. This suggests that the weight distribution could still be classified as “marginally normal” or approximately normal. Such conditions are common in biological data, which are strongly influenced by environmental factors and physiological variations in raw materials. Therefore, the use of ANOVA remains appropriate, although the interpretation should take into account variability among replicates.

For the total soluble solids variable (Figure 4), the Q-Q plot points adhered more closely to the diagonal line compared to the previous two variables, with only slight curvature at the lower tail of the distribution. This indicates a near-ideal distribution with well-controlled variability. The Shapiro–Wilk test yielded a p-value of 0.078, greater than 0.05, further confirming that the sugar data followed a normal distribution. Consequently, this parameter could be analyzed using parametric approaches without substantial risk of bias (Habibzadeh 2024). In contrast, the distribution patterns for sensory variables, namely aroma (Figure 5) and taste (Figure 6), differed considerably. The Q-Q plots showed systematic deviations from the diagonal line, with data points curving and scattering irregularly. This suggests that the sensory data did not follow a normal distribution and instead exhibited asymmetric patterns with very high variability among panelists. Methodologically, this is expected since organoleptic assessments rely on subjective perception, leading to heterogeneous data that are difficult to model parametrically. Therefore, the Kruskal–Wallis non-

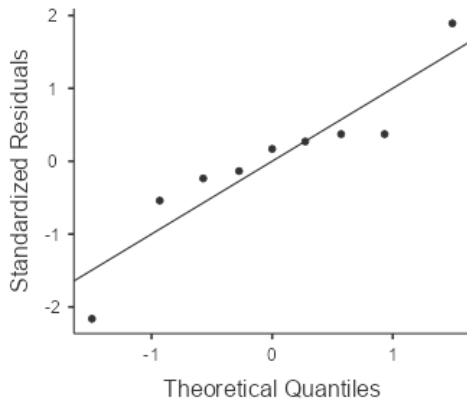
parametric test was deemed more suitable for analyzing these variables, as it does not require the assumption of normality (Nwobi and Akanno 2021). Overall, the Q-Q plot analysis demonstrated that physical parameters such as thickness, weight, and total soluble solids exhibited distributions relatively close to the theoretical diagonal line, with only minor deviations, particularly at the tails. By contrast, sensory parameters such as aroma and taste showed more scattered points that diverged from the diagonal and tended to form distinct curvatures. This contrasting distributional pattern highlights differences in data characteristics, with objectively measured variables appearing more orderly, while subjective variables exhibited high heterogeneity. These Q-Q plot observations provide an initial overview of the underlying data distribution, which served as the basis for selecting the appropriate statistical tests.

## Discussion

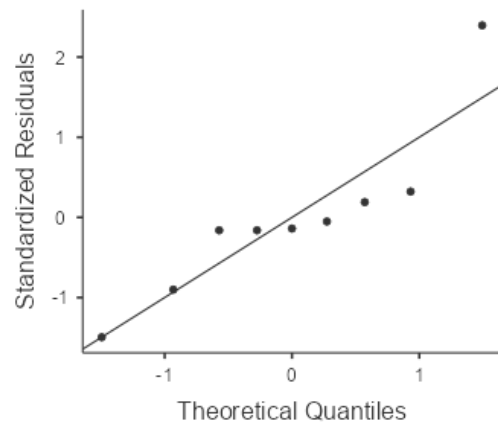
The present study evaluated the effects of mung bean sprout (*V. radiata*) germination phases on the physical and sensory properties of nata de coco. Although statistical analyses indicated no significant differences among treatments, the slight variations observed in color, texture, and aroma suggest that germination-derived bioactive components influence the fermentation process to some degree. Germinated seeds are known to contain higher levels of amino acids, peptides, and reducing sugars (Ratnayani et al. 2022), which may serve as nitrogen and carbon sources for *A. xylinum* during cellulose biosynthesis. These compounds enhance microbial growth and metabolic activity, resulting in more stable nata structures even when differences are not statistically significant.

The absence of significant differences in pH, fiber content, and moisture levels implies that the range of germination periods tested (0–72 h) might not have generated substantial biochemical variation in the extract. Previous studies also reported that moderate germination durations often yield stable nutrient compositions in legumes (Cele et al. 2025). Nevertheless, sensory trends, particularly improved texture and reduced sourness, indicate that sprout-derived amino acids and antioxidants may contribute to more favorable sensory profiles, as reported by Astawan et al. (2024), in fermented soybean-based products.

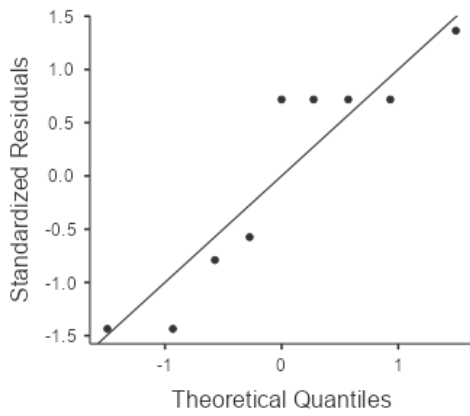
The findings of this study are consistent with earlier research demonstrating that plant-derived nitrogen sources can substitute conventional chemical additives without compromising the quality of nata products (Liu et al. 2023). From a microbial standpoint, the balanced nitrogen-to-carbon ratio provided by mung bean sprouts likely supports cellulose-producing bacteria in maintaining stable pellicle formation. These results reinforce the feasibility of integrating plant-based nutrient sources into microbial fermentation systems, reducing dependency on synthetic supplements such as ammonium sulfate or urea.



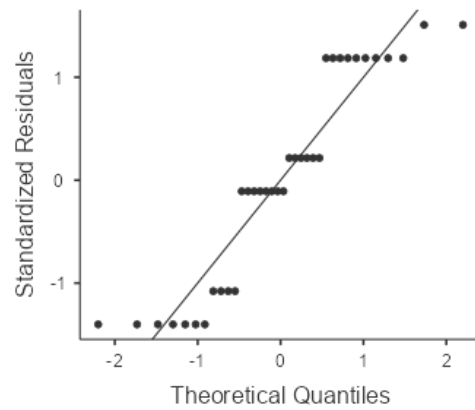
**Figure 2.** Data distribution of nata de coco thickness based on sprout growth phases showing a normal distribution ( $p=0.236$ )



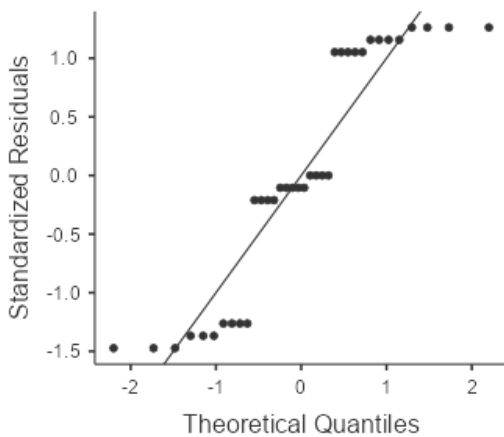
**Figure 3.** Data distribution of nata de coco weight based on sprout growth phases showing a tendency toward normal distribution ( $p=0.076$ )



**Figure 4.** Data distribution of nata de coco sugar content based on sprout growth phases showing a normal distribution ( $p=0.078$ )



**Figure 5.** Distribution of nata de coco aroma assessment by panelists showing a non-normal distribution (non-parametric test applied)



**Figure 6.** Distribution of nata de coco taste assessment by panelists showing a non-normal distribution (non-parametric test applied)

From an agricultural and sustainability perspective, utilizing mung bean sprout extracts aligns with the principles of circular agroindustry. Mung bean sprouts are inexpensive, locally available, and produced from a widely cultivated legume species, allowing farmers and small processors to transform surplus or unsold beans into value-added ingredients. This approach supports resource efficiency and waste minimization within agricultural production systems. Moreover, the application of sprout extracts as natural nitrogen sources in nata fermentation can help local agroenterprises lower production costs while maintaining consistent product quality. Similar strategies have been encouraged in small-scale coconut-based industries to strengthen rural bioeconomy initiatives (Syarifuddin 2022).

Beyond laboratory implications, the practical value of this research lies in promoting low-cost, environmentally friendly fermentation processes that utilize agricultural by-products. Incorporating germination-derived extracts into nata production provides a model for integrating biotechnology with sustainable food processing at the community level. Future studies should explore optimal

germination durations and extraction concentrations to maximize nutrient bioavailability and microbial efficiency in diverse agricultural contexts. Although this study successfully illustrated the effect of mung bean sprout germination phases on the quality of nata de coco, several methodological limitations should be explicitly acknowledged. First, this research did not include a control treatment, such as a conventional synthetic nitrogen source (e.g., ammonium sulfate) or a no-nitrogen control. The absence of such a control limits the interpretation of the results, as comparisons can only be made among germination phases, rather than against the standard benchmark of conventional nata de coco production.

Therefore, all findings in this study should be interpreted as descriptive trends that indicate directional differences among germination phases, rather than absolute differences compared to a standard fermentation system. In addition, the limited number of panelists (12 individuals) and the use of a three-point hedonic scale in the sensory evaluation represent additional constraints that should be considered. Although this approach is appropriate for a preliminary study with a small sample size, the sensory evaluation results should be regarded as indicative rather than conclusive. Future studies are recommended to involve a larger number of panelists and to adopt more detailed hedonic scales (such as five- or nine-point scales) to improve the reliability and generalizability of consumer perception data. Furthermore, this study was limited to small-scale laboratory fermentation and short germination intervals (24-72 hours). Variations in sprout nutrient composition, environmental conditions during germination, and fermentation scale factors were not examined, all of which could influence consistency and outcomes in industrial applications. Further research is recommended to optimize germination duration, extraction methods, and nutrient concentrations to enhance consistency and promote the broader application of plant-based supplements in agricultural bioprocesses. Scaling up fermentation trials and assessing shelf life, textural stability, and consumer acceptance would further support the adoption of natural nitrogen sources in industrial nata de coco production.

In conclusion, this study demonstrated that variations in mung bean sprout germination phases (24 h, 48 h, and 72 h) did not produce statistically significant differences in the physical or sensory properties of nata de coco. However, descriptive trends indicated that the 48-hour germination phase provided a balanced nutrient profile that supported stable fermentation performance. These findings suggest that within the 24-72 h window, the physiological maturity of sprouts exerts only a limited influence on nata quality, implying that the use of sprout extract itself as a natural nitrogen source may be more critical than the specific germination duration. Overall, the results reinforce the potential of mung bean sprout extracts as an eco-friendly and sustainable alternative to synthetic nitrogen sources in microbial cellulose production, supporting the development of safer and more environmentally responsible food biotechnology.

## REFERENCES

- Addo-Preko E, Amissah JGN, Adjei MYB. 2023. The relevance of the number of categories in the hedonic scale to the Ghanaian consumer in acceptance testing. *Front Food Sci Technol* 3: 1071216. DOI: 10.3389/frfst.2023.1071216.
- Agume ASN, Njintang NY, Mbofung CMF. 2017. Effect of soaking and roasting on the physical and pasting properties of soybean flour. *Foods* 6 (2): 12. DOI: 10.3390/foods6020012.
- Akni FV, Melia S, Juliyarsi I. 2024. The effect of using katuk leaves (*Sauropus androgynus* (L) Merr) as a substitute for ZA (ammonium sulfate) on the yield, thickness, color, texture, and organoleptic of nata de whey. *J Nutr Sci* 5 (1): 1-6. DOI: 10.35308/jns.v5i1.8387.
- Alifani SJ, Yuliasari F, Hasannah CS. 2024. Pengaruh penambahan ekstrak daun kelor terhadap sifat fisik dan kimia nata de soya berbahan dasar limbah cair tahu. *Jurnal Sains Teknologi Pangan* 9 (4): 7652-7663. DOI: 10.63071/vrbp7x76. [Indonesian]
- Ammar GAG, Saleh AK, Taha TH, El-Zawawy WK, Abdel-Fattah YR. 2022. Developed applicability of a bacterial cellulose matrix as a gelling substitute for plant tissue culture media. *Cellulose* 29: 7883-7900. DOI: 10.1007/s10570-022-04757-6.
- Astawan M, Prayudani APG, Haekal M, Wresdiyati T, Sardjono RE. 2024. Germination effects on the physical properties and sensory profiles of velvet bean (*Mucuna pruriens*) and soybean tempe. *Front Nutr* 11: 1383841. DOI: 10.3389/fnut.2024.1383841.
- Attaqy F, Kurniasih S, Munarti M. 2023. Effect of sugar type variation on nata de coco growth. *Jurnal Biologi Eksperimen dan Keanekaragaman Hayati* 10 (2): 48-52. DOI: 10.23960/jbekh.v10i2.333.
- Avirasdya RA, Nursiwi A, Sari AM, Zaman MZ, Sanjaya AP. 2022. Kinetics study of bacterial cellulose production by *Acetobacter xylinum* FNC0 0001 with variation of carbon sources. *E3S Web Conf* 344: 03002. DOI: 10.1051/e3sconf/202234403002.
- Biran QK, Zuidar AS, Sartika D, Utomo TP. 2023. Kombinasi ekstrak tauge dan ZA sebagai sumber nitrogen pertumbuhan *Acetobacter xylinum* dalam pembuatan nata berbahan dasar kulit pisang (*Musa paradisiaca* Linn). *J Agroind Berkelanjutan* 2 (1): 161-170. DOI: 10.23960/jab.v2i1.7192. [Indonesian]
- Cardello AV. 2017. Hedonic scaling: assumptions, contexts and frames of reference. *Curr Opin Food Sci* 15: 14-21. DOI: 10.1016/j.cofs.2017.05.002.
- Cele NP, Mianda SM, Sunette L, Sivakumar D. 2025. Insights into the impact of sprouting time on the minerals, amino acids, and bioactive compounds of indigenous Bambara groundnut (*Vigna subterranea* (L.) Verdc.) and cowpea (*Vigna unguiculata* (L.) Walp.). *Intl J Food Sci Technol* 60 (2): vvaf123. DOI: 10.1093/ijfood/vvaf123.
- Chen L, Wu J, Li Z, Liu Q, Zhao X, Yang H. 2019. Metabolomic analysis of energy regulated germination and sprouting of organic mung bean (*Vigna radiata*) using NMR spectroscopy. *Food Chem* 286: 87-97. DOI: 10.1016/j.foodchem.2019.01.183.
- Chugh B, Kamal-Eldin A. 2020. Bioactive compounds produced by probiotics in food products. *Curr Opin Food Sci* 32: 76-82. DOI: 10.1016/j.cofs.2020.02.003.
- Darmawati, Mumi, Sudrajat I, Anwar A. 2022. The effect of fermentation time and different raw materials on N and P content as nutrient sources of *Caulerpa* sp. organic. *IOP Conf Ser Earth Environ Sci* 1119: 012077. DOI: 10.1088/1755-1315/1119/1/012077.
- Devi CB, Kushwaha A, Kumar A. 2015. Sprouting characteristics and associated changes in nutritional composition of cowpea (*Vigna unguiculata*). *J Food Sci Technol* 52 (10): 6821-6827. DOI: 10.1007/s13197-015-1832-1.
- Dey B, Jayaraman S, Balasubramanian P. 2024. Upcycling of tea processing waste into kombucha-derived bioactive cellulosic composite for prospective wound dressing action. *3 Biotech* 14 (10): 253. DOI: 10.1007/s13205-024-04095-3.
- Dong K, Zhen S, Cheng Z, Cao H, Ge P, Yan Y. 2015. Proteomic analysis reveals key proteins and phosphoproteins upon seed germination of wheat (*Triticum aestivum* L.). *Front Plant Sci* 6: 1017. DOI: 10.3389/fpls.2015.01017.
- Fajari WM, Ardigumita F, Kusmayadi A. 2025. Kualitas fisik limbah tauge kacang hijau yang difermentasi effective microorganism-4 dengan level berbeda. *Agrinimal J Ilmu Ternak Tanaman* 13 (1): 65-71. DOI: 10.30598/ajitt.2025.13.1.65-71. [Indonesian]
- Fidyasari A, Ula H. 2021. Effect of sprout juice on the chemical characteristics of nata de *Annona montana*. *Pharmadematica Jurnal Kefarmasian Gizi* 1 (1): 30-39. DOI: 10.54445/pharmadematica.v1i1.7.

- García-Sánchez ME, Robledo-Ortiz JR, Jiménez-Palomar I, González-Reynoso O, González-García Y. 2020. Production of bacterial cellulose by *Komagataeibacter xylinus* using mango waste as alternative culture medium. *Rev Mex Ing Quím* 19 (2): 541-552. DOI: 10.24275/rmiq/Bio743.
- Gu J, Bk A, Wu H, Lu P, Nawaz MA, Barrow CJ, Dunshea FR, Suleria HAR. 2023. Impact of processing and storage on protein digestibility and bioavailability of legumes. *Food Rev Intl* 39 (7): 4586-4619. DOI: 10.1080/87559129.2022.2039690.
- Gumelar G, Fariyanto DE. 2020. Pengaruh waktu perkecambahan biji kacang hijau (*Phaseolus radiatus* L.) terhadap produksi enzim  $\alpha$ -amilase. *Cermin Jurnal Penelitian* 4 (1): 68-74. DOI: 10.36841/cermin\_unars.v4i1.519. [Indonesian]
- Gunathunga C, Senanayake S, Jayasinghe MA, Brennan CS, Truong T, Marapana U, Chandrapala J. 2024. Germination effects on nutritional quality: A comprehensive review of selected cereals and pulses changes. *J Food Compos Anal* 128: 106024. DOI: 10.1016/j.jfca.2024.106024.
- Habibzadeh F. 2024. Data distribution: normal or abnormal? *J Kor Med Sci* 39 (3): e35. DOI: 10.3346/jkms.2024.39.e35.
- Han D, Yang Y, Guo Z, Dai S, Jiang M, Zhu Y, Wang Y, Yu Z, Wang K, Rong C, Yu Y. 2024. A review on the interaction of acetic acid bacteria and microbes in food fermentation: A microbial ecology perspective. *Foods* 13 (16): 2534. DOI: 10.3390/foods13162534.
- Hasanin MS, Abdelraof M, Hashem AH, El Saied H. 2023. Sustainable bacterial cellulose production by *Achromobacter* using mango peel waste. *Microb Cell Fact* 22 (1): 24. DOI: 10.1186/s12934-023-02031-3.
- Hu M, Zhao L, Sun H, Liu Q, Xue Y, Cao R. 2025. Decoding volatile-microbial-physical interplay of sensory preference in commercial shrimp paste based on flavoromics and high-throughput sequencing. *Curr Res Food Sci* 10: 101050. DOI: 10.1016/j.crf.2025.101050.
- Iguchi M, Yamanaka S, Budhiono A. 2000. Bacterial cellulose—a masterpiece of nature's arts. *J Mater Sci* 35: 261-270. DOI: 10.1023/A:1004775229149.
- Ikram A, Saeed F, Afzaal M, Imran A, Niaz B, Tufail T, Hussain M, Anjum FM. 2021. Nutritional and end-use perspectives of sprouted grains: A comprehensive review. *Food Sci Nutr* 9 (8): 4617-4628. DOI: 10.1002/fsn3.2408.
- Indraningtyas L, Kustiyawati ME, Fitriah N. 2024. Physical characteristics of immobilized cells *Acetobacter xylinum* of various concentrations of Na-alginate. *Biol Med Nat Prod Chem* 13 (1): 165-172. DOI: 10.14421/biomedich.2024.131.165-172.
- Junardi J, Febrina A. 2022. Pengaruh perbedaan formulasi tauge terhadap produk nata de-coco. *Pasundan Food Technol J* 9 (2): 32-38. DOI: 10.23969/pftj.v9i2.5591. [Indonesian]
- Latumahina M, Awan A, Rumahlatu D. 2017. Pengaruh suhu dan lama fermentasi terhadap uji organoleptik pada pembuatan nata buah enau (*Areng pinnata* Merr). *Biopendix Jurnal Biologi Pendidikan dan Terapan* 4 (1): 29-37. DOI: 10.30598/biopendixvol4issue1page29-37. [Indonesian]
- Lawless HT, Heymann H. 2010. *Sensory Evaluation of Food: Principles and Practices*. 2nd ed. Springer, New York. DOI: 10.1007/978-1-4419-6488-5.
- Li G, Wang L, Deng Y, Wei Q. 2022. Research progress of the biosynthetic strains and pathways of bacterial cellulose. *J Ind Microbiol Biotechnol* 49 (1): kuab071. DOI: 10.1093/jimb/kuab071.
- Li Z, Wang T, Jiang H, Wang WT, Lan T, Xu L, Yun YH, Zhang W. 2024. Comparative key aroma compounds and sensory correlations of aromatic coconut water varieties: Insights from GC×GC-O-TOF-MS, E-nose, and sensory analysis. *Food Chem X* 21: 101141. DOI: 10.1016/j.fochx.2024.101141.
- Liu X, Cao L, Wang S, Huang L, Zhang Y, Tian M, Li X, Zhang J. 2023. Isolation and characterization of bacterial cellulose produced from soybean whey and soybean hydrolyzate. *Sci Rep* 13 (1): 15404. DOI: 10.1038/s41598-023-42304-w.
- Mandey LC, Tarore D, Kandou JEA, Dumais NM. 2020. Teknologi produksi nata de coco berbahan baku organik. *Pro Food* 6 (2): 665-672. DOI: 10.29303/profood.v6i2.139. [Indonesian]
- McManus JB, Yang H, Wilson L, Kubicki JD, Tien M. 2018. Initiation, elongation, and termination of bacterial cellulose synthesis. *ACS Omega* 3 (3): 2690-2698. DOI: 10.1021/acsomega.7b01808.
- Molina-Ramírez C, Castro M, Osorio M, Torres-Taborda M, Gómez B, Zuluaga R, Gómez C, Gañán P, Rojas OJ, Castro C. 2017. Effect of different carbon sources on bacterial nanocellulose production and structure using the low pH resistant strain *Komagataeibacter medellinensis*. *Materials* 10 (6): 639. DOI: 10.3390/ma10060639.
- Montenegro-Silva P, Ellis T, Dourado F, Gama M, Domingues L. 2024. Enhanced bacterial cellulose production in *Komagataeibacter sucrofermentans*: Impact of different PQQ-dependent dehydrogenase knockouts and ethanol supplementation. *Biotechnol Biofuels Bioprod* 17 (1): 35. DOI: 10.1186/s13068-024-02482-9.
- Murtius WS, Fiana RM, Purwanti G. 2021. Pengaruh konsentrasi sari tauge layu sebagai sumber nitrogen terhadap karakteristik nata jambu biji merah (*Psidium guajava* L.). *Jurnal Teknologi Pertanian Andalas* 25 (2): 230-248. DOI: 10.25077/jtpa.25.2.230-248.2021. [Indonesian]
- Ningsih L, Zakiah Z, Rahmawati. 2021. Fermentasi nira kelapa (*Cocos nucifera* L.) dengan penambahan ekstrak kecambah kacang hijau (*Phaseolus radiata* L.) pada pembuatan nata de nira. *Bioma Jurnal Biologi Makassar* 6 (1): 57-65. DOI: 10.20956/bioma.v6i1.12106. [Indonesian]
- Nurdin GM, Nurhidayah, Aminah. 2023. Pengaruh konsentrasi starter *Acetobacter xylinum* dan lama fermentasi terhadap kualitas produk nata de coco. *Bioma Jurnal Biologi Dan Pembelajarannya* 5 (2): 116-125. DOI: 10.31605/bioma.v5i2.3098. [Indonesian]
- NutriVals. 2025. Mung bean Sprouts – Nutrition Facts. <https://www.nutriVals.com/nutrition-facts/vegetables/mung-bean-sprouts/>.
- Nwobi FN, Akanno FC. 2021. Power comparison of ANOVA and Kruskal–Wallis tests when error assumptions are violated. *Metodol Zvezki* 18 (2): 53-71. DOI: 10.51936/LTGT2135.
- Oliva RL, Khadka UB, Camenzind T, Dyckmans J, Joergensen RG. 2025. Constituent of Extracellular Polymeric Substances (EPS) produced by a range of soil bacteria and fungi. *BMC Microbiol* 25: 298. DOI: 10.1186/s12866-025-04034-z.
- Park SW, Cho TJ, Rhee MS. 2022. Corrigendum to “Characterization of the nitrite production of mesophilic spore-forming bacteria during the handling of reconstituted infant formula”. *Food Res Intl* 160: 111570. DOI: 10.1016/j.foodres.2022.111570.
- Płoska J, Garbowska M, Ścibisz I, Stasiak-Rózańska L. 2025. Study on obtaining bacterial cellulose by *Komagataeibacter xylinus* in co-culture with lactic acid bacteria in whey. *Appl Microbiol Biotechnol* 109 (1): 191. DOI: 10.1007/s00253-025-13582-3.
- Portela R, Leal CR, Almeida PL, Sobral RG. 2019. Bacterial cellulose: A versatile biopolymer for wound dressing applications. *Microb Biotechnol* 12 (4): 586-610. DOI: 10.1111/1751-7915.13392.
- Potočnik V, Gorgieva S, Trček J. 2023. From nature to lab: Sustainable bacterial cellulose production and modification with synthetic biology. *Polymers* 15 (16): 3466. DOI: 10.3390/polym15163466.
- Pradana AP, Mardhiana, Suriana, Adiwena M, Yousif AIA. 2022. Formula bakteri endofit untuk meningkatkan pertumbuhan bibit jagung pada tanah masam podsolik merah-kuning. *Jurnal Ilmiah Inovasi* 22 (1): 30-41. DOI: 10.25047/jii.v22i1.3091. [Indonesian]
- Prasad P, Sahu JK. 2025. Interplay of germination time, nutritional content, bioactive constituents, antioxidant activity, and in-vitro digestibility in kodo, little, and barnyard millets. *Food Humanit* 4: 100545. DOI: 10.1016/j.fooHum.2025.100545.
- Puspitasari A, Harini N, Anggriani R. 2024. Studi karakteristik fisikokimia tepung kacang hijau (*Vigna radiata* L.) germinasi oleh waktu dan media germinasi. *Food Technol Halal Sci J* 7 (1): 93-107. DOI: 10.22219/fths.v7i1.35960. [Indonesian]
- Putri SNY, Syaharani WF, Utami CVB, Safitri DR, Arum ZN, Prihastari ZS, Sari AR. 2021. The effect of microorganism, raw materials, and incubation time on the characteristic of nata: A review. *Jurnal Teknologi Hasil Pertanian* 14 (1): 62-74. DOI: 10.20961/jthp.v14i1.47654.
- Rahman ANF, Asfar M, Suwandi N. 2021. Pengaruh perkecambahan gabah terhadap rendemen, kualitas fisik dan nilai sensori beras. *Jurnal Penelitian Pascapanen Pertanian* 17 (3): 177-183. DOI: 10.21082/jpasca.v17n3.2020.177-183. [Indonesian]
- Ramana KV, Tomar A, Singh L. 2000. Effect of various carbon and nitrogen sources on cellulose synthesis by *Acetobacter xylinum*. *World J Microbiol Biotechnol* 16 (3): 245-248. DOI: 10.1023/A:1008958014270.
- Ratnasari E, Lahming L, Wiharto M. 2020. Analisis kualitas nata de corn dengan berbagai konsentrasi gula pasir. *Jurnal Pendidikan Teknologi Pertanian* 5 (2): 55. DOI: 10.26858/jtp.v5i2.9929. [Indonesian]
- Ratnayani K, Wisaniyasa NW, Wiwik Oktayuni NP. 2022. Effect of solvent type and germination time on the level of free amino acid and peptides of germinated pigeon pea (*Cajanus cajan* (L.) Millsp) extract. *J Pure*

- Appl Chem Res 11 (2): 136-142. DOI: 10.21776/ub.jpacr.2022.011.02.672.
- Rezazadeh M, Babaipoor V, Motamedian E. 2020. Reconstruction, verification and in-silico analysis of a genome-scale metabolic model of bacterial cellulose producing *Komagataeibacter xylinus*. *Bioprocess Biosyst Eng* 43 (6): 1017-1026. DOI: 10.1007/s00449-020-02299-4.
- Rodriguez-Campos J, Escalona-Buendía HB, Contreras-Ramos SM, Orozco-Avila I, Jaramillo-Flores E, Lugo-Cervantes E. 2012. Effect of fermentation time and drying temperature on volatile compounds in cocoa. *Food Chem* 132 (1): 277-288. DOI: 10.1016/j.foodchem.2011.10.078.
- Santosa B, Rozana R, Astutik A. 2021. Pemanfaatan sumber nitrogen organik dalam pembuatan nata de coco. *Teknologi Pangan* 12 (1): 52-60. DOI: 10.35891/tp.v12i1.2431. [Indonesian]
- Sarifudin, Ramadhan A, Mardin S. 2024. Development of an entrepreneurship teaching module based on research on the use of white langkas (*Alpinia galanga*) on the quality of nata de coco. *Intl J Sci Res Arch* 12 (2): 1022-1031. DOI: 10.30574/ijrsra.2024.12.2.1265.
- Sine Y, Pardosi L, Hanas DF, Manlea H, Nalle MN. 2021. Pelatihan pembuatan nata de coco bagi masyarakat kelompok tani Sehati Desa Tublopo. *Bernas Jurnal Pengabdian Kepada Masyarakat* 2 (4): 901-906. DOI: 10.31949/jb.v2i4.1593. [Indonesian]
- Singh OC, Panesar PS, Chopra HK. 2017. Production and optimization of bacterial cellulose with different carbon and nitrogen sources using *Gluconacetobacter xylinus* C18 strain. *Asian J Chem* 29 (4): 933-936. DOI: 10.14233/ajchem.2017.20415.
- Stefanowicz P. 2013. Sensory evaluation of food: Principles and practices. *J Wine Res* 24 (1): 80. DOI: 10.1080/09571264.2013.764662.
- Syarifuddin S. 2022. Coconut-based community economic development strategy in Indragiri Hilir Regency. *ADPEBI Intl J Bus Social Sci* 2 (1): 13-21. DOI: 10.54099/aijbs.v2i1.106.
- Tambunan MPM, Ginting Z, Nurlaila R, Muhammad M, Ishak I. 2021. Pengaruh suhu dan waktu hidrolisis terhadap kadar glukosa dalam pembuatan sirup glukosa dari biji alpukat dengan metode hidrolisis asam. *Chem Eng J Storage* 1 (3): 17-26. DOI: 10.29103/cejs.v1i3.4798. [Indonesian]
- Taokaew S. 2024. Bacterial nanocellulose produced by cost-effective and sustainable methods and its applications: A review. *Fermentation* 10 (6): 316. DOI: 10.3390/fermentation10060316.
- Triandini IGAAH, Wangiyana IGAS. 2022. Mini-review uji hedonik pada produk teh herbal hutan. *Jurnal Silva Samalas* 5 (1): 12-19. DOI: 10.33394/jss.v5i2.5473. [Indonesian]
- Tuncel NY, Kaya HP, Sakarya FB, Andaç AE, Korkmaz F, Ozkan G, Tuncel NB, Capanoglu E. 2025. The effect of germination on antinutritional components, in vitro starch and protein digestibility, content, and bioaccessibility of phenolics and antioxidants of some pulses. *Food Sci Nutr* 13 (5): e70103. DOI: 10.1002/fsn3.70103.
- van Wyk N. 2024. Current research on flavor compounds in fermented food products. *Foods* 13 (5): 730. DOI: 10.3390/foods13050730.
- Wang H, Guo X, Li Q, Lu Y, Huang W, Zhang F, Chen L, Liu RH, Yan S. 2020. Integrated transcriptomic and metabolic framework for carbon metabolism and plant hormones regulation in *Vigna radiata* during post-germination seedling growth. *Sci Rep* 10 (1): 3745. DOI: 10.1038/s41598-020-60771-3.
- Wang W, Mai X, Wang D, Zheng Y, Liu F, Sun Z. 2023. Mathematical modeling of temperature and natural antimicrobial effects on germination and outgrowth of *Clostridium perfringens* in chilled chicken. *LWT* 177: 114555. DOI: 10.1016/j.lwt.2023.114555.
- Wang X, Fan B, Li Y, Fei C, Xiong Y, Li L, Liu Y, Tong L, Huang Y, Wang F. 2024. Effect of germination on the digestion of legume proteins. *Foods* 13 (17): 2655. DOI: 10.3390/foods13172655.
- Wintersohle C, Arnold SJ, Geis HM, Keutgen F, Eitzbach L, Schweiggert-Weisz U. 2024. Impact of short-term germination on dehulling efficiency, enzymatic activities, and chemical composition of mung bean seeds (*Vigna radiata* L.). *Future Foods* 10: 100416. DOI: 10.1016/j.fufo.2024.100416.
- Wu RB, Huang JF, Huan R, Chen LL, Yi CP, Liu D, Wang M, Liu CL, He HL. 2021. New insights into the structure-activity relationships of antioxidative peptide PMRGGGGYHY. *Food Chem* 337: 127678. DOI: 10.1016/j.foodchem.2020.127678.
- Wu Y, Shin WS. 2025. Germination-induced changes in the nutritional, bioactive, and digestive properties of lima bean (*Phaseolus lunatus* L.). *Foods* 14 (12): 2123. DOI: 10.3390/foods14122123.
- Yamin M, Khairuddin, Japa L, Artayasa IP. 2022. Pemanfaatan air buah kelapa untuk pembuatan natadecoco pada Kelompok Wirausaha Mandiri (KWM) di Desa Gunungsari, Kabupaten Lombok Barat. *Jurnal Pengabdian Magister Pendidikan IPA* 5 (2): 59-64. DOI: 10.29303/jmpipi.v5i2.1573. [Indonesian]
- Yi-Shen Z, Shuai S, Fitzgerald R. 2018. Mung bean proteins and peptides: nutritional, functional and bioactive properties. *Food Nutr Res* 62: 1290. DOI: 10.29219/fnr.v62.1290.
- Yu W, Zhang G, Wang W, Jiang C, Cao L. 2020. Identification and comparison of proteomic and peptide profiles of mung bean seeds and sprouts. *BMC Chem* 14 (1): 46. DOI: 10.1186/s13065-020-00700-7.
- Zaura A, Iswadi I, Samingan S. 2023. Pengaruh proporsi volume air cucian beras dalam air kelapa terhadap sifat organoleptik nata de coco. *Jurnal Biologi Edukasi* 15 (1): 1-9. DOI: 10.24815/jbe.v15i1.32209.
- Zhang H, Chen H, Wang W, Jiao W, Chen W, Zhong Q, Yun YH, Chen W. 2020. Characterization of volatile profiles and marker substances by HS-SPME/GC-MS during the concentration of coconut jam. *Foods* 9 (3): 347. DOI: 10.3390/foods9030347.
- Zheng W, Lu P, Jiang D, Chen L, Li Y, Deng H. 2023. An ultrasonographic study of gouty arthritis: Synovitis and its relationship to clinical symptoms: a retrospective analysis. *Health Sci Rep* 6 (6): e1312. DOI: 10.1002/hsr2.1312.
- Živković A, Cigić B, Polak T, Požrl T. 2025. Hulled oat (*Avena sativa* var. Noni) and naked oat (*Avena nuda* var. Kamil): Distribution of selected secondary metabolites during germination. *Food Chem* 492: 145505. DOI: 10.1016/j.foodchem.2025.145505.