JOBIMB, 2025, Vol 13, No 1 SP1, 13-17
https://doi.org/10.54987/jobimb.v13iSP1.1096

HIBISCUS PUBLISHER

JOURNAL OF BIOCHEMISTRY, MICROBIOLOGY AND BIOTECHNOLOGY

Website: http://journal.hibiscuspublisher.com/index.php/JOBIMB/index

JOBIMB VOL 13 NO 1 SP1 2025
Tempeh crisps

Effects of Incorporating Rambutan Juice on the Development, Physicochemical and Sensory Acceptance of Nata de Coco

Megat A'izzul Irfaan M Al-Muz-Zammil[1] and Azizah Mahmood[1]*

[1]Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia.

*Corresponding author:
Azizah Mahmood,
Faculty of Fisheries and Food Science,
Universiti Malaysia Terengganu,
21030 Kuala Nerus,
Terengganu,
Malaysia.
Email: azizah.m@umt.edu.my

HISTORY

Received: 7th April 2025
Received in revised form: 5th July 2025
Accepted: 30th July 2025

KEYWORDS

Nata de coco
Rambutan juice
Bacterial cellulose
Physicochemical
Sensory acceptance

ABSTRACT

Malaysia produces approximately 80,000 tonnes of rambutan annually during the harvesting season, yet its consumption remains largely limited to raw fruit, underscoring the need for innovation and diversification in rambutan-derived food products. This research investigates the feasibility of using rambutan juice as an alternative to coconut water for producing nata de coco, with a focus on maintaining product yield, physicochemical properties, and sensory acceptance. Fermentation media with different ratios of coconut water to rambutan juice were prepared as follows: 100:0 (control), 75:25, 25:75, and 0:100. The mixtures were fermented at room temperature for 21 days, after which the nata was harvested and analyzed for thickness, wet weight, physicochemical properties (moisture and fiber content), texture, color, and sensory acceptance. The study found that higher concentrations of rambutan juice increased both the thickness and yield of nata film. Nata produced with 100% rambutan juice showed significantly greater thickness compared to that made with 100% coconut water. Both 75% and 100% rambutan juice resulted in significantly higher yields than the control, with these ratios producing nata characterized by a harder, chewier, and gummier texture. The addition of rambutan juice did not significantly affect the color of the nata, but it did significantly increase its crude fiber and moisture content. Sensory acceptance of nata made with rambutan juice was comparable to traditional coconut water-based nata de coco, establishing it as a viable alternative for future production. This study demonstrates that rambutan juice serves as an effective and functional alternative to coconut water in nata production, enhancing yield, texture, and nutritional value, especially in terms of crude fiber, while maintaining consumer appeal.

INTRODUCTION

Rambutan (*Nephelium lappaceum*) is a tropical fruit native to Southeast Asia, primarily found in Indonesia, Malaysia, Thailand, and the Philippines. Belonging to the Sapindaceae family, it shares botanical kinship with other notable fruits such as lychee and longan. Rambutan is recognized for its appealing sensory attributes, characterized by a delicate balance of sweetness and acidity, almost similar to those of grapes or lychee [1]. Its flavor profile is attributed to a combination of sugars, primarily glucose and fructose, along with various organic acids such as citric and malic acid. The aromatic compounds present in rambutan contribute to its distinctive floral notes, enhancing its desirability in culinary applications. When in season, the prices of rambutan decrease significantly due to its abundance in the local markets as well as its high perishability. Furthermore, rambutan is typically sold and consumed raw. Therefore, leaving room for further possibilities of its utilization for new products.

Nata de coco is a dessert originating from the Philippines, made from bacterial cellulose resulting from the fermentation of coconut water. The fermentation of this product is aided by acetic acid bacteria, mainly *Acetobacter xylinum*. Typical production of nata de coco allows for the fermentative medium to age for 7-10 days. This product is often used in desserts, fruit cocktails, and fruit jellies. Furthermore, nata de coco is considered neutral in terms of sensory properties; thus, it is frequently modified or complemented with additional flavors, typically those of fruit.

According to previous studies, the bacterial cellulose production of nata can be alternated using low-cost substrates, such as apple and pineapple juices and tomato juice [2]. There have also been previous endeavors to incorporate low-cost carbon substrates sourced from agricultural waste into the production of nata, for instance, the peels of banana and passion fruit [3].

https://doi.org/10.54987/jobimb.v13iSP1.1096

In the fermentation of bacterial cellulose (BC) for nata de coco, the bacterial species applicable for this process are mainly *Achromobacter, Alcaligenes, Aerobacter, Agrobacterium, Azotobacter, Gluconacetobacter, Pseudomonas,* and *Rhizobium* [4]. However, typically, *Acetobacter xylinum* is used in both commercial production and research studies. The production rates of these bacteria and their cellulose are known to be affected by the type and concentration of sugar, nitrogen source, and pH [2]. Many strains of *A. xylinum* are capable of producing cellulose in varying amounts and growing on a wide range of substrates, including glucose, sucrose, fructose, invert sugar, ethanol, and glycerol. The BC produced is a purified form of extracellular polysaccharide, which is formed through the phosphorylation of glucose in the presence of glucokinase. As a result, the fermentation medium of nata can be alternated with different sources of carbon, such as other fruit juices, for example, lychee juice [5].

Given the underutilization of rambutan juice and the increasing demand for functional, sustainable food innovations, this study aims to investigate the feasibility of using rambutan juice as an alternative substrate in nata de coco production. By evaluating its effects on yield, texture, nutritional composition, and consumer acceptability, the research aims to determine whether rambutan juice can serve as a viable substitute for coconut water in producing high-quality nata de coco ("nata").

MATERIALS AND METHODS

Preparation of Rambutan Nata

Rambutan (*Nephelium lappaceum*) and coconut water were purchased from the local markets in Kuala Nerus, Terengganu, Malaysia. *Acetobacter xylinum* culture was purchased from Nata de Coco Indohasco, and food-grade ammonium sulphate was purchased from DCheme Malaysia Sdn. Bhd. White granulated sugar and acetic acid were purchased at a local shop in Kuala Nerus, Terengganu. pH was determined using a pH meter. Sample preparation was modified from [5]. The rambutan was peeled and pitted, and then the juice was extracted. The juice was heated to 70°C for 1 minute. Fermentation media with different concentrations of coconut water and rambutan juice were prepared for treatment. (100:0 (control), 75:25, 50:50, 25:75, and 0:100).

The sample media were adjusted to 8° Brix using white granulated sugar. Then, 0.5% (w/v) of ammonium sulfate was added, and pH was adjusted to 4.0 using acetic acid. After that, the fermentation media were heated to 100°C for 5 minutes, then left to cool. Once the sample media came back down to room temperature, 10% (v/v) of *A. xylinum* was added. The finished sample media were poured into a sterilized container and left to ferment at room temperature for 21 days. On day 21, sheets of nata produced were harvested and then cut into cubes of 1.5 cm × 1.5 cm × 1.5 cm dimensions. These cubes were boiled in water for 5 minutes. Nata cubes were immersed in water for 2 days, with periodic water changes, to eliminate the sour aroma resulting from fermentation. Finally, nata samples were kept in a container filled with water until further analysis.

Thickness

On day 21, the nata sheet was extracted. Three random sides of the sheets were chosen and measured using a ruler. The average value of the three measurements was calculated and chosen as the data.

Wet Weight

On day 21, the fresh nata sheets were patted dry with clean paper towels to remove excess water. The sheets of nata were weighed using an analytical balance. The weight of samples was measured in units of grams (g), rounded to two decimal points.

Colour

The cubes of nata samples were put into a small ziplock bag. For each repetition, the colour of nata was taken in three random areas, whereby the average value was calculated and recorded as data. The colour of nata cubes was recorded in CIELAB colour space, where values were denoted as L* (brightness), a* (red-green), and b* (yellow-blue). The colorimeter used was the Konica Minolta CR-400 Chroma Meter set. The reading was taken for each repetition, whereby the average value was calculated.

Texture

Nata was cut into 2cm × 2cm × 2cm cubes. The hardness, chewiness, springiness, cohesiveness, and gumminess of BC cubes were determined by a texture analyzer (TA-XT plus). The test conditions for the TA were set at 3.0 mm/s for the pre-test speed, 0.5 mm/s for the test speed, and 0.5 mm/s for the post-test speed, with a 50% strain applied to the distance of compression. The trigger force was 5g, and two compression cycles were performed, as modified from [6].

Crude Fiber and Moisture Content

Crude fiber (wet basis) was determined by the gravimetric method, and moisture content was determined based on the weight loss (% w/w) of the samples when dried in a hot air oven, according to AOAC (2000). The percentages of fiber and moisture in the produced nata were calculated using the following formula:

$$\text{Crude fiber (\%)} = \frac{(m3-m1)-(m4-m5)}{m2} \; x \; 100\%$$

Where;
m1 = weight of empty fiber bag
m2 = weight of sample
m3 = weight of fiber bag and crucible before ashing
m4 = weight of fiber bag and crucible after ashing
m5 = weight of ash of empty fiber bag

$$\text{Moisture content (\%)} = \frac{W2-W3}{W2-W1} \; x \; 100\%$$

Where;
W1 = weight of empty crucible (g)
W2 = weight of crucible with sample in it (g)
W3 = weight of crucible with sample after drying (g)

Sensory Evaluation

Hedonic evaluation was carried out by 30 untrained panels randomly selected from Universiti Terengganu Malaysia students. Color, overall appearance, aroma, texture, flavor, and overall acceptability of nata were evaluated on a scale of 1 (extremely disliked) to 9 (extremely liked). During evaluation by panelists, nata was cut into 1.5cm × 1.5cm × 1.5cm cubes and served with sugar water (1:5, sugar to water) carrier.

Statistical Analysis

All samples were replicated in triplicate, and data were presented as means ± standard deviation (SD). The data was analyzed using one-way analysis of variance (ANOVA) followed by Tukey's tests. Statistical significance was defined as $p<0.05$. The statistical analysis was carried out using Minitab Statistical Software version 21.

RESULT AND DISCUSSION

The goal of measuring thickness was to assess and compare the yield of nata across the different formulations. Based on the findings, the thickness of nata generally increases with the addition of rambutan juice. The highest thickness of nata was recorded in a sample with 100% rambutan juice, with a thickness of 1.50 ± 0.30 cm after 21 days of fermentation (**Table 1**). Rambutan juice, in particular, produces optimal growth in thickness when fermented at pH 4.0 [7]. Organic acids such as pyruvic acid, malic acid, citric acid, and lactic acid have been shown to improve nata production and yield [8]. To correlate, rambutan juice has been recorded to be rich in organic acids. Rambutan has been recorded to contain a high amount of citric acid, which is the major organic acid found in the fruit [9]. Furthermore, the study also revealed various levels of tartaric, lactic, and ascorbic acid ranging from 0.1 to 1.2 g/kg. It can be concluded that the observed trend of increasing nata thickness with higher concentrations of rambutan juice in this study may be directly correlated with the organic acid profile of the rambutan juice. Since this study did not involve determining fermentation kinetics, identifying the specific factors that influence nata film thickness remains challenging. Future research could benefit from investigating fermentation dynamics, including pH fluctuations, microbial growth curves, and sugar depletion, throughout the fermentation process.

Table 1. Thickness of nata made with different concentrations of rambutan juice

Concentration of rambutan juice (%)	Thickness (cm)
0	0.81 ± 0.05^{b}
25	0.77 ± 0.19^{b}
75	1.20 ± 0.19^{ab}
100	1.50 ± 0.30^{a}

Note: Values are expressed in mean ± standard deviation for three replications (n=3). Values with different superscript letters ($^{a-b}$) are significantly different at $p < 0.05$

Table 2 shows the weight of nata made with different concentrations of rambutan juice. The objective of measuring weight was to compare the yield between nata samples. Nata made with 75% and 100% rambutan juice yielded the most weight at 269.30 ± 36.20 and 299.67 ± 10.97, respectively, with significant differences from the other two samples. This suggests that increasing the rambutan juice concentration would increase the weight yield of nata. Reducing sugars, such as fructose and glucose, are more easily metabolized by *Acetobacter xylinum* into nata compared to non-reducing sugars [10]. This means faster and more efficient production of cellulose (nata). Moreover, rambutan juice contains high amounts of reducing sugars such as fructose (3.0 g/100 g) and glucose (2.8 g/100 g) [11]. Thus, rambutan juice may have provided the fermentation bacteria with more readily available reducing sugar, causing faster formation of nata.

Table 2. Weight of nata made with different concentrations of rambutan juice

Concentration of rambutan juice (%)	Weight (g)
0	124.67 ± 7.37^{b}
25	112.67 ± 11.59^{b}
75	269.30 ± 36.20^{a}
100	299.67 ± 10.97^{a}

Note: Values are expressed in mean ± standard deviation for three replications (n=3). Values with different superscript letters ($^{a-b}$) are significantly different at $p<0.05$.

Table 3 shows the L*, a*, and b* values of nata with different coconut water/rambutan volume ratios. Through this analysis, it was revealed that 25% of the rambutan juice sample had the highest L* value among all other nata formulations (p < 0.05). This means that this sample was brightest in colour. This occurrence may be due to the reaction between hydrolyzed ions of ammonium sulfate and the sugar or other components within the coconut water and rambutan juices, resulting in more reactions that produce a darker color [12]. The sugars present in rambutan juice, such as glucose and fructose, can participate in Maillard reactions during heating or fermentation, especially in the presence of amino acids, leading to the formation of brown pigments and contributing to the darkening of nata.

Table 3. L*, a* and b* colour values of nata samples,

Concentration of rambutan juice (%)	L* (lightness)	a* (greenness/redness)	b* (blueness/yellowness)
0	45.94 ± 1.93^{b}	0.78 ± 0.09^{a}	0.10 ± 1.69^{ab}
25	52.57 ± 0.49^{a}	1.02 ± 1.14^{a}	1.40 ± 1.06^{a}
75	43.81 ± 1.63^{b}	0.37 ± 0.55^{a}	-1.12 ± 1.25^{ab}
100	46.90 ± 1.90^{b}	0.36 ± 0.21^{a}	-1.92 ± 0.87^{b}

Note: Values are expressed in mean ± standard deviation for three replications (n=3). Values with different superscript letters ($^{a-b}$) are significantly different at $p < 0.05$

Darker color in bacterial cellulose (nata) can be due to the degree of its crystallinity. A study by [13] revealed that the degree of crystallinity can also affect the color of nata in terms of brightness. In the study, the sample with the lowest crystallinity index of 2.750 showed the brightest color, meanwhile, the nata sample with higher crystallinity (3.852) was darkest in colour [13]. **Table 4** shows the texture profile analysis of nata made with different concentrations of rambutan juice. This analysis aimed to examine the effect of rambutan juice on the physical properties of nata. In this analysis, the texture is analyzed in terms of hardness (g), springiness, cohesiveness, gumminess, chewiness (g·cm), and resilience. Results show that increased percentages of rambutan juice (75% and 100%) increase the hardness of nata compared to the control and 25% rambutan juice. Samples 75% and 100% rambutan juice recorded significantly the highest hardness.

Compounds such as sugars and other soluble solids can interact with the cellulose network of bacterial cellulose (nata), thereby filling the space within its structure, making it denser and harder in texture [14]. Rambutan juice is rich in sugars and other soluble solids such as sucrose (5.38-10.01%), fructose (1.75-3.18%), and glucose (1.72-2.43%) [11]. The research suggests that the harder texture of nata can be attributed to closely packed fibrils within the nata structure, which make it more resistant to deformation by external forces.

The chewiness of nata in this study was not proportionally increased in the 100% rambutan juice sample despite its high hardness. This could be due to an alteration in the gel network structure caused by the unique composition of rambutan juice. While hardness was highest in the 100% rambutan juice sample, if either cohesiveness or springiness was reduced, the overall chewiness would not increase proportionally. This is revealed in **Table 4**, although the results are not significantly different in terms of springiness and cohesiveness.

https://doi.org/10.54987/jobimb.v13iSP1.1096

Table 4. Texture profile of nata made with different concentrations of rambutan juice.

Concentration of rambutan juice (%)	Hardness (g)	Springiness	Cohesiveness	Gumminess	Chewiness (g·cm)	Resilience
0	219.8 ± 61.5^{b}	0.3543 ± 0.083^{a}	0.230 ± 0.037^{a}	52.30 ± 17.30^{b}	16.64 ± 3.41^{b}	0.0613 ± 0.0061^{a}
25	135.9 ± 45.7^{b}	0.602 ± 0.279^{a}	0.402 ± 0.221^{a}	52.88 ± 10.27^{b}	36.52 ± 12.25^{a}	0.0860 ± 0.0299^{a}
75	432.4 ± 48.1^{a}	0.459 ± 0.252^{a}	0.305 ± 0.169^{a}	102.5 ± 22.20^{a}	34.06 ± 7.53^{ab}	0.0790 ± 0.0208^{a}
100	393.5 ± 20.8^{a}	0.614 ± 0.275^{a}	0.426 ± 0.202^{a}	41.35 ± 8.42^{b}	40.39 ± 2.88^{a}	0.1033 ± 0.0310^{a}

Note: Values are expressed in mean ± standard deviation for three replications (n=3). Values with different superscript letters ($^{a-b}$) are significantly different at p<0.05

Table 5 shows the moisture content in nata produced with different concentrations of rambutan juice. Differences in the moisture content trends compared to past literature could be due to variations in the structure of the samples themselves. Higher aspect ratio cellulose fiber chains in nata will provide a higher surface area, subsequently leading to a higher water-holding capacity [44]. A higher water-holding capacity would enable the sample to retain more moisture, thereby increasing its moisture content. Moreover, the ability of nata to hold more water is also affected by crystallinity, which is the degree of structural order in a solid. The lower crystallinity of bacterial cellulose (Nata) leads to a higher moisture absorption ability [15]. Thus, nata made with 75% and 100% rambutan juice may have lower crystallinity compared to other samples. Although higher moisture content in nata may reduce its shelf stability and increase susceptibility to microbial growth, this concern is often mitigated in commercial production by storing nata in sugar syrup, which helps preserve its quality during storage.

Table 5. Moisture content of nata made with different concentrations of rambutan juice.

Concentration of rambutan juice (%)	Moisture content (%)
0	78.64 ± 1.95^{c}
25	85.90 ± 1.92^{b}
75	90.67 ± 0.67^{a}
100	91.15 ± 0.73^{a}

Note: Values are expressed in mean ± standard deviation for three replications (n=3). Values with different superscript letters ($^{a-b}$) are significantly different at p<0.05.

The amount of fiber observed in nata is presented in **Table 6**. There was no significant difference between nata made from rambutan juice (2.07-2.78%) and coconut water (2.16%). This finding is supported by [16], who reported that Nata de coco is a low-calorie product with a composition of 2.5% fibre and 98% water content. Nata made with 100% rambutan juice was the highest in crude fiber content, but the increase of around 6% is considered modest. Rambutan juice is rich in various fibers, including pectin, cellulose, and hemicellulose, which are compounds that can integrate into the nata matrix during bacterial fermentation, contributing to an increase in crude fiber content. Thus, there is reason to believe that the usage of rambutan, which is rich in fibrous compounds such as cellulose, lignin and soluble fibers [17], could have caused the increase of fibers seen in the samples. A study [10] revealed that reducing sugars can accelerate cellulose fiber formation by bacteria more quickly compared to non-reducing sugars. Thus, rambutan, which is rich in reducing sugars, contains approximately 4.99% reducing sugar in its pulp [18], may have promoted faster cellulose production due to the more available reducing sugars.

Table 6. Fiber content of nata made with different concentrations of rambutan juice.

Concentration of rambutan juice (%)	Fiber content (%)
0	2.16 ± 0.39^{a}
25	2.42. ± 0.43^{a}
75	2.07 ± 0.24^{a}
100	2.78 ± 0.94^{a}

Note: Values are expressed in mean ± standard deviation for three replications (n=3). Values with different superscript letters ($^{a-b}$) are significantly different at p<0.05

The sensory evaluation scores for nata made with different concentrations of rambutan juice are presented in **Table 7**. All samples had scored similarly in all sensory categories. This shows panellists are satisfied that the products have not been affected by the difference in colour or appearance. Therefore, at all concentrations, rambutan-based nata can still be considered comparable to conventional coconut water-based nata de coco. The formulation containing 100% rambutan juice produced the thickest and heaviest nata; however, it recorded the lowest aroma score (4.70 ± 2.45), although the difference was not statistically significant.

This may be attributed to the accumulation of volatile compounds or excessive acetic acid production during fermentation, potentially leading to a slightly pungent or astringent off-aroma [19]. Previous studies showed that fresh rambutan juice contains no detectable lactic or acetic acid; however, fermentation over eight days can significantly increase the levels of organic acids, with lactic acid rising by 5.5 to 7.8-fold and acetic acid by 6-fold [20].

Table 7. Sensory evaluation score of nata made with different concentrations of rambutan juice.

Concentration of rambutan juice (%)	Colour	Overall appearance	Aroma	Texture	Taste/Flavour	Overall acceptability
0	6.00 ± 2.03^{a}	5.90 ± 2.07^{a}	5.53 ± 1.98^{a}	5.67 ± 2.28^{a}	6.13 ± 2.11^{a}	5.87 ± 2.27^{a}
25	6.30 ± 2.22^{a}	5.97 ± 2.09^{a}	5.37 ± 2.28^{a}	6.60 ± 1.96^{a}	6.20 ± 2.16^{a}	6.07 ± 1.96^{a}
75	6.10 ± 2.06^{a}	5.60 ± 2.22^{a}	5.67 ± 1.97^{a}	6.17 ± 1.78^{a}	6.30 ± 1.58^{a}	6.23 ± 1.68^{a}
100	6.33 ± 2.47^{a}	6.37 ± 2.39^{a}	4.70 ± 2.45^{a}	5.97 ± 2.50^{a}	5.73 ± 2.52^{a}	5.87 ± 2.35^{a}

Note: Values are expressed in mean ± standard deviation for three replications (n=3). Values with different superscript letters ($^{a-b}$) are significantly different at p<0.05

https://doi.org/10.54987/jobimb.v13iSP1.1096

CONCLUSION

Nata produced with 100% rambutan juice showed significantly greater thickness compared to that made with 100% coconut water. Both 75% and 100% rambutan juice resulted in significantly higher yields than the control, with these ratios producing nata characterized by a harder, chewier, and gummier texture. Although the lightness of the nata was affected by the addition of rambutan juice, it did not significantly impact the color acceptance level in sensory evaluation. Thus, sensory acceptance of nata made with rambutan juice was comparable to traditional nata de coco, which is based on coconut water, establishing it as a viable alternative for future production. Utilizing the abundance of rambutan during its season offers opportunities to create value-added products that benefit both farmers and food manufacturers.

CONFLICT OF INTEREST

The authors have declared that no conflict of interest exists.

REFERENCES

1. Suwannarat Y, Ninlanon W, Suwannarat R, Muisee K. Production of bacterial cellulose from *Acetobacter xylinum* using rambutan juice as a carbon source. Int J Agric Technol. 2017;13:1361–1369.
2. Jagannath A, Manjunatha SS, Ravi N, Raju PS. The effect of different substrates and processing conditions on the textural characteristics of bacterial cellulose (nata) produced by *Acetobacter xylinum*. J Food Process Eng. 2009;34(3):593–608.
3. Kongruang S. Bacterial cellulose production by *Acetobacter xylinum* strains from agricultural waste products. Appl Biochem Biotechnol. 2008;148(1–3):245–256.
4. Chua GK, Soo YK. Development of fed-batch strategy to produce bacterial cellulose. ASM Sci J. 2023;18:1–14. doi:10.32802/asmscj.2023.1473
5. Nimitkeatkai H, Fong-in S, Potaros T. Characterization of bacterial cellulose (nata de coco) from lychee. IOP Conf Ser Earth Environ Sci. 2020;515:012063.
6. Pal H, Joardar M, Nikam S, Lele SS. Fermentative production of nata de mango and incorporation in beverage. J Sci Ind Res. 2019;78(4):231–235.
7. Suwannarat Y, Sawasdikarn J, Puttame K. Effect of pH on the production of bacterial cellulose from rambutan and longkong juice. Fermentation Technology for Value Added Agricultural Products. 2015;6:58.
8. Lu H, Jia Q, Chen L, Zhang L. Effect of organic acids on bacterial cellulose produced by *Acetobacter xylinum*. Res Rev J Microbiol Biotechnol. 2016;5(2):1–6.
9. Chai KF, Adzahan NM, Karim R, Rukayadi Y, Ghazali HM. Physicochemical properties of rambutan (*Nephelium lappaceum* L.) seed during natural fermentation of the whole peeled fruit. Int Food Res J. 2020;27(3):397–406.
10. Avirasdya RA, Nursiwi A, Sari AM, Zaman MZ, Sanjaya AP. Kinetics study of bacterial cellulose production by *Acetobacter xylinum* FNCC 0001 with variation of carbon sources. E3S Web Conf. 2022;344:03002.
11. Kong FC, Mohd Adzahan N, Karim R, Rukayadi Y, Ghazali HM. Selected physicochemical properties of registered clones and wild-type rambutan (*Nephelium lappaceum* L.) fruits and their potentials in food products. Sains Malays. 2018;47(7):1483–1490.
12. Herawati H, Kamsiati E, Widyaputri S, Sutanto. Physico-chemical characteristics of nata de coco. IOP Conf Ser Earth Environ Sci. 2020;458:012014.
13. Amarasekara AS, Wang D, Grady TL. A comparison of kombucha SCOBY bacterial cellulose purification methods. SN Appl Sci. 2020;2(2):240.
14. Shi Z, Zhang Y, Phillips GO, Yang G. Utilization of bacterial cellulose in food. Food Hydrocoll. 2014;35:539–545.
15. Mihranyan A, Llagostera AP, Karmhag R, Strømme M, Ek R. Moisture sorption by cellulose powders of varying crystallinity. Int J Pharm. 2004;269(2):433–442.
16. Nugroho DA, Aji P. Characterization of nata de coco produced by fermentation of immobilized *Acetobacter xylinum*. Agric Agric Sci Procedia. 2015;3:278–282. doi:10.1016/j.aaspro.2015.01.053
17. Santosa B, Wignyanto W, Hidayat N, Sucipto S. Quality of nata de coco from Sawarna and Mapanget coconut varieties over storage time of coconut water. Food Res. 2019;4(4):957–963.
18. Manjunath SJ, Geethalekshmy PR, Mini C, Kumar V, Beena R. Postharvest quality of rambutan (*Nephelium lappaceum* L.) associated with packaging and storage conditions. Environ Conserv J. 2018;19(3):1–16.
19. Li R, Xu Y, Chen J, Wang F, Zou C, Yin J. Enhancing the proportion of gluconic acid with a microbial community reconstruction method to improve the taste quality of kombucha. LWT. 2021;155:112937. doi:10.1016/j.lwt.2021.112937
20. Chai KF, Mohd Adzahan N, Karim R, Rukayadi Y, Ghazali HM. Effects of fermentation time and turning intervals on the physicochemical properties of rambutan (*Nephelium lappaceum* L.) fruit sweatings. Sains Malays. 2018;47(10):2311–2318.