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Production and Characterization of Nata from Yam Bean Juice using *Komagataeibacter Nataicola* TISTR 975

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Abstract

This study aimed to produce nata from *Komagataeibacter nataicola* TISTR 975 using yam bean juice as the fermentation substrate. The chemical components of yam bean juice and the physical characteristics of the produced yam bean nata were investigated. Yam bean nata were processed with juices from lemongrass (*Cymbopogon citratus*, Stapf; LG), Gac fruit (*Momordica cochinchinensis Spreng*; GF), and Centella (*Centella asiatica*; CA) and subsequently subjected to CIELAB value analysis, texture profile analysis (TPA), and sensory evaluation. The wet weight and thickness of yam bean nata were recorded as 130.36 ± 0.45 g and 9.64 ± 0.50 mm, respectively. The color analysis of yam bean nata revealed that the L* value slightly tended toward brightness; the a* value was negative, indicating green; and the b* value shifted toward blue. Upon processing, the yam bean nata with LG, GF, and CA exhibited an L* value tending toward white, an a* value indicating green, and a b* value indicating yellow. TPA results revealed a statistically significant disparity in hardness among the processed yam bean nata. Sensory attribute assessment indicated that processing the yam bean nata with LG, GF, and CA juices increased the liking score for overall acceptability.

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Introduction

Nata is a bacterial cellulose (BC) product—a traditional, white, gel-like food widely consumed throughout Southeast Asia—obtained from fermentation with cellulose-producing bacteria. Nata is a good source of insoluble dietary fiber and low-calorie food products, with a 2.5% fiber content and 98% water.[1,2,3] The main efficient producers of BC are *Acetobacter xylinum* (reclassified as *Gluconacetobacter xylinus*) and the genus *Komagataeibacter*, which includes strains such as *Komagataeibacter xylinus* and *Komagataeibacter nataicola*.[4,5,6] These bacterial strains are usually selected for research and food applications owing

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to their high efficiency in producing BC from various carbon sources.[4] Nata, a polysaccharide of glucose polymer produced by bacteria, consists of fine fibers in a cellulose microfiber gel, and its flavor and color are controlled by the raw materials used in its culture medium.[7,8] Nata production requires a glucose-rich culture medium with other nutrient sources. Coconut water is generally used as a basal culture medium, and alternative culture mediums containing fruit juice and agricultural products have also been used to produce nata.[9,10,11]

Yam bean (*Pachyrhizus erosus* L. Urban), also known as Jicama, Mexican yam bean, or Mexican turnip, is a locally planted edible root that is easily grown and widely available in Maha Sarakham, Thailand. The tuber of *P. erosus* is usually consumed raw or as juice and contains a high amount of moisture, carbohydrates, crude fiber, and protein, with a low amount of lipids. Additionally, it contains a high amount of total soluble sugar, reducing sugar, and sucrose.[12,13,14] These components can be used as a nutrient source for an alternative culture medium to produce BC or nata.

In recent years, functional food and beverages produced from herbal plants have gained increasing attention. Yam bean juice has been proposed as a culture medium for cellulose-producing bacteria to yield nata, a dietary fiber food. In addition to being an alternative raw material for producing BC, it adds value to yam beans, a locally grown agricultural tuberous roots product, and allows for the production of nata mixed with herbal juice. Therefore, the objective of this research is to investigate the characteristics of nata produced from *K. nataicola* TISTR 975 using yam bean juice as a culture medium. Furthermore, the physical and sensory attributes of nata and nata processed with herbal juice were examined. The data obtained from this study can serve as a reference for the further development of functional food products using yam bean nata for commercial manufacturing.

Materials and Methods

Microorganisms and Raw Materials

The bacterial strain *K. nataicola* TISTR 975 utilized in this study was obtained from the TISTR Culture Collection, the Thailand Institute of Scientific and Technological Research, Pathum Thani, Thailand. The yam bean (*P. erosus* L. Urban) tubers, lemongrass (*Cymbopogon citratus*, Stapf; LG), Gac fruit (*Momordica cochinchinensis Spreng*; GF), and Centella (*Centella asiatica*; CA) were purchased from a local market in Mueang, Maha Sarakham, Thailand.

Starter Culture Preparation

Stock cultures of *K. nataicola* TISTR 975 were cultivated on glucose yeast extract agar slants (containing 100 g/L glucose, 10 g/L yeast extract, and 10 g/L agar in distilled water) at 30 °C for 3 days. To initiate fermentation, a loopful of the working culture was introduced into 10 mL of glucose yeast extract broth medium. These seed cultures were then incubated at 30 °C for 7 days. Yam bean tubers were peeled, washed, and cut into small pieces, which were then blended. The resulting liquid suspension was filtered three to four times using a filter cloth to separate suspended particles. The chemical components of yam bean juice were evaluated before the medium was prepared. The total soluble solids, pH value, and total titratable acidity were assessed according to the AOAC method,[15] and the total sugar and reducing sugar contents were analyzed via the phenol sulfuric acid method[16] and the dinitrosalicylic acid method,[17] respectively. The yam bean juice was prepared as follows: The initial total soluble solids content was adjusted to 10 °Bx through sucrose addition, and the pH was set to 5 through acetic acid addition. The yam bean juice medium was then sterilized at 121 °C for 15 min before use. Subsequently, a seed culture of 10% (v/v) of the inoculum medium was transferred to the sterilized yam bean juice medium. The cultures were statically incubated at 30 °C for 3 days, during which a BC membrane formed on the surface of the culture medium. This membrane was removed and used as a starter culture.

Production of Yam Bean Nata

Cultivation was conducted using sterilized yam bean juice under the same operating conditions as described above, with the addition of 1.4% (v/v) ethanol to the sterile medium. The cultivation process was performed in rectangular polypropylene containers measuring 14 cm (length), 9.5 cm (width), and 4.5 cm (height), each filled with 250 mL of the respective medium. The containers were inoculated with 10% (v/v) of the inoculum and statically incubated at 30 °C for 10 days.

Wet Weight and Thickness of Nata

The resulting membranes were harvested, purified, and washed with running tap water. Subsequently, they were boiled in distilled water for 20 min. After any remaining bacterial cells and acid residues accumulated during the culture process were removed, the membranes were soaked in distilled water until a neutral pH was achieved. The nata was then weighed (wet weight). The thickness was measured at 10 positions using a Vernier caliper.

Processing of Yam Bean Nata

LG, GF, and CA juices were prepared using 100 g/L of each respective ingredient and 15 g/L of sugar in water. Purified nata was cut into small cubes and boiled in water for 30 min. These nata cubes were then cooked in LG, GF, and CA juices for 20 min and allowed to soak in each herbal juice for 24 h before further analyses.

CIELAB Value Analysis

Color values were measured using HunterLab ColorFlex EZ, VA, USA. The color of nata was evaluated using the CIELAB scale with the color space values L* (lightness, 0–100), a* (+red/−green), and b* (+yellow/−blue).

Textural Profile Analysis

The texture of the nata membrane was evaluated through the texture profile analysis (TPA) method using a texture analyzer (TA.XTPlus, Stable Micro Systems, Surrey, UK) and a cylindrical probe P/2. The distance between the probe and the sample was set to 2 mm, and the probe was compressed twice to 40% of the original membrane height at a compression speed of 1 mm/s.

Sensory Evaluation

Organoleptic analysis was conducted to determine the characteristics, preference, and acceptability of the produced nata using a nine-point hedonic scale.[18] Fifty untrained panelists participated in the sensory evaluation. The samples were presented in cups to the panelists, and the sensory attributes evaluated were color, flavor, taste, texture, appearance, and overall acceptability.

Statistical Analysis

All experiments were conducted in triplicate, and the data were presented as mean ± standard deviation. The collected data were subjected to statistical analysis using SPSS statistical software (SPSS Inc., Chicago, IL, USA). One-way analysis of variance (ANOVA) was performed, followed by Duncan's multiple comparison tests. Statistical significance was defined as $p < 0.05$.

Results and Discussion

Chemical Components of Yam Bean Juice and Physical Characteristics of Yam Bean nata

The chemical composition of yam bean juice is presented in Table 1. After fermentation for 10 days, nata produced using yam bean juice as a culture medium exhibited high wet weight and thickness. As shown in Table 1, the thickness and wet weight of the nata were influenced by the water content within the membrane, which directly contributed to the distinctively soft texture of the final product. In previous studies, BC membranes obtained from static cultures typically consisted of up to 99% (w) water.[19,20]

Table 1: Chemical compositions of yam bean juice and physical characteristics of yam bean nata

Parameters	Yam bean juice
Total soluble solids (^{0}Bx)	6.33 ± 0.58
pH	6.99 ± 0.01
Total titratable acidity (%)	8.39 ± 0.50
Total sugar (mg/L)	4.21 ± 0.00
Reducing sugar (g/L)	4.39 ± 0.02
	Yam bean nata
Wet weight (g)	130.36 ± 0.45
Thickness (mm)	9.64 ± 0.50

Data are means of three replicates (n = 3) ± standard deviation

Processed Yam Bean Nata Characteristics

Color Values

Color is one of the most widely measured attributes of product quality in food processing research and holds significant importance as a product characteristic for consumers. Nata's color was determined using a colorimeter with the CIELAB color parameters, in which L* represents the CIE lightness coordinate, a* corresponds to the CIE red (+)/green (−) color attribute, and b* indicates the CIE yellow (+)/blue (−) color attribute. The color assessment of nata using a yam bean juice

medium revealed that the L* value leaned slightly toward brightness, the a* value exhibited a negative value indicating green, and the b* value showed a shift toward blue. Furthermore, processed yam bean nata with LG, GF, and CA juices exhibited an L* value tending toward white, an a* value indicating green, and positive b* values indicating yellow (+b*), as shown in Table 2. These distinct color values stemmed from the utilization of various raw materials in BC production.[21] Instrumental colorimetry measurements are associated with the consumer perception of a product's acceptable appearance. The correlation between instrumental color and sensory acceptance was evaluated, as non-destructive color measurement has been utilized in predictive modeling for assessing the nutritional quality of both fresh and processed food products.[22]

Table 2: Color comparison of processed yam bean nata

Sample	CIELAB values		
	L*	a*	b*
Nata	30.86 ± 0.61^{b}	−1.47 ± 0.04^{b}	−3.79 ± 0.28^{d}
LG	30.46 ± 0.05^{b}	−2.15 ± 0.08^{c}	0.91 ± 0.33^{c}
GF	32.03 ± 0.85^{a}	−0.98 ± 0.16^{a}	2.26 ± 0.79^{b}
CA	26.64 ± 0.29^{c}	−1.98 ± 0.03^{c}	4.30 ± 0.67^{a}

L*: Lightness; a* axis; b* axis. Data represent mean ± standard deviation; values that do not share a common superscript (a, b, c, d) in the column indicate significant differences among the groups at $p < 0.05$, as analyzed via one-way ANOVA with Duncan's post hoc tests

Table 3: Texture profile analysis of processed yam bean nata

Sample	TPA parameters				
	Hardness (N)	Springiness	Cohesiveness	Gumminess (N)	Chewiness (N)
Nata	147.63 ± 1.65^{c}	1.51 ± 0.14^{a}	0.23 ± 0.23^{a}	49.21 ± 0.35^{a}	186.30 ± 0.19^{a}
LG	136.43 ± 0.65^{d}	1.93 ± 0.25^{a}	0.33 ± 0.46^{a}	46.67 ± 0.66^{a}	198.69 ± 0.34^{a}
GF	195.57 ± 1.22^{a}	3.21 ± 0.21^{a}	0.31 ± 0.25^{a}	46.09 ± 0.49^{a}	248.06 ± 0.26^{a}
CA	158.86 ± 1.05^{b}	1.69 ± 0.19^{a}	0.24 ± 0.25^{a}	48.16 ± 0.41^{a}	182.76 ± 0.11^{a}

Data represent mean ± standard deviation; values that do not share a common superscript (a, b, c, d) in the column indicate significant differences among the groups at $p < 0.05$, as analyzed via one-way ANOVA with Duncan's post hoc tests

Texture Analysis

During the processing of yam bean nata, texture, appearance, and flavor are the key sensory factors that underpin food acceptability for consumers. The textural parameters, namely hardness, springiness, cohesiveness, gumminess, and chewiness, were evaluated via TPA. Statistically significant differences in hardness were identified among the various processed forms of yam bean nata (Table 3). Hardness corresponds to the peak force encountered during the initial compression; that is, the maximum force attained during the first bite or compression. This characteristic can be experienced by customers as a degree of crunchiness, crumbliness, or brittleness. Springiness refers to the extent to which a product physically rebounds after being deformed during the initial compression. It signifies the degree to which the

food restores its original height after compression and is often expressed as a ratio or percentage of the original height of the product. Cohesiveness refers to the product's resistance to a second deformation relative to its resistance under the first deformation. It is calculated as the ratio of the area of work during the second compression to the area of work during the first compression. Gumminess corresponds to the energy required to disintegrate a semi-solid food to a point at which it can be swallowed. It is computed as the product of cohesiveness and hardness and applies solely to semi-solid items. This attribute is mutually exclusive with chewiness, as a product cannot be both semi-solid and solid simultaneously. Chewiness corresponds to the energy needed to masticate solid food until it is suitable for swallowing. It is calculated as the product of gumminess and springiness and is exclusive to solid products.[23,24]

Table 4: Sensory assessment of processed yam bean nata

	Attributes					
Sample	**Color**	**Flavor**	**Taste**	**Texture**	**Appearance**	**Overall acceptability**
Nata	5.80 ± 1.67^{c}	5.02 ± 1.67^{c}	4.98 ± 1.46^{c}	6.38 ± 1.34^{b}	6.54 ± 1.33^{b}	6.08 ± 1.31^{b}
LG	7.66 ± 1.42^{a}	7.76 ± 1.39^{a}	7.62 ± 1.46^{a}	7.44 ± 1.16^{a}	7.26 ± 1.19^{a}	7.50 ± 1.31^{a}
GF	7.92 ± 1.28^{a}	6.02 ± 1.73^{b}	5.72 ±2.24b^{c}	6.78 ± 1.40^{b}	6.58 ± 1.18^{b}	6.56 ± 1.33^{b}
CA	6.98 ± 2.13^{b}	5.20 ± 2.75^{c}	6.00 ± 2.55^{b}	6.72 ± 1.63^{b}	6.42 ± 1.69^{b}	6.42 ± 2.17^{b}

Data represent mean ± standard deviation; values that do not share a common superscript (a, b, c) in the column indicate significant differences among the groups at $p < 0.05$, as analyzed via one-way ANOVA with Duncan's post hoc tests

Sensory Characteristics

The sensory evaluation of the processed yam bean nata, encompassing attributes such as color, flavor, taste, texture, appearance, and overall preference, is detailed in Table 4. The outcomes from the sensory assessment indicated that the processing of cooked yam bean nata with LG, GF, and CA juices increased the liking score for overall acceptability. Nata processing, involving boiling with sugar or herbal juice, influences textural characteristics such as hardness, adhesiveness, cohesiveness, springiness, gumminess, and resilience,[25] ultimately enhancing the liking score for sensory attributes.[26] The utilization of different substrates or culture media to produce cellulose bacteria (nata) influences the sensory acceptance of the resultant food products. This influence is attributable to the culture source employed, such as coconut water for nata de coco and pineapple juice for nata de pina. In this study, the use of yam bean juice controlled the flavor of the nata products.[7,8]

Conclusion

Nata was produced using yam bean juice as a culture medium for *K. nataicola* TISTR 975. Yam bean juice, abundant in nutritional components such as total soluble solids, total sugar, and reducing sugar, serves as a promising nutrient source for cellulose-producing bacteria to produce nata. The wet weight and thickness of yam bean nata were measured as 130.36 ± 0.45 g and 9.64 ± 0.50 mm, respectively. The color assessment of yam bean nata indicated that the L* value slightly tended toward brightness; the a* value was negative, suggesting green; and the b* value shifted toward blue. Upon processing, yam bean nata with LG, GF, and CA juices showed an L* value tending toward white, an a* value indicating green, and a b* value indicating yellow (+b*). TPA revealed a statistically significant variance in hardness among the processed yam bean nata. The sensory attribute assessment results showed that the processing of yam bean nata with LG, GF, and CA juices increased the liking score for overall acceptability. These findings of the study can serve as a reference for the commercial production of functional foods using yam beans' nata derived from yam beans.

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Conflict of Interest
The author declares no conflict of interest.

References

1. Ma T., Ji K., Wang W., Wang J., Li Z., Ran H., Liu B., Li G. Cellulose synthesized by *Enterobacter* sp. FY-07 under aerobic and anaerobic conditions. *Bioresour Technol*. 2012; 126: 18-23. doi: 10.1016/j.biortech.2012.09.040
2. Santosa B., Wignyanto W., Hidayat N., Sucipto S. The quality of nata de coco from sawarna and mapanget coconut varieties to the time of storing coconut water. *J Food Sci.* 2020; 4(4): 957-963.
3. Ullah H., Santos H.A., Khan T. Applications of bacterial cellulose in food, cosmetics and drug delivery. *Cellulose*, 2016; 23: 2291–2314. doi: 10.1007/s10570-016-0986-y
4. Singhsa P., Narain R., Manuspiya H. Physical structure variations of bacterial cellulose produced by different *Komagataeibacter xylinus* strains and carbon sources in static and agitated conditions. *Cellulose*, 2018; 25(3): 1571–1581. doi: 10.1007/s10570-018-1699-1
5. Yamada Y. Transfer of *Acetobacter oboediens* Sokollek *et al* 1998 and *Acetobacter intermedius* Boesch *et al*. 1998 to the genus Gluconacetobacter as *Gluconacetobacter oboediens* comb. nov. and *Gluconacetobacter intermedius* comb. nov. *Int J Syst Evol Microbiol*. 2000; 50 Pt 6: 2225-2227. doi:10.1099/00207713-50-6-2225
6. Yamada Y, Hoshino K, Ishikawa T. The phylogeny of acetic acid bacteria based on the partial sequences of 16S ribosomal RNA: the elevation of the subgenus Gluconoacetobacter to the generic level. *Biosci Biotechnol Biochem.* 1997; 61(8): 1244-1251. doi:10.1271/bbb.61.1244
7. Iguchi M., Yamanaka S., Budhiono, A. Bacterial cellulose—a masterpiece of nature's arts. *J Mater Sci.* 2000; 35(2): 261–270.
8. Shi Z., Zhang Y., Phillips G. O., Yang G. Utilization of bacterial cellulose in food. *Food Hydrocoll*. 2014; 35: 539–545. doi: 10.1016/j.foodhyd.2013.07.012
9. Hungund B., Prabhu S., Shetty C., Acharya S., Prabhu V., Gupta, S. Production of bacterial cellulose from *Gluconacetobacter persimmonis* GH-2 using dual and cheaper carbon sources. *J Microb Biochem Technol.* 2013; 5(2): 31–33. doi: 10.4172/1948-5948.1000095
10. Jozala A. F., Pértile R. A., dos Santos C. A., de Carvalho Santos-Ebinuma V., Seckler M. M., Gama F. M., Pessoa A. Jr. Bacterial cellulose production by *Gluconacetobacter xylinus* by employing alternative culture media. *Appl Microbiol Biotechnol.* 2015; 99(3): 1181-1190. doi: 10.1007/s00253-014-6232-3
11. Kurosumi A., Sasaki C., Yamashita Y., Nakamura Y. Utilization of various fruit juices as carbon source for production of bacterial cellulose by *Acetobacter xylinum* NBRC 13693. *Carbohydr Polym*. 2009; 76(2): 333–335. doi: 10.1016/j.carbpol.2008.11.009
12. Jaiswal V., Chauhan S., Lee H. J. The Bioactivity and phytochemicals of *Pachyrhizus erosus* (L.) Urb.: a multifunctional underutilized crop plant. *Antioxidants* (Basel). 2021; 11(1): 58. doi: 10.3390/antiox11010058.
13. Moongngarm A., Trachoo N., Sirigungwan, N. Low molecular weight carbohydrates, prebiotic content, and prebiotic activity of selected food plants in Thailand. *Adv J Food Sci Technol*. 2011; 3(4): 269-274.
14. Noman A. S. M., Hoque M. A., Haque M. M., Pervin F., Karim, M. R. Nutritional and anti-nutritional components in *Pachyrhizus erosus* L.tuber. *Food Chem.* 2007; 102(4): 1112–1118.
15. AOAC. Official methods of analysis. 17th Edition. The association of official analytical chemists: Gaithersburg, MD, USA; 2000.

16. Dubois M., Gilles K. A., Hamilton, J. K., Rebers P. A., Smith F. Colorimetric method for determination of sugars and related substances. *Anal Chem*. 1956; 28(3): 350-356. doi: 10.1021/ac60111a017
17. Miller G. L. Use of dinitrosalicylic acid reagent for determination of reducing sugar. *Anal Chem.* 1959; 31(3): 426-428. doi: 10.1021/ac60147a030
18. Wichchukit S., O'Mahony M. The 9-point hedonic scale and hedonic ranking in food science: some reappraisals and alternatives. *J Sci Food Agric.* 2015; 95(11): 2167-2178. doi:10.1002/jsfa.6993
19. Campano C., Balea A., Blanco Á., Negro C. Enhancement of the fermentation process and properties of bacterial cellulose: a review. *Cellulose.* 2016; 23(1): 57–91.
20. Yamanaka S., Watanabe K., Kitamura N., Iguchi M., Mitsuhashi S., Nishi Y., Uryu M. The structure and mechanical properties of sheets prepared from bacterial cellulose. *J Mater Sci.* 1989; 24(9): 3141–3145.
21. Kongruang S. Bacterial cellulose production by *Acetobacter xylinum* strains from agricultural waste products. *Appl. Biochem. Biotechnol.*, 2008; 148(1-3): 245-256.
22. Pathare P. B., Opara U. L., Al-Said, F. A. J. Colour measurement and analysis in fresh and processed foods: a review. *Food Bioprocess Technol.* 2013; 6: 36-60.
23. Bourne M. C. Texture profile analysis. *Food Technol.* 1978; 32(7): 62¬¬-66.
24. Pons M., Fiszman S. Instrumental texture profile analysis with particular reference to gelled systems. *J Texture Stud.* 1996; 27(6): 597-624. doi: 10.1111/j.1745-4603.1996.tb00996.x
25. Jagannath A., Manjunatha S., Ravi N., Raju P.S. The effect of different substrates and processing conditions on the textural characteristics of bacterial cellulose (nata) produced by *Acetobacter xylinum*. *J Food Process Eng.* 2011; 34(3): 593-608.
26. Photphisutthiphong Y., Vatanyoopaisarn S. (2020). The production of bacterial cellulose from organic low-grade rice. *Curr Res Nutr Food Sci Jour.* 2020; 8(1): 206-216.