Antioxidant and antibacterial activities of *Pandanus amaryllifolius* Roxb. (Pandanaceae) prop roots and its application for a novel bacterial cellulose (*Nata*) fermentation by enzymatic hydrolysis

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**ABSTRACT**

*Pandanus amaryllifolius* Roxb. (Pandanaceae) prop root was investigated for biological activities, i.e. antioxidant (DPPH radical scavenging assay) and antibacterial activity against *Staphylococcus aureus* DMST 2933 and *Escherichia coli* DMST 4212. The results showed that a crude extract of pandan prop roots exhibited antioxidant activity with IC₅₀ of 230.24 ± 10.69 µg/ml, and it had a total phenolic content of 24.75 ± 0.74 mg GAE/g of TPC content and inhibited the growth of *S. aureus* DMST 2933 with 9.75 ± 0.35 mm of inhibition zone diameter. The prop root powder was used to develop a novel bacterial cellulose (BC) production using enzymatic hydrolysis. The maximum total soluble solids content at 2.67 ± 0.29 Brix was found when using prop root powder at 100 g/l with 4.0% (v/v) of the commercial enzyme (iKnowZyme® cellulase) after incubated at 50°C, pH 5.0 for 24 h. The hydrolysis pandan prop root was fermented at room temperature for nine days with *Komagataeibacter xylinus* AGR 60, yielded 13.5 ± 0.50 mm of thickness with 7.90 ± 0.10 g of dry weight. Scanning electron microscope and Fourier-transform infrared spectroscopy were used to characterize the physical and chemical structure of the BC produced from pandan prop root, revealing that pandan prop root has the potential for a novel BC production with bioactivities of antioxidant and antibacterial properties.

1. INTRODUCTION

*Pandanus amaryllifolius* Roxb. is a tropical plant in the Pandanaceae family which usually used as a source of natural coloring, flavoring, and bioactive compounds in food additives and the pharmaceutical industry [1,2]. Clemen-Pascal et al. [3] reported that pandan leaves contain alkaloids, flavonoids, glycosides, and tannins that can be used to reduce fever, antibacterial and anticancer. Moreover, the pandan leaves also contained polyphenols with antioxidant and antihyperglycemic activities [4,5]. However, information about the bioactivities and applications of pandan prop root is scarce since it is discarded as waste. Then it is interesting to study and utilize for value-added through the biotechnological process. Bhuyan and Sonowal [6] reported that pandan prop root contained various bioactive compounds such as polyphenolic compounds and flavonoids, which were able to scavenge the free superoxide radicals as anti-aging and anticancer properties. Peungvicha et al. [7] found that pandan prop root extracts prolonged the sleeping time and reduced the locomotor activity in mice, while

Jimtaisong and Krisdaphong [8] reported on the antioxidant properties of pandan root and bioactivities for the possible development of novel healthy foods or functional products in the future.

Bacterial cellulose (BC) is composed of β-1,4 linkages of glucose polymer (C₆H₁₀O₅)n and can be produced from various bacterial species, including *Komagataeibacter* [9]. BC is applied in foods, medicines, and cosmetic products [10], which were produced from various substrates such as coconut juice, fruit juice, rice syrup, and industrial waste [11,12]. A novel substrate for BC production will provide an alternative BC product that generates the unique functions and bioactivities which has not been found in the conventional substrate [13]. The pandan leave syrup was currently supplemented *Nata*.

Here, the bioactivities of pandan prop root include antioxidant DPPH radical scavenging assay, total phenolic content (TPC), and antibacterial activities against *Staphylococcus aureus* DMST 2933 and *Escherichia coli* DMST 4212 were investigated, together with the development of a novel BC product from pandan prop root using enzymatic hydrolysis.
2. MATERIALS AND METHODS

2.1. Substrates, Enzyme and Bacterial Strain

Organic pandan prop root was obtained from Chachoengsao Province, Thailand. The prop root was washed twice in tap water, dried at 50°C in a hot air oven for 12 h, then powdered by an electric grinder and stored under dry condition. Commercial cellulase enzyme (iKnowZyme® cellulase) was purchased from Reach Biotechnology Co., Ltd. and stored at -20°C. Komagataeibacter xylinus AGR 60 was obtained from the Institute of Food Research and Product Development, Kasettsart University, Thailand. The AGR 60 strain was grown in a coconut juice inoculum medium reported by Noree et al. [13] and used as the starter culture for BC fermentation.

Pathogenic bacteria, including S. aureus DMST 2933 and E. coli DMST 4212, were obtained from the Department of Medical Sciences Culture Collection Center, Ministry of Public Health, Thailand, and grown on TSB medium at 37°C for 24 h and diluted to 10^6 CFU/mL for disc diffusion assay.

2.2. Chemical Composition Analysis of Pandan Prop Root

Proximate analysis of pandan prop root including protein, fat, moisture, and ash contents was analyzed by the Central Laboratory (Thailand) Co., Ltd. following the method of analysis for nutrition labeling (1993) p.106 and AOAC methods [15]. Hemicellulose, cellulose, and lignin were analyzed using AOAC methods [15]. All values were reported as g/100 g sample.

2.3. Methanol Extraction of Pandan Prop Root

Pandan prop root powder at 500 g was immersed in 1.0 L of 95% methanol at room temperature for 24 h. The extract solution was filtered using Whatman No.1 filter paper, and the solvent was removed using a rotary evaporator at boiling point [16]. The obtained pandan prop root was used to determine antioxidant (DPPH radical scavenging assay) and antibacterial activity on S. aureus DMST 2933 and E. coli DMST 4212 by the disc diffusion method.

2.4. Determination of Antioxidant Activity

2.4.1 DPPH radical scavenging assay

The antioxidant assay was reported as the amount of antioxidant with the ability to reduce DPPH absorption compared to the control (IC₅₀), defined in units of µg/mL, following the modified procedure of Suwannakul et al. [17]. A reduction in DPPH concentration was recorded by the decrease in absorbance at 520 nm. Ascorbic acid was used as the positive control with ethanol as the negative control and extract without DPPH as the blank.

2.4.2 TPC

The TPC of pandan prop root extract was determined by the Folin-Ciocalteu method as described by Butsat and Siriamornpun [18]. Diluted Folin-Ciocalteu reagent (1:10) was added to 200 µL of the sample. Then, 800 µL of sodium carbonate (Na₂CO₃) was added, and the reaction volume was increased to 5.0 mL by distilled water. The reaction was incubated at room temperature for 2.0 h and measured at 760 nm. Gallic acid was used as the standard reagent, with results expressed as mg gallic acid equivalent per g of sample (mg GAE/g sample).

2.5. Antibacterial activity

To determine the in vitro activity of prop root crude extract against pathogenic bacteria, including S. aureus DMST 2933 and E. coli DMST 4212, prop root crude extracts at 12.5, 25, 50, and 100 mg/ml were incorporated in a 6.0 mm paper disc and tested using the paper disc diffusion method [19]. The testing plates were incubated at 35 ± 2°C for 18 h to determine the mean inhibition zone of each sample (mm). The extracted solvent was used as a control.

2.6. Hydrolysis of Pandan Prop Root by Commercial Hydrolytic Enzyme

Pandan prop root hydrolysis reactions were investigated in 250 mL Erlenmeyer flasks containing 50 mL of enzyme solution. Pandan prop root powder content was varied at 25–150 g/l in the reaction containing iKnowZyme® cellulase concentration at 4.0% (%v/v) dissolved in 0.1 M acetate buffer pH 5.5. The reactions were incubated at 50°C for 24 h, modified from Kobkam et al. [20] and determined for total soluble solids (TSS) content using a refractometer (RA-250WE, Kyoto Electronics, Kyoto, Japan). The optimum substrate concentration was used, with enzyme concentration ranging from 1.0–6.0 (%v/v). The reactions were incubated at 50°C for 24 h and determined for TSS content as described above. The optimum substrate and enzyme concentrations were used to upscale the hydrolysis in a 5.0 L glass jar chamber for sugar syrup production.

2.7. Production of BC by K. xylinus AGR 60

Sugar syrup obtained from the hydrolysis of pandan prop root was used as the substrate for BC fermentation by K. xylinus AGR 60 in a plastic tray (15 × 15 × 6 cm) with the working volume at 500 mL. The fermentation medium was supplemented with 3.0 g of ammonium sulfate and 0.6 mL of glacial acetic acid following the methods of Jagannath et al. [21] and Noree et al. [13] with slight modifications and 10% (v/v) of K. xylinus AGR 60 was used as a starter culture. The fermentation was incubated at room temperature, and the characteristics of BC were determined after nine days of cultivation. To compare with the traditional BC production, coconut juice was used as a substrate. The thickness of each sample was recorded every day. At the end of fermentation, all the BC samples were dried at 50°C for 24 h to determine the dry weight. The structure of freeze-dried BC was determined by a scanning electron microscope (SEM) (model SU8020; Hitachi, Tokyo, Japan) at 10.0 kV, while functional groups and chemical bonds of BC produced from pandan prop root syrup were determined by Fourier-transform infrared spectroscopy (FTIR, Thermo Scientific Nicolet is5, USA) in the range 4000–400 cm⁻¹ following the methods of Saleh et al. [21] and Noree et al. [13].

2.8. Statistical Analysis

The significance of the data was analyzed by one-way analysis of variance (SPSS 21.0, USA). Values were considered significant at P < 0.05 using Duncan’s multiple range tests.

3. RESULTS AND DISCUSSION

3.1. Chemical Composition of Pandan Prop Root

P. amaryllifolius Roxb. is a monocot that grows in tropical regions, commonly known as pandan. The prop roots of pandan are adventitious roots that incorporate in a 6.0 mm paper disc and tested using the paper disc diffusion method [19]. The leaves and stems have a unique and pleasant aroma. They are used as flavorings for various foods and herbal beverages and reduce fever, relieve indigestion and as a diuretic, cardio-tonic, and anti-diabetic [22-25]. Bhuyan and Sonowal [6] reported that pandan leaves and roots contained various bioactive compounds such as phenolic compounds and flavonoids, which showed the bioactivities of antioxidant, anticancer, and anti-
aging bioactivities. The pandan prop root was traditionally used for diabetic patients treated with the antihyperglycemic property of 4-hydroxybenzoic acid [8, 25]. However, the pandan prop root is usually discarded as waste, which is interesting to utilize as a novel substrate for food and beverage production.

The chemical composition of pandan prop root powder is shown in Table 1. The components were cellulose at 38.88 ± 0.11 g/100g and hemicellulose at 15.40 ± 0.16 g/100g, with small amounts of lignin (8.99 ± 0.03 g/100g), protein (4.67 ± 0.01 g/100g), carbohydrate (80.24 ± 0.11 g/100g), fat (1.11 ± 0.01 g/100g), moisture (7.56 ± 0.35 g/100g) and ash (6.31 ± 0.01 g/100g). Prop roots develop from the nodes to provide additional support for plants, and they contain cellulose as the major component. The high amount of cellulose showed the potential of the substrate for cellulase enzyme hydrolysis to produce fermentable sugar and bioactive compounds. The pandan prop root was investigated for bioactivities and used as a substrate for BC fermentation.

3.2. Antioxidant Activity of Pandan Prop Root Extract

Antioxidant assay of pandan prop root was expressed as the half-maximal inhibitory concentration (IC$_{50}$) as described in the method. The IC$_{50}$ value of DPPH scavenging activity from pandan prop root crude extract was 230.24 ± 10.69 µg/ml. TPC was 24.75 ± 0.74 mg GAE/g. Suwannakul et al. [17] reported the IC$_{50}$ and TPC of pandan leaf extract at 110.57 ± 36.42 µg/ml and 57.25 ± 0.02 mg GAE/g, respectively. Results revealed that pandan prop root contained bioactive compounds and showed antioxidative activities for possible use as an ingredient in functional foods and cosmetic products in the future. At the same time, Jimtaisong and Krisdaphong [8] confirmed that pandan root extract exhibited antioxidant activity of DPPH as IC$_{50}$ value at 2,340 µg/ml and TPC content at 28.8 mg GAE/g that could be used in topical pharmaceutical and cosmetic applications.

3.3. Antibacterial Activity

The crude extract of pandan prop root was evaluated for the antibacterial ability of S. aureus DMST 2933 and E. coli DMST 4212 using the disc diffusion assay method as described above. Results of crude extract at different concentrations on antibacterial activity are shown in Table 2. Crude extract of pandan prop root inhibited the growth of S. aureus DMST 2933 in all concentrations (12.5–100 mg/ml), with the highest mean zone of inhibition at 9.75 ± 0.35 mm using 100 mg/ml of crude extract. However, the pandan prop root crude extract showed no in vitro activity against E. coli DMST 4212, concurring with Dumaal et al. [19], who reported that pandan leaf crude extract had activity against the growth of S. aureus ATCC 25923 but not against the growth of E. coli ATCC 25922. Pandan leaf and root contain phytochemicals as bioactive compounds and essential oil that inhibit the growth of some pathogenic bacteria [8, 19]. Mar et al. [26] found 54 compounds in essential oil from pandan leaves that inhibited the growth of various Gram-positive and Gram-negative bacteria, including S. aureus, a common cause of minor skin infections, mainly when introduced into a wound or skin incision. From our knowledge, most of the previous findings focused on the antibacterial activity of pandan leaves. However, the study concurring with pandan prop root is scarce. Then, this study is the first report for evaluating the antibacterial activity of pandan prop root crude extract, which showed the potential for application as an ingredient for skin cosmetic and pharmaceutical products.

3.4. Hydrolysis of the Pandan Prop Root by Commercial Hydrolytic Enzyme

For sugar syrup production, pandan prop root powder was hydrolyzed by commercial cellulase as described above. Maximum TSS was found at 2.67 ± 0.29 Brix using prop root powder at 100 g/l with 4.0% (v/v) of the commercial enzyme after incubated at 50°C for 24 h, as shown in Figure 2. At low substrate concentrations (25, 50, and 75 g/l), the obtained fermentable sugar was lower than the optimum substrate concentration (100 g/l). TSS increased at higher substrate concentration until beyond the point of optimum concentration [Figure 2a] when TSS slightly decreased due to limits of mixing of enzyme-substrate suspension as reported by Sangngern et al. [27] and Lomthong et al. [28]. In the case of enzyme concentration, which directly affects the hydrolysis efficiency due to increasing the degradation rate when increasing the enzyme concentration until

![Figure 1: Pandanus amaryllifolius Roxb. (Pandanaceae) showing leaves and prop roots.](image)

| Component (%) | (g/100g) |
|---------------|----------|
| Cellulose     | 38.88±0.11 |
| Hemicellulose | 15.40±0.16 |
| Lignin        | 8.99±0.03 |
| Protein       | 4.67±0.01 |
| Fat           | 1.11±0.01 |
| Moisture      | 7.56±0.03 |
| Ash           | 6.31±0.01 |

*Values are averages of three determinations.

| Crude extracted concentration (mg/ml) | Mean zone of inhibition (mm) |
|--------------------------------------|------------------------------|
| **S. aureus DMST 2933**               |                              |
| 100                                  | 9.75±0.35<sup>e</sup>        |
| 50                                   | 6.75±0.35<sup>d</sup>        |
| 25                                   | 5.00±0.71<sup>c</sup>        |
| 12.5                                 | 3.00±0.71<sup>b</sup>        |
| Control                              | 0.00±0.00<sup>a</sup>        |

NA is no activity against the growth of bacteria. Different letters within the same column are statistically different at P<0.05, S. aureus: Staphylococcus aureus, E. coli: Escherichia coli.
the optimum point. Lomthong et al. [29] reported that substrate and enzyme concentrations play an important role in sugar syrup production from broken rice. This is similar to Thongpoem et al. [30] finding that substrate concentration affected the sugar syrup production from unripe banana flour when using enzymatic hydrolysis. Therefore, the optimum conditions at 100 g/l with 4.0% (v/v) of the commercial enzyme were upscaled in a 5.0 L glass jar chamber to produce pandan prop root syrup and used as a substrate for BC fermentation.

3.5. Production of BC by K. xylinus AGR 60

BC was fermented from pandan prop root syrup using K. xylinus AGR 60 at room temperature for nine days. K. xylinus AGR 60 was reported as a potent commercial strain for BC production, which coconut juice and other syrups could be used as a substrate for fermentation [13].

Time courses of BC fermentation by pandan prop root syrup and coconut juice are shown in Figure 3. Results indicated that BC produced from pandan prop root had the highest thickness at 13.5 ± 0.05 mm with 7.90 ± 0.10 g of dry weight, and slightly lower than BC produced from coconut juice (14.2 ± 0.60 mm with 8.35 ± 0.22 g). The pH of coconut juice decreased from 4.40 ± 0.10 to 3.43 ± 0.25, while the pH of pandan prop root syrup decreased from 4.37 ± 0.12 to 3.78 ± 0.14. The dry weight matter was used to calculate BC production (P, g/l) and BC production rate (Rp, g/l/day), as shown in Table 3. BC production (P, g/l) values from pandan prop root syrup and coconut juice were 15.80 ± 0.20 and 16.70 ± 0.44 g/l, respectively, while BC production rates were recorded at 1.76 ± 0.02 and 1.85 ± 0.05 g/l/day from pandan prop root syrup and coconut juice, respectively. Moukamnerd et al. [12] reported BC production from banana peel and passion fruit peel at 0.89 ± 0.04 and 0.31 ± 0.07 g/l, respectively, and lower than BC production from pandan prop root syrup in this study, while production of BC from pandan prop root syrup was slightly

Table 3: Bacterial cellulose (BC) production parameters from pandan prop root syrup and coconut juice by K. xylinus AGR 60.

| Parameter                  | Substrate                          | Pandan prop root syrup | Coconut juice |
|----------------------------|------------------------------------|------------------------|---------------|
| BC thickness (mm)          |                                    | 13.50±0.05             | 14.20±0.60    |
| Dry weight (g)             |                                    | 7.90±0.10              | 8.35±0.22     |
| pH                         |                                    | 3.78±0.14              | 3.43±0.25     |
| BC production (P, g/l)     |                                    | 15.80±0.20             | 16.70±0.44    |
| BC production rate (Rp, g/l/day) |                            | 1.76±0.02             | 1.85±0.05     |

Values are averages of three determinations, *Based on dry matter, K. xylinus: Komagataeibacter xylinus.
lower than from coconut juice. This study’s lower BC production from a novel substrate resulted from some coconut juice nutrients that promoted BC fermentation, such as minerals, vitamins, and amino acids [31]. Noree et al. [13] reported lower production of BC from rice syrup than coconut juice by K. xylinus AGR 60 that had a similar structure with higher bioactive compound content. Photographs and electron micrographs of BC produced from coconut juice and pandan prop root syrup are shown in Figure 4. The BC sample produced from pandan prop root syrup [Figure 4c] was slightly brown compared to the BC produced from coconut juice [Figure 4a]. The color faded after boiling at 100°C for 30 min. The BC structure investigated by SEM was similar in both samples [Figure 4b and d]. FTIR spectra of BC produced from pandan prop root syrup are shown in Figure 5. FTIR spectra patterns were similar to spectra of BC produced from coconut juice, as reported previously [13]. Bands assigned to –OH and –CH stretching were found at wavenumbers 3200–3400 cm⁻¹, similar to BC produced from banana peel and passion fruit peel reported by Moukamnerd et al. [10] and rice syrup reported by Noree et al. [13]. The absorption band at 1600–1650 cm⁻¹ was recorded as carboxyl (C=O) functional group [32], while peaks at 950–1100 cm⁻¹ were recorded as the C–O–C functional group by Noree et al. [13]. This study is the first report showing the possibility of using pandan prop root as the substrate to produce novel BC as an alternative application in future functional food and pharmaceutical products.

4. CONCLUSION

*P. amaryllifolius* Roxb. (Pandanaceae) prop root was shown to be a source of bioactive compounds, with interesting applications for novel healthy foods or functional drink products. Pandan prop root was elucidated for its antioxidant and antibacterial bioactivities to inhibit the growth of *S. aureus*. Application of pandan prop root in BC fermentation using enzymatic hydrolysis was also achieved. Results revealed a novel process and progression in bio-cellulose production technology using enzymatic hydrolysis.

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6. AUTHORS’ CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the international committee of medical journal editors (ICMJE) requirements/guidelines.

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8. CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

9. ETHICAL APPROVALS

This study does not involve experiments on animals or human subjects.

10. DATA AVAILABILITY

All relevant data are provided within the manuscript.

11. PUBLISHER’S NOTE

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REFERENCES

1. Ghasemzadeh A, Jaafar HZ. Profiling of phenolic compounds and their antioxidant and anticancer activities in pandan (*Pandanus amaryllifolius* Roxb.) extracts from different locations of Malaysia. BMC Complement Altern Med 2013;13:1-9.

2. Minh NP, Vo TT, Phong TD, Van Toan N, Nam VH. Green pigment extraction from pandan (*Pandanus Amaryllifolius*) and its application...
in food industry. J Pharm Sci 2019;11:925-9.
3. Clemen-Pascual LM, Macahig RA, Rojas NR. Comparative toxicity, phytochemistry, and use of 53 Philippine medicinal plants. Toxicol Rep 2022;9:22-35.
4. Aini R, Mardiyaningsih A. Pandan leaves extract (Pandanus amaryllifolius Roxb) as a food preservative. J Kedokteran Indonesia 2016;7:166-73.
5. Chiabchalard A, Nooron N. Antihyperglycemic effects of Pandanus amaryllifolius Roxb. leaf extract. Pharmacogn Mag 2015;11:117.
6. Bhuyan B, Sonowal R. An overview of Pandanus amaryllifolius Roxb. Ex Lindl. and its potential impact on health. Curr Trends Pharm Res 2021;8:138-57.
7. Prades A, Dornier M, Diop N, Pain JP. Coconut water uses, phytochemistry, and use of 53 Philippine medicinal plants. Toxicol Rep 2022;9:651-62.
8. Ghasemzadeh A, Jaafar HZ. Optimization of reflux conditions for total flavonoid and total phenolic extraction and enhanced antioxidant capacity in pandan (Pandanus amaryllifolius Roxb.) using response surface methodology. Sci World J 2014;2014:523120.
9. Cheepatham N, Towers GH. Light-mediated activities of some Thai medicinal plant teas. Fitoterapia 2002;73:651-62.
10. Lomthong T, Praksen JK, Tezuka Y, Kadota S, Thirawaranpan SS, Watanabe H. 4-Hydroxybenzoic acid: A hypoglycemic constituent of aqueous extract of Pandanus odoros root. J Ethnopharmacol 1998;62:79-84.
11. Hussain Z, Sajjad W, Khan T, Wahid F. Production of bacterial cellulose from industrial wastes: A review. Cellulose 2019;26:2895-911.
12. Moukamnerd C, Ounmuang K, Konboa N, Insomphun C. Bacterial cellulose as a raw material for food and food packaging applications. Front Sustain Food Syst 2019;3:7.
13. Naloka K, Matsushita K, Theraorangkal E. Enhanced ultrafine nanofibril biosynthesis of bacterial nanocellulose using a low-cost material by the adapted strain of Komagataeibacter xylinus MSKU12. Int J Biol Macromol 2020;150:1113-20.
14. Mar A, Mar AA, Thin PP, Zin MM. Study on the phytochemical constituents in essential oil of Pandanus amaryllifolius Roxb. Leaves and their antibacterial efficacy. Yadavabon Univ Res J 2019;10:1-9.
15. Naloka K, Matsushita K, Theraorangkal E. Enhanced ultrafine nanofibril biosynthesis of bacterial nanocellulose using a low-cost material by the adapted strain of Komagataeibacter xylinus MSKU12. Int J Biol Macromol 2020;150:1113-20.
16. Prades A, Dornier M, Diop N, Pain JP. Coconut water uses, phytochemistry, and use of 53 Philippine medicinal plants. Toxicol Rep 2022;9:651-62.
17. Cheepatham N, Towers GH. Light-mediated activities of some Thai medicinal plant teas. Fitoterapia 2002;73:651-62.
18. Lomthong T, Praksen JK, Tezuka Y, Kadota S, Thirawaranpan SS, Watanabe H. 4-Hydroxybenzoic acid: A hypoglycemic constituent of aqueous extract of Pandanus odoros root. J Ethnopharmacol 1998;62:79-84.
19. Hussain Z, Sajjad W, Khan T, Wahid F. Production of bacterial cellulose from industrial wastes: A review. Cellulose 2019;26:2895-911.
20. Moukamnerd C, Ounmuang K, Konboa N, Insomphun C. Bacterial cellulose as a raw material for food and food packaging applications. Front Sustain Food Syst 2019;3:7.
21. Hussain Z, Sajjad W, Khan T, Wahid F. Production of bacterial cellulose from industrial wastes: A review. Cellulose 2019;26:2895-911.
22. Lomthong T, Praksen JK, Tezuka Y, Kadota S, Thirawaranpan SS, Watanabe H. 4-Hydroxybenzoic acid: A hypoglycemic constituent of aqueous extract of Pandanus odoros root. J Ethnopharmacol 1998;62:79-84.
23. Hussain Z, Sajjad W, Khan T, Wahid F. Production of bacterial cellulose from industrial wastes: A review. Cellulose 2019;26:2895-911.
24. Lomthong T, Praksen JK, Tezuka Y, Kadota S, Thirawaranpan SS, Watanabe H. 4-Hydroxybenzoic acid: A hypoglycemic constituent of aqueous extract of Pandanus odoros root. J Ethnopharmacol 1998;62:79-84.
25. Naloka K, Matsushita K, Theraorangkal E. Enhanced ultrafine nanofibril biosynthesis of bacterial nanocellulose using a low-cost material by the adapted strain of Komagataeibacter xylinus MSKU12. Int J Biol Macromol 2020;150:1113-20.
26. Prades A, Dornier M, Diop N, Pain JP. Coconut water uses, phytochemistry, and use of 53 Philippine medicinal plants. Toxicol Rep 2022;9:651-62.
27. Hussain Z, Sajjad W, Khan T, Wahid F. Production of bacterial cellulose from industrial wastes: A review. Cellulose 2019;26:2895-911.
28. Lomthong T, Praksen JK, Tezuka Y, Kadota S, Thirawaranpan SS, Watanabe H. 4-Hydroxybenzoic acid: A hypoglycemic constituent of aqueous extract of Pandanus odoros root. J Ethnopharmacol 1998;62:79-84.
29. Hussain Z, Sajjad W, Khan T, Wahid F. Production of bacterial cellulose from industrial wastes: A review. Cellulose 2019;26:2895-911.
30. Lomthong T, Praksen JK, Tezuka Y, Kadota S, Thirawaranpan SS, Watanabe H. 4-Hydroxybenzoic acid: A hypoglycemic constituent of aqueous extract of Pandanus odoros root. J Ethnopharmacol 1998;62:79-84.
31. Prades A, Dornier M, Diop N, Pain JP. Coconut water uses, phytochemistry, and use of 53 Philippine medicinal plants. Toxicol Rep 2022;9:651-62.
32. Prades A, Dornier M, Diop N, Pain JP. Coconut water uses, phytochemistry, and use of 53 Philippine medicinal plants. Toxicol Rep 2022;9:651-62.