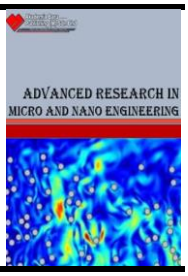
Penerbit Akademia Baru

Journal of Advanced Research in Micro and Nano Engineering

Journal homepage:
https://www.akademiabaru.com/submit/index.php/armne/index
ISSN: 2756-8210




# A Systematic Review of Synthesis and Application Base Nanomaterial using Pandanus Extract Plant

Nor Diyana Md Sin[1,2,*], Mohamad Hafiz Mamat[2], Mohamad Zhafran Hussin[1], Norlina Md Zain[1], Fazlinashatul Suhaidah[1], Nur Amalina Muhamad[1], Noor Asnida Asli[3], Habibah Zulkefle[4], Mohd Hanapiah Abdullah[5], Eko Adhi Setiawan[6]

[1] Electrical Engineering Studies, College of Engineering, Universiti Teknologi MARA, Cawangan Johor Kampus Pasir Gudang, 81750 Masai Johor, Malaysia
[2] NANO-ElecTronic Centre (NET), Universiti Teknologi MARA (UiTM) Selangor, 40450 Shah Alam, Selangor, Malaysia
[3] NANO-SciTech Lab, Functional Materials and Nanotechnology Centre, Institute of Science, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
[4] School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
[5] School of Electrical Engineering, College of Engineering, Universiti Teknologi MARA, Cawangan Pulau Pinang,13500 Permatang Pauh, Pulau Pinang, Malaysia
[6] Tropical Renewable Energy Center, Faculty of Engineering, Universitas Indonesia, Kampus UI, Depok 16424, Indonesia; & Energy System Engineering, Faculty of Engineering, University of Indonesia, Kampus UI Depok, Depok 16424, Indonesia

**ARTICLE INFO**

***Article history:***
Received 3 June 2024
Received in revised form 20 July 2024
Accepted 28 August 2024
Available online 30 September 2024

***Keywords:***
*Pandanus amaryllifolius*; extract plant; nanomaterial; biosynthesized

**ABSTRACT**

This systematic review investigates the production and utilization of nanomaterials using an extract from the *Pandanus amaryllifolius* plant. The introduction outlines the imperative role of nanomaterials in addressing the challenges faced by conventional materials, emphasizing the need for sustainable and efficient alternatives. Note that the problem statement underscores the existing gaps in the literature regarding the comprehensive exploration of Pandanus-based nanomaterials toward applications. The study conducted an extensive search on Scopus and Web of Science (WoS) databases, employing specific keywords. The exhaustive search produced 17 articles, which were classified into three primary themes: (1) Nanomaterials synthesis and utilization using extracts from *Pandanus amaryllifolius*, (2) Characteristics and uses of nanomaterials biosynthesized through biological processes, and (3) Bioactivity and practical applications of materials derived from plants. The review thoroughly examines the findings related to these specific topics, offering valuable information on the various uses and characteristics of nanomaterials produced with the help of *Pandanus amaryllifolius* extract. This paper enhances the comprehension of the potential applications of Pandanus-based nanomaterials in different fields by providing a detailed analysis of the current research. It serves as a significant reference for practitioners as well as researchers intrigued by the combination of plant extracts and nanotechnology.

* *Corresponding author.*
*E-mail address: diyana0366@uitm.edu.my*

https://doi.org/10.37934/armne.23.1.6176

## 1. Introduction

The synthesis and application of nanomaterials are highly advanced fields in materials science, providing exceptional prospects for technological progress in multiple areas. *Pandanus amaryllifolius*, a versatile plant renowned for its numerous applications, presents itself as a promising and sustainable resource for the synthesis of nanomaterials [1-3]. This article explores the process of creating and using nanomaterials made from *Pandanus amaryllifolius*. It highlights the potential of using nature's cleverness on a very small scale to bring about significant changes.

*Pandanus amaryllifolius*, also known as pandan, contains distinctive biochemical components that can be used to create a wide range of nanomaterials in an environmentally friendly and sustainable manner. The incorporation of this plant-derived substance in the production of nanomaterials is consistent with the current focus on environmentally friendly and biocompatible methods, which aim to address the issues associated with traditional chemical techniques [3-7]. Researchers have discovered that extracts from *Pandanus amaryllifolius* have natural properties that can reduce and stabilize nanomaterials [7,8]. This opens up new possibilities for customizing nanomaterials with greater precision and less harm to the environment.

This article examines the different nanomaterials created using *Pandanus amaryllifolius*, including metal nanoparticles and metal oxides. The distinct chemical makeup of pandan leaves gives rise to specific characteristics in the synthesized nanomaterials, which in turn affect their structure, optical properties, and morphology. An analysis of the mechanistic aspects of the synthesis process reveals the relationship between *Pandanus amaryllifolius* extracts and precursor materials, offering a basis for comprehending and enhancing the production of nanomaterials [10-12].

In addition to discussing the complexities of synthesizing *Pandanus amaryllifolius*-based nanomaterials, this article explores a wide range of potential uses for these materials. These nanomaterials demonstrate impressive functionality in numerous aspects, for instance, biomedical and catalysis implementations, highlighting nanotechnology's versatility and effectiveness derived from pandan. The investigation of these applications not only emphasizes the direct practical consequences but also suggests the wider societal and industrial changes that could be achieved by incorporating *Pandanus amaryllifolius*-based nanomaterials. This article offers an in-depth analysis of the production and use of nanomaterials derived from *Pandanus amaryllifolius*. It explores the merging of nature-inspired chemistry and advanced nanotechnology, offering a thorough analysis of the field's present status and its potential future advancements.

## 2. Methodology

Nanomaterials have garnered considerable interest in recent years owing to their distinctive characteristics and potential utility in diverse domains, such as medicine, electronics, and energy. The Pandanus extract plant has been recognized as a high-potential source in producing nanomaterials thanks to its abundant phytochemical composition. Multiple studies have been undertaken to examine the process and utilization of nanomaterials derived from the Pandanus extract plant. In a review by S. Priyadarshini *et al.,* [7], the authors discussed the potential of *Pandanus amaryllifolius* leaf extract for synthesizing silver nanoparticles with antimicrobial and anticancer properties, highlighting the material's versatility in nanocomposite applications. Furthermore, a literature review by M. S. Hossain *et al.,* [8] explored the use of natural fibres, including *Pandanus amaryllifolius*, in polymer nanocomposites, emphasizing their potential for enhancing the resulting materials' thermal as well as mechanical properties. The silver nanoparticles' antibacterial activity synthesized via the Pandanus extract plant was examined in a research

conducted by S. S. Patil *et al.,* [9]. The findings demonstrated that the synthesized nanoparticles displayed substantial antibacterial efficacy against Gram-negative and Gram-positive bacteria. Here, the investigation determined that the Pandanus extract plant can be utilized as a cost-efficient and environmentally friendly method for producing silver nanoparticles with the opportunity to be utilized as antibacterial agents.

In a separate investigation conducted by S. K. Mishra *et al.,* [10], the process of creating Zinc Oxide (ZnO) nanoparticles using the Pandanus extract plant was examined, and their ability to catalyze chemical reactions through exposure to light was assessed. The results demonstrated that the synthesized nanoparticles displayed exceptional photocatalytic efficacy in decomposing methylene blue dye when exposed to UV light. The study determined that Pandanus extract can serve as a promising resource for producing ZnO nanoparticles with photocatalytic properties. Alternatively, a newly conducted research by S. K. Singh *et al.,* [11] involved the synthesis of gold nanoparticles using extracts from the Pandanus plant. The researchers then assessed the nanoparticles' antioxidant activity. The findings demonstrated that the artificially produced nanoparticles displayed noteworthy antioxidant properties, which can be attributed to the existence of phytochemicals in the Pandanus extract plant. The study determined that the Pandanus extract plant has the potential to be utilized as a source for synthesizing gold nanoparticles that can be used for their antioxidant properties.

Moreover, researchers have investigated the utilization of deep eutectic solvents and carrageenan as capping agents for nanoparticles to meet the requirement for safer and non-toxic methods in producing biocompatible nanomaterials [17,18]. These biocompatible alternatives have demonstrated promise in guaranteeing the safety, structure, high production, and uniformity of the produced nanomaterials. Nevertheless, there have been reports of challenges regarding the ability to reproduce results and problems with the amount of output produced, emphasizing the necessity for additional investigation and advancement in this field [12]. Ultimately, conducting a thorough examination of the existing body of literature regarding the production and utilization of nanomaterials derived from Pandanus extract and other plant-based sources is crucial for comprehending the possibilities, obstacles, and future prospects of this environmentally-friendly method in the field of nanotechnology. The review should cover the mechanistic aspects, toxicological considerations, and the advancement of safer and more efficient synthesis methods in order to fully achieve the advantages of green nanobiotechnology.

## 3. Materials and Methods

### *3.1 Identification*

Several key steps in the systematic review process were used to select a great deal of relevant literature for this study. First, keywords are selected, and then related terms are searched for using dictionaries, thesauri, encyclopaedias, and past research. All relevant keywords were selected after the search strings for the Web of Science (WoS), as well as Scopus databases, were formed (refer to Table 1). In the systematic review process initial phase, the current study project managed to acquire 36 publications from both databases.

**Table 1**
The search string

| | |
|---|---|
| Scopus | TITLE-ABS-KEY ("Pandanus Amaryllifolius" AND nano* ) AND ( LIMIT-TO ( DOCTYPE, "ar") OR LIMIT-TO ( DOCTYPE, "cp") OR LIMIT-TO ( DOCTYPE, "cr") ) AND ( LIMIT-TO ( LANGUAGE, "English") ) |
| Wos | "Pandanus Amaryllifolius" AND nano* (Topic) and 2023 or 2022 or 2021 or 2020 or 2019 (Publication Years) and Article (Document Types) |

### *3.2 Screening*

During the screening step, the gathering of potentially pertinent research items is reviewed for content that aligns with the predetermined research question or questions. Afterwards, the screening phase often involves the use of content-related criteria, such as the research items' selection depending on the machine learning-based classification with respect to cervical cancer cells. Subsequently, all duplicate papers will be eliminated from the list that was searched in this step. 11 publications were excluded in the first screening stage, and 25 papers were examined in the second stage of the screening process employing distinct inclusion and exclusion criteria based on this study (refer to Table 2). Since research papers are the main source of useful recommendations, this criterion was applied before any other. The most recent study did not incorporate meta-syntheses, reviews, books, meta-analyses, chapters, book series, or conference proceedings. In addition, the review was restricted to publications that are only in the English language. Therefore, it is crucial to note that the approach was constrained to the period from 2017 to 2023. Due to duplication criteria, a total of four publications were rejected.

**Table 2**
The selection criterion is searching

| Criterion | Inclusion | Exclusion |
|---|---|---|
| Language | English | Non-English |
| Timeline | 2017 – 2023 | < 2017 |
| Literature type | Journal (Article) Conference, | Book, Review |
| Publication Stage | Final | In Press |
| Subject Area | Material Science, Engineering, Chemistry and Environmental | Beside Material Science, Engineering, Chemistry and Environmental |

### *3.3 Eligibility*

A collection of 17 articles was put together during the third stage, which is known as the eligibility assessment. In order to verify that the articles fulfilled the inclusion criteria and were pertinent to the research goals of the ongoing research, a thorough review of the titles and body of each article was carried out during this phase. As a result, two papers, articles, and data were disqualified as they fell outside the scope, their titles did not significantly align with the research's goal, their abstracts had nothing to do with the goal, and their full-text access was not supported by empirical data. Consequently, there are now articles left for the forthcoming review (Figure 1).

### *3.4 Data Abstraction and Analysis*

This study's assessment strategy, among others, was an integrative analysis, which looked at and synthesised a range of research designs (quantitative methods). Hence, the primary aim with respect to the competent study was to determine relevant subtopics as well as subjects. Here, the initial stage in the theme's evolution was the data collection phase. As can be seen, Figure 1 illustrates how the authors meticulously scrutinized a set of 15 publications for statements or information related to the subjects of the present study. Thereafter, they assessed the important research being done right now on pandanus nanocomposite for electronic devices. Investigations are underway regarding the research findings as well as the methodologies employed in all of the studies. Subsequently, the author collaborated with fellow co-authors to formulate themes derived from the data within the context of this study. Observations, opinions, puzzles, and other ideas pertinent to the interpretation

of the data throughout the data analysis process were recorded in a log. To determine whether the theme design process was inconsistent in any way, the authors finally contrasted the outcomes. To address any disparities in the theme-creation procedure, the authors also compared their findings. It should be noted that the authors address any discrepancies that may arise regarding the themes with one another. Ultimately, minor adjustments were made to the developed themes to guarantee coherence.

### *3.5 Quality of Assessment/Appraisal of Quality*

Two experts—one with a speciality in advanced material and nanotechnology semiconductors —performed the examinations to verify the problems' validity. By demonstrating domain validity, the expert review stage contributed to ensuring the sufficiency, clarity, and importance of each sub-theme. Here, the author has incorporated changes in his or her prudence in response to expert comments and remarks.

## 4. Results and Finding

The analysis and study of Pandanus nanocomposites hold significant importance in contemporary research, especially for various device applications. Pandanus nanocomposites, derived from the Pandanus plant, offer a unique and sustainable material for diverse applications in devices. Researchers are exploring their potential in fields such as electronics, sensors, and energy storage due to their distinctive properties. The plant's natural characteristics, coupled with nanocomposite technology, contribute to the development of materials with enhanced strength, conductivity, and other tailored features. This exploration is crucial as it is in line with the rising emphasis on eco-friendly materials as well as sustainability in the development of advanced technologies. Understanding and harnessing the properties of Pandanus nanocomposites can pave the way for innovative and environmentally friendly solutions across various device applications in the current technological landscape. All articles were classified into three main themes, namely Synthesis and Applications of Nanomaterials Using *Pandanus amaryllifolius* Extracts as shown in Table 3 (10 articles), Properties and Applications of Biosynthesized Nanomaterials as shown in Table 4 (2 articles), and Bioactivity and Functional Applications of Plant-Based Materials as shown in Table 5 (3 articles)

### *4.1 Nanomaterials Synthesis and Utilization Using Extracts from Pandanus amaryllifolius*

The use of *Pandanus amaryllifolius* extracts as a versatile and sustainable source for synthesizing nanomaterials has garnered considerable attention in the field of nanotechnology. This article combines findings from three distinct studies that examine the creation and use of nanomaterials using extracts from the *Pandanus amaryllifolius* plant. The initial study investigates the influence of *Pandanus amaryllifolius* dye on the optical characteristics of ZnO nanoflakes produced through the anodization technique. Figure 2(a)-(c) illustrates the preparation of the Pandanus leaves dye extract. It reveals an improved capacity for absorbing ultraviolet light following the application of the dye [13]. The second study investigates the production of Silver Nanoparticles (PARLE-AgNPs) using an extract from *Pandanus amaryllifolius* Roxb. Leaves, which are biocompatible. The study demonstrates the potential of these nanoparticles to effectively combat lung and breast cancer cells [9]. Furthermore, the third study showcases the eco-friendly production of $Au/TiO_2$ nanocomposite by utilizing extracts from *Averrhoa bilimbi* fruit and *Pandanus amaryllifolius* leaves. This study

demonstrates that the nanocomposite exhibits enhanced photocatalytic activity in degrading methylene blue, surpassing the performance of $TiO_2$ nanoparticles [14]. Moreover, the investigations highlight the potential of *Pandanus amaryllifolius* extracts in creating nanomaterials sustainably. These nanomaterials have various applications, including improved optical properties as well as biomedical and environmental uses.

The use of *Pandanus amaryllifolius* extracts for creating nanomaterials has become a novel and environmentally friendly method, providing a broad aspect of applications in different fields. Here, the utilization of *Pandanus amaryllifolius*-assisted solution immersion in the preparation of nanostructured ZnO on glass substrates resulted in ZnO formation having a hexagonal wurtzite structure. This method is both environmentally friendly and economical. The properties of the ZnO produced using this method are comparable to those synthesized using conventional methods but at a lower temperature [15]. Consequently, a separate investigation was conducted to examine the *Pandanus amaryllifolius* Roxb. leaf extract's potential to be employed as a natural mouthwash, employing the nanoemulsion technique. The study discovered that the nanoemulsion mouthwash, specifically with a 4% extract concentration, indicated a salivary pH similar to that of commercial mouthwash, highlighting its potential as a viable and natural alternative for oral care [16].

Moreover, a single-step production of Gold Nanoparticles (AuNPs) utilising *Pandanus amaryllifolius* leaf extract exhibited encouraging biological and biocompatible effects. The synthesized AuNPs demonstrated antioxidant properties, moderate antibacterial effects, and the capability to restrain the growth of human breast cancer cells. These findings suggest that these NPs have diverse possible uses in cancer treatment, food packaging, and cosmetics [11]. The studies emphasize the importance of using *Pandanus amaryllifolius* extracts for the environmentally friendly production of nanomaterials that have various properties and potential applications. The theme "Synthesis and Applications of Nanomaterials Using Pandanus amaryllifolius Extracts" focuses on the development of environmentally friendly techniques for producing nanomaterials and investigating their practical uses. Two studies in this context introduce innovative methods for producing ZnO micro as well as nanorods, utilizing *Pandanus amaryllifolius* as an environmentally friendly stabilizer. The initial investigation [6] involved the ZnO microrods synthesis employing *Pandanus amaryllifolius* and Hexamethylenetetramine (HMTA) as stabilizing agents. Figure 3 illustrates the boiling process and Pandanus leaves extract.

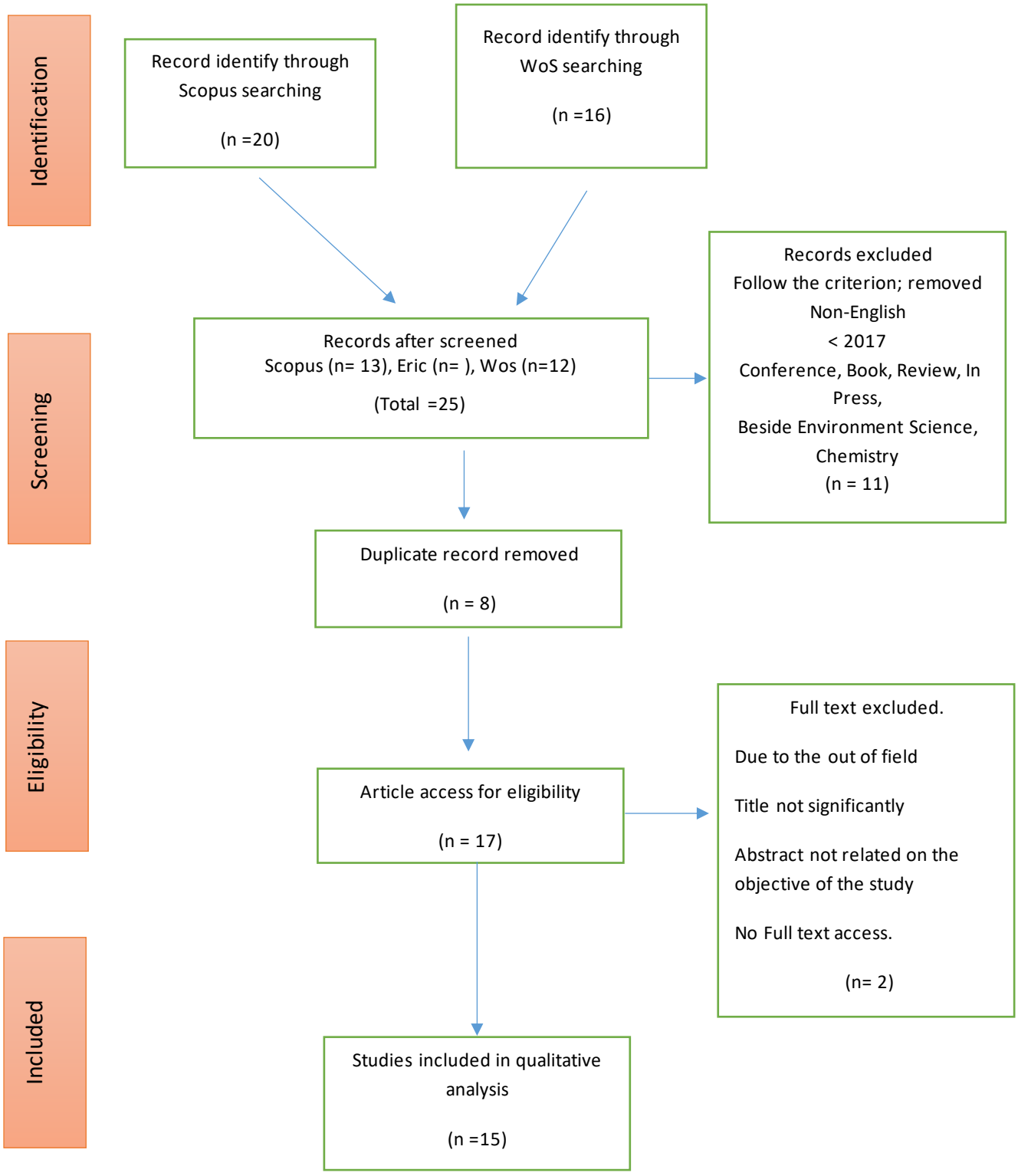



**Fig. 1.** Flow diagram of the proposed searching study [17]


(a) (b) (c)

**Fig. 2.** (a) Pandanus leaves, (b) process of stirring, and (c) pandanus dye extract [13]

(a) (b)

**Fig. 3.** (a) Boiling process and (b) Pandanus leaves extract [6]

These microrods demonstrated UV absorption at approximately 375 nm, which was similar to the nanorods synthesized with HMTA.On the other hand, *Pandanus amaryllifolius* exhibited a distinctive capability to cultivate compact ZnO microrod structures with improved crystalline quality, offering potential progress in optoelectronic uses, specifically in UV sensors. The second study [5] investigated the process of producing ZnO nanorods by utilizing *Pandanus amaryllifolius* as a substitute stabilizer. By subjecting the material to various temperatures, it was discovered that the most favorable conditions for growth were achieved. The presence of *Pandanus amaryllifolius* greatly facilitated the formation of ZnO nanorods that were both highly crystalline and densely packed. The discoveries provide valuable knowledge for optoelectronic applications, specifically in the field of ultraviolet sensors.

This theme investigates the use of environmentally sustainable techniques for the production of nanomaterials. Two distinct studies contribute to this theme. The initial investigation [18] involved the biofabrication of $CeO_2$ nanostructures with an extract derived from *Pandanus amaryllifolius* leaves. Monoethanolamine (MEA) was utilized as both a stabilizing as well as bio-reducing agent. Note that the addition of MEA and higher calcination temperatures resulted in the formation of nanostructures with improved crystallinity, which exhibited a spherical shape. The nanospherical $CeO_2$ structures enveloping the Si substrate underwent examination through High-Resolution X-ray Diffraction (HRXRD) and Field Emission Scanning Electron Microscopy (FESEM) to analyze their crystal

structure and morphology, which revealed dense agglomerations. The second study by Buniyamin *et. al* [19] employed a green synthesis technique that utilized extracts from A. malaccensis as well as *Pandanus amaryllifolius* leaves, producing $SnO_2$ NPs. Subjecting *Pandanus amaryllifolius*-derived $SnO_2$ NPs to calcination at different temperatures improved their crystallinity and morphological regularities, resulting in a greater surface-to-volume ratio. Moreover, the UV-vis diffuse reflectance analysis showed exceptional light absorption capabilities of these NPs, indicating their high potential for use in catalytic applications, especially in the field of water remediation. Both studies demonstrate the capacity of *Pandanus amaryllifolius* extracts in sustainable nanomaterial synthesis with a wide range of applications.

### *4.2 Characteristics and Uses of Nanomaterials Biosynthesized Through Biological Processes*

This thematic article focuses on two separate studies that examine the properties and applications of $CeO_2$ nanostructures and sensitized $TiO_2$-$ZrO_2$ films for dye-sensitized solar cell applications within the field of biosynthesized nanomaterials. The initial study showcases the utilization of a $CeO_2$ seed layer to facilitate the growth of $CeO_2$ nanostructures. This growth is achieved by employing *Pandanus amaryllifolius* leaf extract as a stabilizing agent. The results demonstrate that the leakage current density has been enhanced due to a higher concentration of oxygen and sufficient oxygen vacancies. This improvement has led to an increased ability to trap electrons and an overall enhancement in the performance of the device [20]. In the second study, $TiO_2$, $ZrO_2$, and $TiO_2$-$ZrO_2$ films created through a layer-by-layer approach are sensitized with a natural dye derived from Pandan leaves. These films are used for dye-sensitized solar cell fabrication. Here, the artificially produced solar cells demonstrate improved photovoltaic characteristics, such as fill factor, open-circuit voltage, as well as power conversion efficiency, indicating the promise of bioengineered nanomaterials in the field of renewable energy [21]. Collectively, these studies enhance our understanding of the distinctive characteristics and varied uses of biosynthesized nanomaterials, highlighting their importance in the progress of nanotechnology.

### *4.3 Bioactivity and Practical Applications of Materials Derived from Plants*

This theme article examines the varied bioactivity and functional uses of *Pandanus amaryllifolius* across a range of domains in the context of plant-based materials. The research consists of three separate studies that highlight the applicability and potential of *Pandanus amaryllifolius* in food, biomaterials, and textiles with antimicrobial coatings. The first study aims to create stable Essential Oil Nanoemulsions (EONEs) using pandan and betel leaves for use in food applications. The EONEs show promise as functional ingredients for the food industry because of their advantageous characteristics, which include low turbidity, small particle size, as well as high antioxidant activity [22]. Meanwhile, *Pandanus Amaryllifolius* Fiber (PAF) is creatively used to create thermoplastic blends of cassava starch and beeswax that degrade naturally. The resulting bio-composites show the potential of *Pandanus amaryllifolius* in the biopolymer and bio-packaging industries, with improved mechanical, thermal, and biodegradation properties [23]. The third study investigates the application of natural substances, such as ZnO obtained from *Pandanus amaryllifolius*, for antimicrobial-coated fabric textiles. The refined mixture demonstrates enhanced structural characteristics and antimicrobial efficacy, demonstrating the adaptability of *Pandanus amaryllifolius* for use in textile applications [24]. All of these studies highlight the remarkable bioactivity and functional qualities of *Pandanus amaryllifolius* in advancing the development of biopolymers, antimicrobial textiles, and food technology.

**Table 3**
The research article findings are based on The Synthesis and Applications 0f Nanomaterials using Pandanus amaryllifolius Extracts

| Authors | Title | Year | Journal | Methodology | Finding and advantages |
|---|---|---|---|---|---|
| Asli N.A.; Zainol S.Z.; Yusoff K.M.; Azhar N.E.A.; Nurfazianawatie M.Z.; Omar H.; Rosman N.F.; Malek N.S.A.; Md Akhir R.; Buniyamin I.; Khusaimi Z.; Malek M.F.; Md Sin N.D.; Rusop M.[25] | Performance of Pandannus amaryllifolius dye on zinc oxide nanoflakes synthesized via electrochemical anodization method | 2023 | Inorganic and Nano-Metal Chemistry | Synthesis of ZnO nanoflakes using anodization method | The 12 V sample exhibited the highest XRD intensity, and UV absorption increased by 50% after *Pandanus amaryllifolius* dye adsorption. |
| Patil S.B.; Hublikar L.V.; Raghavendra N.; Shanbhog C.; Kamble A.[26] | Synthesis and exploration of anticancer activity of silver nanoparticles using Pandanus amaryllifolius Roxb. leaf extract: Promising approach against lung cancer and breast cancer cell lines | 2021 | Biologia | Green synthesis of AgNPs with *Pandanus amaryllifolius* Roxb. | AgNPs synthesized from *Pandanus amaryllifolius* Roxb. leaves demonstrated potent anticancer effects on A549 and MCF7 cell lines. |
| Yulizar Y.; Sudirman; Apriandanu D.O.B.; Wibowo A.P.[14] | Plant extract-mediated synthesis of Au/$TiO_2$ nanocomposite and its photocatalytic activity under sodium light irradiation | 2019 | Composites Communications | Au/$TiO_2$ nanocomposite synthesis using *Averrhoa bilimbi* and *Pandanus amaryllifolius* | The photocatalytic activity of the Au/$TiO_2$ nanocomposite demonstrated a 2.17-fold increase compared to $TiO_2$ NPs in the degradation of methylene blue. |
| Md Akhir R.; Umbaidilah S.Z.; Abdullah N.A.; Mahmood M.R.; Khusaimi Z.[15] | A preliminary study on the effect of pandanus amaryllifolius extract as a green stabilizer on the growth of nanostructured ZnO | 2020 | Materials Science Forum | Green synthesis of ZnO nanostructures with phyto-assisted solution immersion | Nanostructured ZnO with the advantages of low working temperature and cost-effectiveness grown on a glass substrate. |
| Safrida S.; Khairil K.; Artika W.; Rinaldi R.[16] | Pandanus amaryllifolius Roxb. leaf extract prepared by nanoemulsion technique as a natural mouthwash | 2020 | Journal of Physics: Conference Series | Nanoemulsion technique for *Pandanus amaryllifolius* mouthwash | The nanoemulsion technique with *Pandanus amaryllifolius* extract maintains salivary pH, offering a potential natural mouthwash alternative. |
| Kasi G.; Thanakkasaranee S.; Seesuriyachan P.; Rachtanapun P.[11] | One–pot synthesis of gold nanoparticles using Pandanus amaryllifolius leaf extract and their antibacterial, antioxidant, anticancer, and ecotoxicity assessment | 2023 | Biocatalysis and Agricultural Biotechnology | Biosynthesis of Au Nanaopariclee Ps using *Pandanus amaryllifolius* leaf extract | AuNPs demonstrated anticancer as well as antioxidant activities, with biocompatibility. |

| | | | | | |
|---|---|---|---|---|---|
| Akhir R.M.; Umbaidilah S.Z.; Abdullah N.A.; Alrokayan S.A.H.; Khan H.A.; Soga T.; Rusop M.; Khusaimi Z.[6] | The potential of pandanus amaryllifolius leaves extract in the fabrication of dense and uniform Zno micro rods | 2020 | Micromachines | ZnO micro and nanorods synthesis with *Pandanus amaryllifolius* and HMTA | The utilization of *Pandanus amaryllifolius* as a green stabilizer led to the formation of dense ZnO micro rods exhibiting enhanced morphological and structural characteristics. |
| Akhir R.M.; Harrum W.M.W.; Buniyamin I.; Rusop M.; Khusaimi Z.[5] | Enhanced structural and morphological properties of ZnO nanorods using plant extract-assisted solution immersion method | 2021 | Materials Today: Proceedings | ZnO nanorods synthesis with modified biosynthesis approach | The utilization of *Pandanus amaryllifolius* as a substitute stabilizer showcased a ZnO nanorods structure characterized by high crystallinity and density. |
| Ali Nsar S.M.; Hassan Z.; Cheong K.Y.; Lim W.F.[27] | Synergetic effects of monoethanolamine (MEA) and post-deposition calcination on biosynthesized $CeO_2$ nanostructures spin-coated on a silicon substrate | 2022 | Materials Chemistry and Physics | Biosynthesis of $CeO_2$ nanostructures with *Pandanus amaryllifolius* | MEA enhanced crystal growth, morphology, and optical properties with respect to biosynthesized $CeO_2$ nanostructures |
| Buniyamin I.; Akhir R.M.; Nurfazianawatie M.Z.; Omar H.; Malek N.S.A.; Rostan N.F.; Eswar K.A.; Rosman N.F.; Abdullah M.A.; Asli N.A.; Khusaimi Z.; Rusop M.[19] | Aquilaria malaccensis and Pandanus amaryllifolius mediated synthesis of tin oxide nanoparticles: The effect of the thermal calcination temperature | 2022 | Materials Today: Proceedings | $SnO_2$ Nps' green synthesis using A. malaccensis and *Pandanus amaryllifolius* | $SnO_2$ NPs synthesized with leaf extracts exhibited a higher surface-to-volume ratio and lower band gap, suitable for catalytic applications. |

**Table 4**
The research article findings based on The Properties and Applications of Biosynthesized Nanomaterials

| Authors | Title | Year | Journal | Methodology | Finding and advantages |
|---|---|---|---|---|---|
| Milad S.; Nsar A.; Hassan Z.; Cheong K.Y.; Lim W.F.; Lim W.[20] | Investigation of incorporating $CeO_2$ seed layer for overgrowth of Green synthesized $CeO_2$ nanostructures deposited on Si (111) substrate | 2023 | Journal of Materials Science: Materials in Electronics | $CeO_2$ nanostructure growth with Pandanus amaryllifolius | Lower leakage current density was demonstrated by Samples 1 and 2 with the $CeO_2$ seed layer. Improvement attributed to high oxygen composition. |
| Pawar, KS; Baviskar, PK; Inamuddin; | Layer-by-layer deposition of TiO2- | 2019 | MATERIALS FOR | doctor blade method followed by sensitization with natural | Prepared $TiO_2$, $ZrO_2$, and layer-by-layer $TiO_2$-$ZrO_2$ films for dye-sensitized solar cell application. |

| | | | | |
|---|---|---|---|---|
| Nadaf, AB; Salunke-Gawali, S; Pathan, HM[21] | ZrO2 electrode sensitized with Pandan leaves: natural dye-sensitized solar cell | RENEWABLE AND SUSTAINABLE ENERGY | dye extracted from Pandan leaves | Investigated structural, optical, morphological, and compositional properties using various techniques.<br>Fabricated dye-sensitized solar cells with $ZrO_2$, $TiO_2$, and layer-by-layer $TiO_2$-$ZrO_2$ films sensitized having natural dye from Pandan leaves.<br>J-V characteristics were recorded to assess photo-response, while electrochemical impedance spectroscopy was employed to examine electron behavior, lifetime, and series resistance.<br>The assessment of photovoltaic parameters revealed that the layer-by-layer $TiO_2$-$ZrO_2$ configuration exhibited the most favourable power conversion efficiency, reaching 3.13%. |

**Table 5**
The research article's findings are based on Bioactivity and Functional Applications of Plant-Based Materials

| Authors | Title | Year | Journal | Methodology | Finding and advanatges |
|---|---|---|---|---|---|
| Tan T.N.; Mnocaran Y.P.A.; Ramli M.E.; Utra U.; Ariffin F.; Yussof N.S.[22] | Physical Properties, Antioxidant Activity, and In Vitro Digestibility of Essential Oil Nanoemulsions of Betel and Pandan Leaves | 2023 | ACS Food Science and Technology | Spontaneous Emulsification (SE) method | Produced stable EONEs of pandan and betel leaves.<br>Investigated EONEs from pandan leaf, betel leaf, as well as a blend of betel/pandan leaf (1:1 v/v).<br>Examined Polydispersity Index (PDI), particle size, Particle Size Distribution (PSD), zeta potential, morphology, turbidity, in vitro digestibility, antioxidant activity, as well as physical stability.<br>Among the EONE samples from Pandan or betel leaves, the one derived from Pandan leaves exhibited the smallest size (24 nm), the highest ζ potential (-33 mV), and the lowest turbidity (86.66% transmittance).<br>EONE from betel leaves demonstrated the lowest PDI at 0.23.<br>Betel leaf EONE exhibited the most significant 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity, reaching 88.01%.<br>Pandan/betel leaf EONE exhibited a superior combination of in vitro digestibility and physical stability, particularly noticeable after an 8-week period. |
| Diyana, ZN; Jumaidin, R; Selamat, MZ; Suan, MSM; Hazrati, KZ; Yusof, FAM; Ilyas, RA; Eldin, SM[23] | Effect of Pandanus Amaryllifolius Fibre on Physio-Mechanical, Thermal and Biodegradability of Thermoplastic | 2023 | JOURNAL OF POLYMERS AND THE ENVIRONMENT | Hot Moulding Compression Method | Developed beeswax blends/biodegradable Thermoplastic Cassava Starch reinforced with *Pandanus amaryllifolius* fibre (TCPS/BW/PAF) bio-composites.<br>Different concentrations of *Pandanus amaryllifolius* fibre ranging from 0 to 60 wt% were used, with a consistent beeswax loading of 2.5 wt%. |

| | | | | | |
|---|---|---|---|---|---|
| | Cassava Starch/Beeswax Composites | | | | Characterized BW/TCPS/PAF bio-composites in terms of mechanical, physical, thermal, and biodegradation properties.<br>Enhanced tensile modulus, tensile strength, flexural modulus, and flexural strength with *Pandanus amaryllifolius* fibre loading.<br>Enhanced thermal stability crystallinity, reduced water and moisture affinity, and lowered biodegradation rate.<br>Demonstrated potential of BW/ TCPS/PAF bio-composites in bio-packaging industries as well as biopolymer application |
| Pardi, H; Fitriyah, D; Silitonga, FS; Edelwis, TW; Wardani, RK; Permana, D; Priyangga, A; Subagyo, R; Ramdhani, EP[24] | The antimicrobial potential of ZnO-chitosan/pandan leaves: advancing antimicrobial textile technology | 2023 | JOURNAL OF DISPERSION SCIENCE AND TECHNOLOGY | Coating method | Explored natural compounds (ZnO from chitosan, aloe vera, and pandan leaves extract) for antimicrobial-coated fabric textiles.<br>Optimized formulation, structural properties, and antimicrobial effectiveness via FTIR, PSA, and SEM-EDX.<br>Utilized NaOH as a base with a pH of 13.0 to achieve smaller particles and enhance overall homogeneity.The XRD analysis verified the presence of a hexagonal crystalline structure of ZnO within the composite.<br>NaOH and Chloroacetamide (CAA) binder influenced the ZnO-Chitosan/Pandan leaf coating on cotton fibers.<br>A substantial decrease in the carbonyl absorption peak was observed when using a molar ratio of 1:2 for CAA and NaOH, suggesting a more complete coating. |

## 5. Discussion and Conclusions

### *5.1 Synthesis and Applications of Nanomaterials using Pandanus amaryllifolius Extracts*

The research demonstrates the impressive capability of *Pandanus amaryllifolius* extracts in producing and improving various nanomaterials with promising practical uses. The extract demonstrates its versatility in the synthesis of green nanomaterials, ranging from durable anticancer silver nanoparticles to biocompatible antioxidant gold nanoparticles. Pandanus-stabilized ZnO nanorods and $CeO_2$ structures demonstrate exceptional morphology and improved properties, emphasizing the extract's function as a natural stabilizer. Furthermore, nanoemulsions derived from Pandanus extract have the potential to serve as environmentally friendly substitutes in oral hygiene products. Additionally, $SnO_2$ nanoparticles produced using the extract show promise for use in catalytic applications. To summarize, this study presents promising opportunities for the application of *Pandanus amaryllifolius* extracts in the creation of environmentally friendly and efficient nanomaterials in different industries.

### *5.2 Characteristics and Uses of Nanomaterials Biosynthesized through Biological Processes*

This study showcases the potential use of biosynthesized nanomaterials to improve Dye-Sensitized Solar Cells' (DSSCs) effectiveness. Here, we have effectively created photoelectrodes using $TiO_2$, $ZrO_2$, and a layer-by-layer $TiO_2$-$ZrO_2$ fabrication method, with natural dyes derived from Pandan leaves as the source of colour. The layer-by-layer method was used to combine $TiO_2$ and $ZrO_2$, resulting in a power conversion efficiency of 3.13%, greater compared to the individual metal oxides. It is worth mentioning that samples containing a $CeO_2$ seed layer exhibited a lower density of leakage current, which can be attributed to their elevated oxygen composition. These discoveries present promising opportunities for investigating naturally produced nanomaterials as environmentally friendly and effective substitutes to enhance DSSCs performance, thus leading to more sustainable and cost-effective solar energy solutions.

### *5.3 Bioactivity and Practical Applications of Materials Derived from Plants*

This study explores the biological activity and practicality of materials derived from plants, highlighting their potential in various applications. The study showcases the adaptability of Pandan leaf extract in creating stable nanoemulsions of essential oil, which exhibit improved antioxidant activity and digestibility. In addition, the *Pandanus amaryllifolius* fiber incorporation enhances the thermal as well as mechanical properties of cassava starch bio-composites, making them more suitable for applications in biopolymers and bio-packaging. Consequently, the investigation of natural antimicrobial coatings uncovers the potential synergy between ZnO derived from chitosan, aloe vera, and Pandan leaf extract, creating opportunities for environmentally friendly fabric preservation. This study explores the potential of utilizing the bioactivity and functional properties of easily accessible plant-based materials. The findings of this research open up possibilities for sustainable alternatives in various industries, including food, packaging, healthcare, and textiles.

**Acknowledgement**
This research was funded by a grant from the Universiti Teknologi MARA (UiTM) (GIP). The main author (Nor Diyana Md Sin) would like to convey her gratitude to the Research Management Centre (RMC), Universiti Teknologi MARA (UiTM) and Ministry of Higher Education (MOHE) for financial support ( 600-TNCPI 5/3/DDN (01) (016/2021).

## References

[1] Jabbar, Abdullah Hasan, Hayder Shkhair Obayes AL-Janabi, Maytham Qabel Hamzah, Salim Oudah Mezan, Alaa Nahad Tumah, Amira Saryati Binti Ameruddin, and Mohd Arif Agam. "Nanocomposite Assisted Green Synthesis of Polyvinylpyrrolidone-Silver Nanocomposite Using Pandanus atrocarpus Extract for Antiurolithiatic Activity." *Systematic Reviews in Pharmacy* 11, no. 6 (2020): 1436-1442.

[2] Swapna, M. S., H. V. Saritha Devi, G. Ambadas, and S. Sankararaman. "Tunable fluorescence from natural carbon source: Pandanus." *Pramana* 92, no. 5 (2019): 80. https://doi.org/10.1007/s12043-019-1755-x

[3] Jaffur, Nausheen, and Pratima Jeetah. "Production of low cost paper from Pandanus utilis fibres as a substitution to wood." *Sustainable Environment Research* 29 (2019): 1-10. https://doi.org/10.1186/s42834-019-0023-6

[4] Vijian, Rashmeera Siva, Mostafa Yusefi, and Kamyar Shameli. "Plant extract loaded sodium alginate nanocomposites for biomedical applications: A review." *Journal of Research in Nanoscience and Nanotechnology* 6, no. 1 (2022): 14-30. https://doi.org/10.37934/jrnn.6.1.1430

[5] Akhir, Rabiatuladawiyah Md, Wan Marhaini Wan Harrum, Irmaizatussyehdany Buniyamin, M. Rusop, and Zuraida Khusaimi. "Enhanced structural and morphological properties of ZnO nanorods using plant extract-assisted solution immersion method." *Materials Today: Proceedings* 48 (2022): 1855-1860. https://doi.org/10.1016/j.matpr.2021.09.205

[6] Md Akhir, Rabiatuladawiyah, Siti Zulaikha Umbaidilah, Nurul Afaah Abdullah, Salman AH Alrokayan, Haseeb A. Khan, Tetsuo Soga, M. Rusop, and Zuraida Khusaimi. "The potential of pandanus amaryllifolius leaves extract in fabrication of dense and uniform ZnO microrods." *Micromachines* 11, no. 3 (2020): 299. https://doi.org/10.3390/mi11030299

[7] Deivanathan, Saravana Kumar, and J. Thomas Joseph Prakash. "Green synthesis of silver nanoparticles using aqueous leaf extract of Guettarda speciosa and its antimicrobial and anti-oxidative properties." *Chemical Data Collections* 38 (2022): 100831. https://doi.org/10.1016/j.cdc.2022.100831

[8] Mohammed, Layth, Mohamed NM Ansari, Grace Pua, Mohammad Jawaid, and M. Saiful Islam. "A review on natural fiber reinforced polymer composite and its applications." *International journal of polymer science* 2015, no. 1 (2015): 243947. https://doi.org/10.1155/2015/243947

[9] Patil, Sumangala B., Leena V. Hublikar, Narasimha Raghavendra, Chirag Shanbhog, and Arvind Kamble. "Synthesis and exploration of anticancer activity of silver nanoparticles using Pandanus amaryllifolius Roxb. leaf extract: Promising approach against lung cancer and breast cancer cell lines." *Biologia* 76 (2021): 3533-3545. https://doi.org/10.1007/s11756-021-00878-8

[10] Joseph, Angel, and Arya Vijayanandan. "Photocatalysts synthesized via plant mediated extracts for degradation of organic compounds: A review of formation mechanisms and application in wastewater treatment." *Sustainable Chemistry and Pharmacy* 22 (2021): 100453. https://doi.org/10.1016/j.scp.2021.100453

[11] Kasi, Gopinath, Sarinthip Thanakkasaranee, Phisit Seesuriyachan, and Pornchai Rachtanapun. "One–pot synthesis of gold nanoparticles using Pandanus amaryllifolius leaf extract and their antibacterial, antioxidant, anticancer, and ecotoxicity assessment." *Biocatalysis and Agricultural Biotechnology* 50 (2023): 102695. https://doi.org/10.1016/j.bcab.2023.102695

[12] Ong, Wee-Jun, Sunita Varjani and Joon Ching Juan. "The role of deep eutectic solvents and carrageenan in synthesizing biocompatible anisotropic metal nanoparticles." (2021).

[13] Asli, N. A., S. Z. Zainol, K. M. Yusoff, N. E. A. Azhar, M. Z. Nurfazianawatie, H. Omar, N. F. Rosman et al. "Performance of Pandannus amaryllifolius dye on zinc oxide nanoflakes synthesized via electrochemical anodization method." *Inorganic and Nano-Metal Chemistry* (2023): 1-8. https://doi.org/10.1080/24701556.2023.2172583

[14] Yulizar, Yoki, Dewangga Oky Bagus Apriandanu, and Aji Prasetiyo Wibowo. "Plant extract mediated synthesis of Au/TiO2 nanocomposite and its photocatalytic activity under sodium light irradiation." *Composites Communications* 16 (2019): 50-56. https://doi.org/10.1016/j.coco.2019.08.006

[15] Akhir, Rabiatuladawiyah Md, Siti Zulaikha Umbaidilah, Nurul Afaah Abdullah, Mohamad Rusop Mahmood, and Zuraida Khusaimi. "A Preliminary Study on the Effect of Pandanus amaryllifolius Extract as Green Stabilizer to the Growth of Nanostructured ZnO." In *Materials Science Forum*, vol. 990, pp. 277-282. Trans Tech Publications Ltd, 2020. https://doi.org/10.4028/www.scientific.net/MSF.990.277

[16] Safrida, S., K. Khairil, W. Artika, and R. Rinaldi. "Pandanus amaryllifolius Roxb. leaf extract prepared by nanoemulsion technique as a natural mouthwash." In *Journal of Physics: Conference Series*, vol. 1460, no. 1, p. 012050. IOP Publishing, 2020. https://doi.org/10.1088/1742-6596/1460/1/012050

[17] Mustafa, Wan Azani, Afiqah Halim, Mohd Wafi Nasrudin, and Khairul Shakir Ab Rahman. "Cervical cancer situation in Malaysia: A systematic literature review." *Biocell* 46, no. 2 (2022): 367. https://doi.org/10.32604/biocell.2022.016814

[18] Nsar, Saad Milad Ali, Zainuriah Hassan, Kuan Yew Cheong, and Way Foong Lim. "Synergetic effects of

monoethanolamine (MEA) and post-deposition calcination on biosynthesized CeO2 nanostructures spin-coated on silicon substrate." *Materials Chemistry and Physics* 278 (2022): 125656. https://doi.org/10.1016/j.matchemphys.2021.125656

[19] Buniyamin, I., R. M. Akhir, M. Z. Nurfazianawatie, H. Omar, N. S. A. Malek, N. F. Rostan, K. A. Eswar et al. "Aquilaria malaccensis and Pandanus amaryllifolius mediated synthesis of tin oxide nanoparticles: The effect of the thermal calcination temperature." *Materials Today: Proceedings* 75 (2023): 23-30. https://doi.org/10.1016/j.matpr.2022.09.580

[20] Milad, Saad, Ali Nsar, Zainuriah Hassan, Kuan Yew Cheong, Way Foong Lim, and W. F. Lim. "Investigation of incorporating CeO2 seed layer for overgrowth of Green synthesized CeO2 nanostructures deposited on Si (111) substrate." *Journal of Materials Science: Materials in Electronics* 34, no. 9 (2023): 810. https://doi.org/10.1007/s10854-023-10172-9

[21] Pawar, Kalpana S., Prashant K. Baviskar, Inamuddin, Altafhusain B. Nadaf, Sunita Salunke-Gawali, and Habib M. Pathan. "Layer-by-layer deposition of TiO 2–ZrO 2 electrode sensitized with Pandan leaves: natural dye-sensitized solar cell." *Materials for Renewable and Sustainable Energy* 8 (2019): 1-9. https://doi.org/10.1007/s40243-019-0148-x

[22] Pawar, Kalpana S., Prashant K. Baviskar, Inamuddin, Altafhusain B. Nadaf, Sunita Salunke-Gawali, and Habib M. Pathan. "Layer-by-layer deposition of TiO 2–ZrO 2 electrode sensitized with Pandan leaves: natural dye-sensitized solar cell." *Materials for Renewable and Sustainable Energy* 8 (2019): 1-9. https://doi.org/10.1007/s40243-019-0148-x

[23] Diyana, Z. N., R. Jumaidin, M. Z. Selamat, M. S. M. Suan, K. Z. Hazrati, Fahmi Asyadi Md Yusof, R. A. Ilyas, and Sayed M. Eldin. "Effect of Pandanus Amaryllifolius Fibre on Physio-Mechanical, Thermal and Biodegradability of Thermoplastic Cassava Starch/Beeswax Composites." *Journal of Polymers and the Environment* 32, no. 3 (2024): 1406-1422. https://doi.org/10.1007/s10924-023-03039-x

[24] Pardi, Hilfi, Dina Fitriyah, Friska Septiani Silitonga, Tri Widya Edelwis, Ratih Kusuma Wardani, Dian Permana, Arif Priyangga, Riki Subagyo, and Eka Putra Ramdhani. "The antimicrobial potential of ZnO-chitosan/pandan leaves: advancing antimicrobial textile technology." *Journal of Dispersion Science and Technology* (2023): 1-10. https://doi.org/10.1080/01932691.2023.2296593

[25] Asli, N. A., S. Z. Zainol, K. M. Yusoff, N. E. A. Azhar, M. Z. Nurfazianawatie, H. Omar, N. F. Rosman et al. "Performance of Pandannus amaryllifolius dye on zinc oxide nanoflakes synthesized via electrochemical anodization method." *Inorganic and Nano-Metal Chemistry* (2023): 1-8. https://doi.org/10.1080/24701556.2023.2172583

[26] Patil, Sumangala B., Leena V. Hublikar, Narasimha Raghavendra, Chirag Shanbhog, and Arvind Kamble. "Synthesis and exploration of anticancer activity of silver nanoparticles using Pandanus amaryllifolius Roxb. leaf extract: Promising approach against lung cancer and breast cancer cell lines." *Biologia* 76 (2021): 3533-3545. https://doi.org/10.1007/s11756-021-00878-8

[27] Nsar, Saad Milad Ali, Zainuriah Hassan, Kuan Yew Cheong, and Way Foong Lim. "Synergetic effects of monoethanolamine (MEA) and post-deposition calcination on biosynthesized CeO2 nanostructures spin-coated on silicon substrate." *Materials Chemistry and Physics* 278 (2022): 125656. https://doi.org/10.1016/j.matchemphys.2021.125656