Food Sustainability, Environmental Awareness, and Adaptation and Mitigation Strategies for Developing Countries

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A volume in the Advances in Environmental Engineering and Green Technologies (AEEGT) Book Series

IGI Global
PUBLISHER of TIMELY KNOWLEDGE

Published in the United States of America by
IGI Global
Engineering Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA, USA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

Library of Congress Cataloging-in-Publication Data

Names: Al-Baarri, Ahmad Ni'matullah, editor. | Afifah, Diana Nur, editor.
Title: Food sustainability, environmental awareness, and adaptation and mitigation strategies for Developing Countries / Ahmad Al-Baarri and Diana Nur Afifah, editors.
Description: Hershey, PA : Engineering Science Reference, [2023] | Includes bibliographical references and index. | Summary: "Food products are perishable, particularly in tropical countries with high temperature and humidity environment. Therefore, best strategy and mitigation in order to minimize losses is urgently required to solve the sustainable issues that is dominantly occurred problem in emerging countries. Furthermore, in order to fulfill the demand of food supply, the increase in the productivity of food crops, enlarge the cultivation area, and the use of technology such as GMO and IoT seems important key as exit strategy to solve the sustainability, diversity, and environmental issues. Therefore, the issues in food sustainability, adaptation and mitigation strategy, environmental awareness seems important topic to expose using the approach in country's diversity and their recent application Since the emerging areas is close to the dynamic change in the supply and demand, therefore, the information provided by the research in emerging countries in really needed"-- Provided by publisher.
Identifiers: LCCN 2022039735 (print) | LCCN 2022039736 (ebook) | ISBN 9781668456293 (hardcover) | ISBN 9781668456309 (ebook)
Subjects: LCSH: Sustainability--Developing countries. | Food supply--Developing countries. | Crops and climate--Developing countries.
Classification: LCC HD9018.D44 F6665 2023 (print) | LCC HD9018.D44 (ebook) | DDC 338.1/91724--dc23/eng/20221104
LC record available at https://lccn.loc.gov/2022039735
LC ebook record available at https://lccn.loc.gov/2022039736

This book is published in the IGI Global book series Advances in Environmental Engineering and Green Technologies (AEEGT) (ISSN: 2326-9162; eISSN: 2326-9170)

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

Advances in Environmental Engineering and Green Technologies (AEEGT) Book Series

ISSN:2326-9162
EISSN:2326-9170

Editor-in-Chief: Sang-Bing Tsai, Zhongshan Institute, University of Electronic Science and Technology of China, China & Wuyi University, China, Ming-Lang Tseng, Lunghwa University of Science and Technology, Taiwan, Yuchi Wang, University of Electronic Science and Technology of China Zhongshan Institute, China

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The Advances in Environmental Engineering and Green Technologies (AEEGT) Book Series (ISSN 2326-9162) is published by IGI Global, 701 E. Chocolate Avenue, Hershey, PA 17033-1240, USA, www.igi-global.com. This series is composed of titles available for purchase individually; each title is edited to be contextually exclusive from any other title within the series. For pricing and ordering information please visit http://www.igi-global.com/book-series/advances-environmental-engineering-green-technologies/73679. Postmaster: Send all address changes to above address.

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Table of Contents

Detailed Table of Contents

Hendra Wijaya, Centre for Agro-Based Industry, Ministry of Industry, Bogor, Indonesia & Department of Nutritional Science, Faculty of Health Science, Universitas Esa Unggul, Jakarta, Indonesia
Zaekhan Zaekhan, Centre for Agro-Based Industry, Ministry of Industry, Bogor, Indonesia
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This study assesses the contribution of the food and beverage industry to the Indonesian economy based on firm characteristics. The comparative descriptive statistical method describes a detailed mapping of the firm's character and the main supporting factors, such as processed commodities, firm size, island region, capital ownership, and exporters. The contribution of the food and beverage sub-industry varies; the vegetable and animal oils and fats industry is the largest and most effective. Small and medium firms have the lowest contribution compared to large firms. Firms in the Sumatra region have the highest contribution compared to firms in other regions. PMDN firms have a higher contribution than PMA firms. Non-exporting firms have a high average contribution compared to exporting firms. Based on the results, policymakers can concentrate on the potential to increase the contribution of a particular group of firms.

Metabolic syndrome (MetS) is a metabolic disorder characterized by central obesity, insulin resistance, hypertension, and hyperlipidemia. MetS is associated with an increase in reactive oxygen species (ROS), triggered by oxidative stress. Oxidative stress occurs when the number of free radicals in the body exceeds its ability to neutralize them, causing cells, tissues, or organs damage, and triggering type 2 diabetes mellitus (DM) and coronary heart disease. One of the ways to manage of MetS is through functional food. Various studies have shown that functional foods contain bioactive components such as dietary fibers (beta-glucans, pectin, inulin), phytosterols, oleic acid, polyunsaturated fatty acids, antioxidant vitamins, phytochemicals such as flavonoids, and bioactive peptides. In addition, functional food processing uses state-of-the-art technology that generates heat through internal transmission energy and does not use high-temperature technology. This minimizes the deterioration of sensory characteristics, nutrients, and functional foods.

Tempeh gembus is a traditional Indonesian prepared from solid tofu waste fermented by Rhizopus oligosporus. It contained some nutritional value and bioactives from fermentation, making tempeh gembus a functional food with variety of health benefits. Previous research had investigated functional properties of tempeh gembus, such as amidolytic, antimicrobial, and antioxidant, as well as proteolytic, fibrinolytic, fibrinogenolytic, and anti-inflammation, which were linked to a variety health benefits, including atherosclerosis, diabetes mellitus, hyperlipidaemia, obesity, metabolic syndrome, and osteopenia. Tempeh gembus is sometimes underestimated because it is prepared from tofu waste and is frequently consumed by low-income people

Section 2
Environmental Awareness

Since the water splitting breakthrough using semiconductor reported in 1972, titanium dioxide (TiO2) has been extensively investigated as a promising material used in broad range of research areas. TiO2 is a transition metal oxide semiconductor with three distinct polymorph crystalline structures. With that alone TiO2 established remarkable performance as photocatalyst for organic photodegradation in the irradiation of UV. However, improvement on the light absorption properties that support the excellent photocatalytic activity still needs to be pursued for wider environmental application. In this book chapter, the limitations of TiO2 as photocatalyst were discussed especially in the industrial wastewater treatment application. The strategies in overcoming the limitation by TiO2 morphology and surface modification were also presented. The modified TiO2 nanomaterials proves to have excellent photocatalytic activity in dyes (Rhodamine B, Methyl Orange and Methylene Blue) as representative of organic pollutant degradation and Cu (II) reduction as representative of inorganic pollutant.

Green energy and environmental awareness have grown because human activities have an impact and are harmful to the environment. Recently, renewable energy and the environment are hot issues in the world that are facing serious challenges. A new photocatalyst, Ag3PO4, has great potential to be applied in producing renewable energy and the environment. The recent design of Ag3PO4-based photocatalysts and their applications are discussed in this book chapter. Modifications of Ag3PO4 photocatalysts are carried out to increase photocatalytic activity and stability. Surface modification and composite design into binary, ternary, and quaternary have given very important results in increasing the capability of this photocatalyst. The application of Ag3PO4-based photocatalyst is very prospective for hydrogen/oxygen production, organic pollutant degradation, antibiotic degradation, antibacterial, and environmental sensors.

Water is one of the vital resources of human life. The rapid development of the industrial sector in developing countries is one of the main factors that contribute to water pollution, due to a lack of environmental awareness. Therefore, it is very important to remove the pollutants from industrial wastewater before being discharged into water bodies. Adsorption using inexpensive and high availability materials such as magnetic biochar is a promising alternative. Embedding magnetite (Fe3O4) into biochar not only aims to solve the separating problem, but also to strengthen the adsorption performance of the biochar. This book chapter introduces the preparation and characterization of magnetic biochar derived from betung bamboo. Furthermore, a discussion was conducted to provide a perspective on the use of magnetic biochar in adsorption technology, particularly in the removal of dyes in an aqueous solution. Finally, the isotherm models for the magnetic biochar-dye system are discussed at the end of this chapter.

The environmental issue occurs along with the waste released from the agricultural or agroindustrial sector. Biomass waste from agricultural or agroindustrial activities has potential value due to its composition and cost. The extraction and treatment of biomass could convert the organic compound into valuable material or energy source. A pretreatment or preprocessing needs to be applied before the application of biomass waste. Biogas, biohydrogen, and bioethanol are the most energy-providing source products from agricultural waste biomass. The technology is developed to obtain successful fermentation and generate optimum biogas and bioethanol. Biopellet production from biomass waste is also promising for a solid energy sources that recently developed. Conversion and utilization of biomass waste from agricultural or agroindustrial sectors not only promote environmentally friendly process results, but also deliver a circular economy.

Materials with superhydrophobic surfaces have received great attention fom scientists recently. One of the materials that have this property is silica thin film. Silica thin film has been widely studied due to its high hydrophobicity and ability to be applied in various materials. Superhydrophobic silica thin film has a water contact angle of more than 150; consequently, it is suitable for applications as an anti-fogging, anti-reflective and self-cleaning material which is in great demand by the industry to develop. The development of superhydrophobic materials with self-cleaning capabilities has several advantages, such as reducing maintenance costs, increasing durability, preventing snow or ice adhesion, and protecting materials from the effects of environmental pollution. Superhydrophobic silica thin films have been developed in various materials that are on glass surfaces, wood surfaces, stainless-steel, and cotton fabric coatings. This chapter focuses on discussing the latest developments of superhydrophobic thin film silica applied on various materials.

Most of the fruit and vegetable production ends up as agricultural waste. The waste is generated not only from fruits and vegetable residues that cannot be consumed directly, such as seeds, peels, and stems, but also from the result of inefficient post-harvest processing, in addition to the perishable nature of fruits and vegetables. Those wastes undoubtedly become a problem to the environment because it contributes to gas emissions production. Meanwhile, those wastes contain lignocellulose, starch, or sugar, which can be processed into bioethanol. As is known, bioethanol is an alternative in dealing with the problem of dwindling fossil energy. So, this chapter will overview various fruits and vegetable waste potential as raw materials for bioethanol production and the processing steps such as hydrolysis, fermentation, distillation, and dehydration. Besides, it will suggest future research about bioethanol production from fruits and vegetable wastes.

Preface

The Sustainable Development Goals (SDGs) are a global action plan agreed upon by world leaders to end poverty, reduce inequality and protect the environment which are contains 17 goals and 169 Targets that are expected to be achieved by 2030. In line with this mission, the book entitled Food Sustainability, Environmental Awareness, and Adaptation and Mitigation Strategies for Developing Countries is expected to contribute to the achievement of the SDGs with the cross collaborative work between researchers, government, industry, and the society, thus this book was composed to find out the best strategy among enrolled parties, to develop countries.

This book contains 14 chapters in 3 sections with the initial section focuses on food sustainability. The second and third sections discuss about environmental awareness and adaptation and mitigation strategies for developing countries.

For the first section begins with the discussion about the current status of food industry in Indonesia, followed by several chapters about local food in developing countries and its relation to health. Some of these chapters are functional food innovation for the treatment of the metabolic syndrome, health benefits Indonesian fermented food of *Tempeh Gembus* upon national readiness for sustainable development goals achievement, physicochemical characteristic of Indonesian native starch, and animal - based fermented foods in tropical countries: functional aspects and benefits.

Chapter 1 assesses the contribution of the food and beverage industry to the Indonesian economy based on firm characteristics. The comparative descriptive statistical method describes a detailed mapping of the firm's character and the main supporting factors, such as processed commodities, firm size, island region, capital ownership, and exporters. The contribution of the food and beverage sub-industry varies; the vegetable and animal oils and fats industry is the largest and most effective. Small and medium firms have the lowest contribution compared to large firms. Firms in the Sumatra region have the highest contribution compared to firms in other regions. PMDN firms have a higher contribution than PMA firms. Non-exporting firms have a high average contribution compared to exporting firms.

Based on the results, policymakers can concentrate on the potential to increase the contribution of a particular group of firms.

Metabolic syndrome (MetS) is a metabolic disorder characterized by central obesity, insulin resistance, hypertension, and hyperlipidemia is visited in Chapter 2. MetS associated with an increase in Reactive Oxygen Species (ROS), triggered by oxidative stress. Oxidative stress occurs when the number of free radicals in the body exceeds its ability to neutralize them, causing cells, tissues, or organs to damage and triggering type 2 diabetes mellitus (DM) and coronary heart disease. One of the management of MetS is through functional food. Various studies have shown that functional foods contain bioactive components such as dietary fibers (beta-glucans, pectin, inulin), phytosterols, oleic acid, polyunsaturated fatty acids, antioxidant vitamins, phytochemicals such as flavonoids, and bioactive peptides. In addition, functional food processing uses state-of-the-art technology that generates heat through internal transmission energy and does not use high-temperature technology. This minimizes the deterioration of sensory characteristics, nutrients, and functional foods.

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Indonesia has many local starch sources, including rice, taro, arrowroot, sago, corn, konjac, cassava, and elephant foot yam (suweg). Several uses of natural starch have been widely used as the primary raw material or as a food additive. Natural starch generally has some drawbacks limiting its use, such as color, solubility index, retrogradation, and paste stability. Starch modification is needed to improve these limitations. Starch modification is carried out physically and chemically (Karmakar & Ban, 2014). In Chapter 4, the physical and chemical characteristics of several local Indonesian starches, both natural and modified, and their potential to be developed as food ingredients is discussed.

Chapter 5 focuses on how tropical countries are rich in fermented animal foods, such as meat paste, shrimp paste, ronto, dadih, Nem chua, chin som mok. The salt addition (2.4-3.0%) and carbon sources resulted fermentation process at room temperature in tropical countries. The abundance of Salinococcus spp. during dough preparation and Lentibacillus spp. during fermentation contributes to the distinctive taste and umami of the shrimp paste. Lactic acid bacteria isolated from fermented animal foods have the potential as probiotics. Probiotics can play a role in increasing antioxidant activity and antimicrobial properties. Corynebacterium sp, Bacillus subtilis and Lactobacillus plantarum were designated as functional starter cultures that could inhibit the growth of pathogenic bacteria (Staphylococcus aureus, Salmonella sp. and Escherichia coli). Animal based fermented foods in tropical countries are very diverse and have functional properties for health, related to antioxidant, probiotic and antimicrobial properties

For the environmental awareness section, the use of waste and materials for a better environment was explained. There are six chapters in this section that are modified TiO2 nanomaterials as photocatalyst for environmental application, The recent design of Ag3PO4-Based photocatalyst for renewable energy and environmental applications, betung bamboo based magnetic biochar for dye removal, recent trend of renewable energy from agricultural wasted biomass, development of silica thin film as self-cleaning surface on various materials, utilization of vegetable and fruit waste as raw material of bioethanol.

Since the water splitting breakthrough using semiconductor reported in 1972, titanium dioxide (TiO2) has been extensively investigated as a promising material used in broad range of research areas. TiO2 is a transition metal oxide semiconductor with three distinct polymorph crystalline structures. With that alone TiO2 established remarkable performance as photocatalyst for organic photodegradation in the irradiation of UV. However, improvement on the light absorption properties that support the excellent photocatalytic activity still needs to be pursued for wider environmental application. In this book chapter, the limitations of TiO2 as photocatalyst were discussed especially in the industrial wastewater treatment application. The strategies in Chapter 6 overcoming the limitation by TiO2 morphology and surface modification were also presented. The modified TiO2 nanomaterials proves to have excellent photocatalytic activity in dyes (Rhodamine B, Methyl Orange and Methylene Blue) as representative of organic pollutant degradation and Cu (II) reduction as representative of inorganic pollutant.

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In Chapter 9, the environmental issue occurs along with the waste released from the agricultural or agroindustrial sector. Biomass waste from agricultural or agroindustrial activities has potential value due to its composition and cost. The extraction and treatment of biomass could convert the organic compound into valuable material or energy source. A pretreatment or preprocessing need to be applied before the application of biomass waste. Biogas, biohydrogen, and bioethanol are the most energy source product from agricultural waste biomass. The technology is developed to obtain successful fermentation and generate optimum biogas and bioethanol. Biopellet production from biomass waste is also promising for a solid energy sources that recently developed. Conversion and utilization of biomass waste from agricultural or agroindustrial sectors not only promote environmentally friendly process results but also deliver a circular economy.

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Finally, last section describes the strategy in adaptation and mitigation for developing countries. Internet of Things (IoT) application in the first chapter on this section, followed by the mediating role of innovation in financial literacy and financial performance, and close by discussion about the coastal protection and rehabilitation technology as climate mitigation and adaptation strategies in Indonesia.

The rapid increase in applications that combine modern concepts and innovations due to the development of the Internet of Things (IoT) and cloud computing around the world, make all areas of life continue to move towards an advanced and intelligent society. This innovation continues to enter almost all fields, ranging from simple to complex innovations. In Chapter 12, IoT is used as a means for tuning PID parameters, when the error does not converge to zero. The experimental results show that the PID parameter tuning process can be done through IoT. And the results are quite encouraging, as an alternative way of tuning PID parameters.

The purpose of Chapter 13 was to determine the relationship between financial literacy, innovation capability, and financial performance and to determine the effect of mediators of innovation capability on the relationship between financial literacy and financial performance with implementation in small and medium enterprises (SMEs). To test the hypothesis in the research model, a field study was conducted using a survey method with a total of 189 owners and managers, out of 189 SMEs operating in the manufacturing sector of tempe chips and dinoyo ceramics. The data collected from 189 owners and managers were analyzed using correlation and regression analysis with the SEM Structural Equation Model. The analysis was carried out using SPSS and AMOS software. As a result of this study, it is evident that innovation capability has a partial mediator effect on the dimensions of market orientation and export performance. This empirical finding contributes to the achievement of the competitive advantage of SMEs through increasing market-based innovation capabilities.

Chapter 14 focuses on the North Coast of Java Indonesia, and how it is an area threatened by erosion due to rising sea levels triggered by climate change. Sayung District, Demak which experienced severe erosion impacts. Restoring lost sediment is an effective way to stop erosion processes and restore a stable coastline. In this chapter, the strategies of coastal protection carried out are presented with the ultimate goal of restoring the natural defense of the coast namely mangroves. The first step is to build a coastal protective building to reduce waves and create calm waters. It will accelerate the sedimentation process so that new sludge-substrate land will be formed that is suitable for mangrove ecosystem growth. This coastal erosion mitigation activity is an effort to increase the resilience of coastal areas from physical aspects that cause deterioration or reduction of coastal functions. The concept of building together with nature has a very high technical, socioeconomic, and environmental feasibility because it is a coastal engineering approach as one of the solutions to the problem of sustainable erosion.

The editors are grateful to the World Class University Program of Universitas Diponegoro for the financial support and also to all authors for their participation to kindly publish ideas in order to achieve the goal of this book program.

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Section 1

Food Sustainability

Chapter 1
Current Status of the Food Industry in Indonesia

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ABSTRACT

This study assesses the contribution of the food and beverage industry to the Indonesian economy based on firm characteristics. The comparative descriptive statistical method describes a detailed mapping of the firm's character and the main supporting factors, such as processed commodities, firm size, island region, capital ownership, and exporters. The contribution of the food and beverage sub-industry varies; the vegetable and animal oils and fats industry is the largest and most effective. Small and medium firms have the lowest contribution compared to

DOI: 10.4018/978-1-6684-5629-3.ch001

large firms. Firms in the Sumatra region have the highest contribution compared to firms in other regions. PMDN firms have a higher contribution than PMA firms. Non-exporting firms have a high average contribution compared to exporting firms. Based on the results, policymakers can concentrate on the potential to increase the contribution of a particular group of firms.

INTRODUCTION

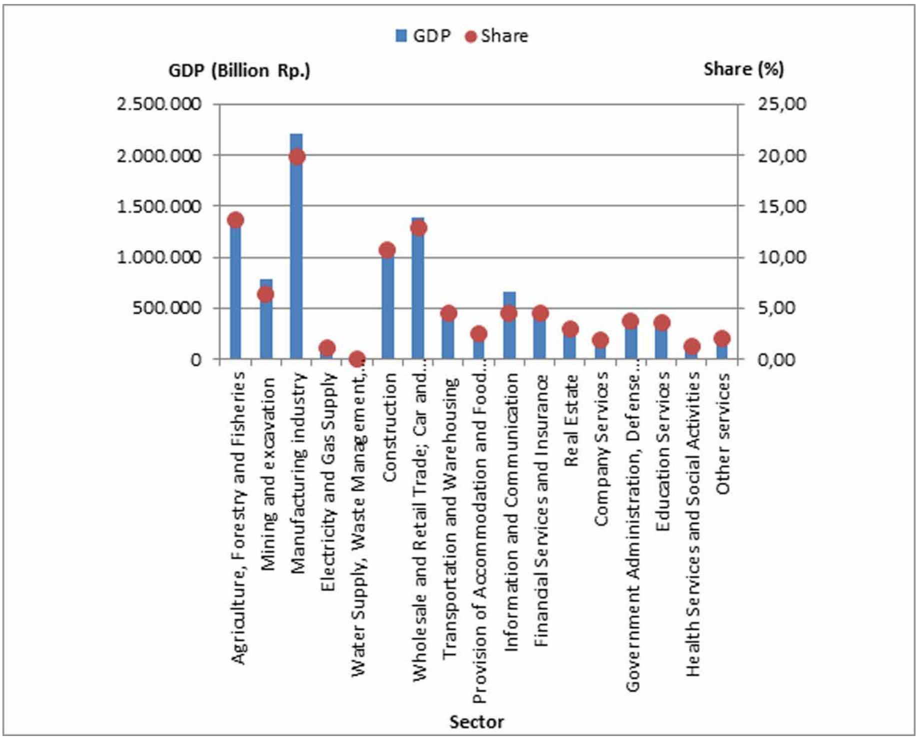
The manufacturing sector is an industry that plays a vital role in the national economy (Attiah, 2019; Banerjee, 2020; Chakravarty & Mitra, 2009; Herman, 2016; Khan & Siddiqi, 2011; Qayyum, Khalid, & Muhammad Usman, 2021; Su & Yao, 2017; Nusratovich, 2019; Sengupta, Sinha, & Dutta, 2019). National Gross Domestic Product (GDP) data for the 2010-2020 period illustrate that the manufacturing sector consistently contributes the most to national GDP compared to other sectors (Statistics Indonesia, 2021a). The performance of manufacturing can provide a contribution share of 19.70 - 22.04 percent, with an average of 20.64 percent per year. In 2020, the manufacturing sector will remain the largest contributor to GDP at 19.88 percent (Figure 1).

In most developing countries, manufacturing sectors play a significant role in increasing economic development since the primary sectors have a low contribution to speeding up the national economy. To construct economic development, the role of manufacturing and labor-intensive industries are very significant in their contribution to non-mining export, absorbing the surplus manpower, and influencing the emergence of new employments (Wijaya, Kurniawati, & Hutama, 2018; Haraguchi, Cheng, & Smeets, 2017).

The food industry indicated higher total factor productivity growth compared to other industries. Meanwhile, the industry of processing and preserving meat, fish, fruits, vegetables, cooking oil, and fat (ISIC 151) has the highest productivity growth. General evidence shows that technical progress becomes the main factor of TFP growth, followed by scale and technical efficiency change (Widodo, Salim, & Bloch, 2015; Liu, Wang, Yang, Rahman, & Sriboonchitta, 2020).

The increasing trend of economic growth denotes that the Indonesian economy is experiencing an increase in production and expenditure, components that exist in GDP. Indonesia also experienced increased economic growth per capita (Suryahani, Susilowati, & M., 2018). The agricultural sector has proven to restore the economy in the domestic economic crisis. This sector contributes to the national economy and plays an important role in increasing income, creating job opportunities, as a source of foreign exchange, ensuring local food needs, and producing raw materials. In general, the agricultural sector plays a vital role in maintaining food security and

Figure 1. GDP of the sector and its contribution to national GDP in 2020 (Statistics Indonesia, 2021a), author's calculation



economic stability (Firmansyah, Widodo, Karsinah, & Oktavilia, 2017; Rozaki, 2021; Nugroho et al., 2022; Pawlak & Kołodziejczak, 2020).

Deindustrialization and diminishing economic growth have become one of the main issues caused by the COVID-19 pandemic. One of the sub-sectors of manufacturing believed to be very important and capable of sustaining its expansion is the food and beverage industry (F&B). The growth of the F&B has proven to be stable during the pandemic period because it is one of the efforts to increase endurance in anticipation of the COVID-19 pandemic (Adhiem, 2021). In addition, the F&B sub-sector can consistently provide the highest contribution share increase in national GDP from 5.25% in 2010 to 6.85% in 2020 (an average of 6.05%). The share of this contribution was 28.18% in 2010 and 38.29% in 2020 to the GDP of the manufacturing sector (average of 33.24%) (Table 1). Thus, the F&B sub-sector becomes one of the sub-sectors that drive the national economy and can accelerate national economic recovery.

The tendency in Indonesia during the covid-19 crisis is the availability of imported food, including rice, horticulture, and livestock products. Covid-19 has affected each food exporting country to reduce food exports to other countries to keep food available. Covid-19 has indicated policyholders to change their strategy to fulfill food availability (Sumekar, Sumarsono, Prasetyo, & Prayoga, 2021; Laborde, Martin, Swinnen, & Vos, 2020; Aday & Aday, 2020).

Table 1. Contribution of industrial sub-sectors to national GDP and manufacturing sector GDP

Manufacture (Non-Migas)		Contribution to national GDP (in percentage)			Contribution to manufacturing sector GDP (in percentage)		
		2010	2020	Mean	2010	2020	Mean
1	Food and Beverages	5.25	6.85	6.05	28.18	38.29	33.24
2	Tobacco Processing	0.98	0.88	0.93	5.26	4.92	5.09
3	Textile and Product textile	1.40	1.21	1.31	7.53	6.76	7.15
4	Leather, Leather Goods, and Footwear	0.29	0.25	0.27	1.54	1.42	1.48
5	Wood, bamboo, and rattan	0.83	0.51	0.67	4.44	2.85	3.64
6	Paper and Paper Goods; Printing and Reproduction of Recorded Media	0.99	0.72	0.85	5.32	4.01	4.66
7	Chemical, Pharmaceutical, and Traditional Medicine	1.67	1.92	1.79	8.94	10.75	9.84
8	Rubber and Plastic	0.97	0.54	0.75	5.22	3.00	4.11
9	Non-Metal Mineral	0.74	0.56	0.65	3.98	3.11	3.55
10	Basic Metal	0.79	0.78	0.79	4.26	4.38	4.32
11	Metal Goods; Computers, Electronic Goods, Optics; and Electrical Equipment	1.90	1.63	1.77	10.22	9.13	9.68
12	Machinery and Equipment	0.35	0.28	0.31	1.86	1.57	1.71
13	Transport Equipment	1.96	1.35	1.65	10.50	7.57	9.03
14	Furniture	0.29	0.25	0.27	1.57	1.40	1.48
15	Other Processing Industries; Repair and Installation Services for Machinery and Equipment	0.22	0.15	0.19	1.18	0.84	1.01
	Total of contribution	**18.63**	**17.89**	**18.26**	**100**	**100**	**100**

Sources: Statistics Indonesia (2021a), author's calculation

The descriptive statistical exploration of firm characteristics was carried out to describe the dynamics of the contribution of the F&B group. The firm's characteristics are commodity level, size, island region, type of ownership, and exporter. Information from this study can assist policymakers in designing better sectoral and cost-effective policies. The implementation of stimulus or incentive policies is being implemented. However, the focus of the policy and the benchmark for the success of the policy can still be optimized. This exploratory study effectively assesses performance and opportunities to increase the potential contribution of the food and beverage industry sub-sector in supporting the national economic recovery.

There are several studies on the role of the food and beverage industry's contribution to economic growth. Sunetra (Lekuthai, 2007) uses the Input-Output model of 1980, 1990, and 2000. The results of this study provide a sector comparison of the benefits of the F&B for the economy in Thailand as a whole. Its empirical conclusion is that the F&B makes the strongest contribution to the economy in Thailand compared to various leading industries in terms of production drivers, job creation, value-added drivers, and foreign exchange earnings. The export value is still not the highest. Another study by Unnevehr in 2017 concluded that the F&B plays a role in several ways, including; providing a stable source of employment, playing an important role in the local economy, contributing to food system innovation, responding to increasing export demand, contributing to food affordability, address increasingly sophisticated consumer demands, meet social goals (public policy and the role of industry), and look to the future front. This study uses data for the period 1993-2015 that comes from various sources and applies the descriptive statistics method.

DATA

The data used to describe the current descriptive statistics of the F&B are secondary data from the annual Indonesian Large Medium Industry Survey for the 2010-2018 periods, which was prepared by the Central Statistics Agency (Statistics Indonesia, 2021b). The survey sample used is assumed to represent the population of firms in the Indonesian manufacturing industry. In addition, the data only reached 2018, the last year IBS data was released, and the updated year data could not be obtained. The advantage of this IBS survey data because it provides detailed information on all firms. This data provides information on all firms with 20 or more laborers for at least six months and cover more than 20000 firms annually. This survey provides a unique identifier for each firm, which did not change over the 2010–2018 period, and provides an unbalanced panel. This survey contains output and characteristics at the enterprise level, such as commodities processed, number of laborers (firm size), regional area (island), type of capital ownership, and exporters.

Output data is measured as added value in billions of Indonesian rupiah based on constant prices in 2010. Commodities processed are based on the 3-digit International Standard Industrial Classification (ISIC). Firm size is based on the number of laborers; small firms have less than 100 laborers; small-medium enterprises have between 100 and 199 laborers; medium-sized enterprises have between 200 and 499 laborers; medium-large enterprises have between 500 and 999 laborers; Big firm has more than 1000 workforce. Firm region based on the island; Java-Bali, Sumatra, Kalimantan, Sulawesi, and Maluku-Papua. Based on the type of capital ownership, companies can be classified into Domestic Investment (PMDN), Foreign Investment (PMA), and Non-Facilities. Classification of exporters based on export and non-export characteristics.

Processed Commodities

The classification of processed food and beverage commodities considers firms with the same food and beverage business line according to the 3-digit ISIC. Food industry firms are classified into eight industrial sub-sectors, and beverage industry firms remain in one sub-sector (Table 2). In Table 2, the food industry sub-sectors with the highest average in 2010-2018 are manufacturing other products, representing more than 48%. While the lowest average is the manufacture of dairy products only represents 1%.

However, this industry does not automatically contribute to the highest and lowest output share. The industry with the highest output share is the manufacture of vegetable and animal oil and fat (57%). The lowest output share is the processing and preserving of meat (0.7%). Manufacture of other products only has an output share of 18%. Let's look at the ratio between output share and firm share. The sub-sectors with the top three highest ratios are the manufacture of prepared animal feeds, vegetable and animal oils and fats, and dairy products.

Considering the results of the descriptive statistics of share output and share of firms above, the food industry's highest contributor to the national economic recovery is in the Manufacture of vegetable and animal oil and fat and Manufacture of other products. The output and the firm effect both play a role in the food industry's contribution to economic recovery. These effects have maintained a stable share of the food industry's contribution to economic recovery during the COVID-19 pandemic. However, when considering the results of descriptive statistics on share ratio data, the manufacture of prepared animal feeds, vegetable and animal oils and fats, and dairy products are the most effective and efficient in national economic recovery. According to the beverage industry, there is only one sub-sector group of the beverage industry according to the 3-digit ISIC classification, so the contribution is 100% to the share of the food and beverage industry in the national economic recovery.

FIRM SIZE

Table 3 shows that food firms with a workforce of less than 100 represent more than 73% of the Indonesian food industry. However, they account for less than 13% of output. On the other hand, large enterprises (laborer number >1000) represent less than 3% of the total number of enterprises. They account for more than 26% of the output share. From these results, there is consistency that the highest number of firm sizes does not guarantee the highest output share and vice versa. It indicates that the highest contributors to the food industry in the national economic recovery are large firms, followed by medium and small firms. Small firms may use a high proportion of manual labor to produce small output and vice versa. This is in line with the results of descriptive statistics on share ratio data so that large firms are the most effective and efficient in contributing to national economic recovery, while small firms are the opposite.

Table 2. Characteristics of the food and beverage industry by 3-digit ISIC sub-sector

Sub-sectors **(ISIC 3-digit)**	**Food Industry**								
	Number of firms				**The industrial output [Rp. trillion]**				*Ratio of Share*
	2010	**2018**	**Mean**	*Share*	**2010**	**2018**	**Mean**	*Share*	
F-[101]	64	111	84	1.4	2.66	19.28	6.16	0.7	0.5
F-[102]	695	1127	1061	17.4	18.40	90.84	49.10	5.6	0.3
F-[103]	245	265	245	4.0	3.44	8.44	4.93	0.6	0.1
F-[104]	638	1173	850	13.9	245.43	842.35	498.64	57.0	4.1
F-[105]	51	92	62	1.0	10.20	53.30	19.04	2.2	2.1
F-[106]	717	660	729	11.9	37.74	91.33	63.39	7.2	0.6
F-[107]	2747	3192	2963	48.5	94.18	397.93	160.60	18.3	0.4
F-[108]	91	155	117	1.9	32.71	111.37	73.43	8.4	4.4
Total	**5248**	**6775**	**6110**	**100.0**	**444.76**	**1,614.84**	**875.29**	**100.0**	**1.0**
Sub-sectors **(ISIC 3-digit)**	**Beverage Industry**								
	Number of firms				**The industrial output [Rp. trillion]**				***Ratio of Share***
	2010	**2018**	**Mean**	***Share***	**2010**	**2018**	**Mean**	***Share***	
B-[110]	328	583	425	100.0	15.46	68.75	29.88	100.0	1.0
Total	**328**	**583**	**425**	**100.0**	**15.46**	**68.75**	**29.88**	**100.0**	**1.0**

Sources: Statistics Indonesia (2021b), author's calculation

Notes: F-[101] Processing and preserving of meat; F-[102] Processing and preserving of fish, crustacean, and mollusks; F-[103] Processing and preserving of fruit and vegetables; F-[104] Manufacture of vegetable and animal oils and fats; F-[105] Manufacture of dairy products; F-[106] Manufacture of grain mill products, starches, and starch products; F-[107] Manufacture of other products; F-[108] Manufacture of prepared animal feeds; B-[110] Manufacture of beverages.

In general, the trend in the descriptive statistics for the beverage industry is similar to the results for the descriptive statistics for the food industry, although some are slightly different. Beverage small firms (laborer <100) represent more than 67% of the Indonesian beverage industry. Large firms (laborer >1000) represent 1.8% of the total number of firms. However, both of them account for 17% of output. On the other hand, medium-sized firms (number of laborers 200-499), representing 11.7% of the total number of enterprises, can contribute more than 31% output share. Based on the results of descriptive statistics on share output and share of firms, the highest contributors to the beverage industry in the national economic recovery are medium-sized firms. Medium-sized firms may optimize the proportion of labor and increase capital. When viewed from a share ratio, firms in the beverage industry also show the same trend of results as firms in the food industry.

Island Region

The island region considers the geographical position of a firm in the archipelago. This position concerns transportation and logistics costs for product distribution and marketing. In Table 4, food firms in the Java-Bali region illustrate more than (> 70%) of the total Indonesian food industry firms. This region contributes more than 38% of the share of output. Meanwhile, the largest average share of output is in Sumatra (44.7%), followed by Java-Bali (38.5%). Food firms in the Maluku-Papua region have a small contribution because of the small proportion of firms in its location (<1%). In addition, this may happen because this area is far from the center of government, so they are less touched by government policies or product marketing not optimal. Based on these results, the highest contributors to the food industry's national economic recovery are firms in the Sumatra and Java-Bali regions. However, when viewed in terms of the ratio of output share to the share of the number of firms, firms in the Kalimantan region have the highest ratio, followed by Sumatra than Maluku-Papua. This shows that firms in this region are very effective and efficient in contributing to the recovery of the national economy.

Based on descriptive statistics, trends in the number of firms and share of beverage industry output show the same results. The largest number of firms and the highest output share in the Java-Bali region, representing 70% and 86%, respectively. Meanwhile, the smallest number of firms and the lowest output share in the Maluku-Papua, representing 2.8% and 0.4%, respectively. The beverage industry in the Maluku-Papua region is consistent with the food industry, which has a small contribution because of the small proportion of firms in its location. Based on the results of statistics descriptive of the shared output and share of the firm, the highest contributors to the beverage industry in the national economic recovery are

Table 3. Characteristics of the food and beverage industry by firm size

Firm size (laborers)	Food Industry								
	Number of firms				The industrial output [Rp. trillion]				*Ratio of Share*
	2010	2018	Mean	*Share*	2010	2018	Mean	*Share*	
F-[20-99]	4024	4729	4508	73.8	48.90	212.94	110.59	12.6	0.2
F-[100-199]	578	1062	789	12.9	112.29	375.84	195.96	22.4	1.7
F-[200-499]	355	613	462	7.6	99.36	397.64	184.10	21.0	2.8
F-[500-999]	167	213	196	3.2	72.83	343.36	153.97	17.6	5.5
F-[>1000]	124	158	155	2.5	111.37	285.06	230.66	26.4	10.4
Total	**5248**	**6775**	**6110**	**100.0**	**444.76**	**1,614.84**	**875.29**	**100.0**	**1.0**
Firm size (laborers)	**Beverage Industry**								
	Number of firms				**The industrial output [Rp. trillion]**				***Ratio of Share***
	2010	**2018**	**Mean**	***Share***	**2010**	**2018**	**Mean**	***Share***	
B-[20-99]	231	382	286	67.2	3.32	12.28	5.08	17.0	0.3
B-[100-199]	46	81	64	15.1	2.74	7.46	4.11	13.8	0.9
B-[200-499]	37	78	50	11.7	6.00	21.86	9.50	31.8	2.7
B-[500-999]	11	27	18	4.2	2.24	11.05	5.92	19.8	4.8
B-[>1000]	3	15	8	1.8	1.16	16.10	5.26	17.6	9.5
Total	**328**	**583**	**425**	**100.0**	**15.46**	**68.75**	**29.88**	**100.0**	**1.0**

Sources: Statistics Indonesia (2021b), author's calculation

firms in the Java-Bali region. The highest ratio in terms of the ratio of output share to the number of firm's shares is also in the Java-Bali region. This illustrates that beverage industry firms in the Java-Bali region are very effective and efficient in contributing to the national economic recovery.

Urbanization can promote productivity and economic opportunities and increase income. Due to positive externalities in the form of agglomeration, urban areas are generally economically more competitive and productive compared to rural. Urban areas create opportunities for the establishment of localization economies through the clustering of related activities. In contrast, urbanization economies may emerge in dense urban areas where the transaction cost of conducting business is lower and knowledge spillover opportunities are high. Businesses within such economies tend to be more economically productive, as demonstrated by a faster rate of growth in GRDP than in rural areas, with the benefits of agglomeration (Pangarso, Suharyadi, & Rijanta, 2020; Nguyen, 2018; Turok, 2017; Tadjoeddin & Mercer-Blackman, 2018).

The empirical results show that the effect of specialization and diversity on firm-level technical efficiency is positive and negative, respectively. This indicates that specialization is more favorable than diversity to stimulate enterprise-level technical efficiency. Competition has positive indications, indicating that areas with high levels of competition tend to be more conducive to accelerating enterprise-level technical efficiency. In terms of firm location, both urban and industrial complexes are positive, indicating that firms in these areas experience higher technical efficiency (Widodo et al., 2015).

Generally, many manufacturing industries agglomerated in the coastal region with a proliferation of Special Economic Zones (SEZs) to attract export-oriented industries. Coastal areas often experience high industrial growth for obvious reasons of topography, access to infrastructure, supply, high market demand, and waste disposal into the sea (Fariha, Buchori, & Sejati, 2021; Priyanto, 2010)

Table 4. Characteristics of the food and beverage industry by island regions

Island regions	**Food Industry**								
	Number of firms				**The industrial output [Rp. trillion]**				*Ratio of Share*
	2010	**2018**	**Mean**	*Share*	**2010**	**2018**	**Mean**	*Share*	
F-[Java-Bali]	3887	4401	4304	70.4	164.04	753.72	337.29	38.5	0.6
F-[Sumatera]	967	1491	1189	19.5	210.28	608.64	391.10	44.7	2.3
F-[Kalimantan]	129	388	231	3.8	44.72	189.34	96.21	11.0	2.9
F-[Sulawesi]	235	436	333	5.4	22.78	52.30	41.60	4.8	0.9
F-[Maluku-Papua]	30	59	53	0.9	2.94	10.84	9.08	1.0	1.2
Total	**5248**	**6775**	**6110**	**100.0**	**444.76**	**1,614.84**	**875.29**	**100.0**	**1.0**
Island regions	**Beverage Industry**								
	Number of firms				**The industrial output [Rp. trillion]**				***Ratio of Share***
	2010	**2018**	**Mean**	***Share***	**2010**	**2018**	**Mean**	***Share***	
B-[Java-Bali]	231	396	295	69.4	13.28	60.55	25.75	86.2	1.2
B-[Sumatera]	55	103	72	17.0	1.56	6.00	2.94	9.8	0.6
B-[Kalimantan]	14	36	22	5.2	0.16	0.81	0.38	1.3	0.2
B-[Sulawesi]	17	30	24	5.6	0.36	1.19	0.70	2.3	0.4
B-[Maluku-Papua]	11	18	12	2.8	0.10	0.21	0.11	0.4	0.1
Total	**328**	**583**	**425**	**100.0**	**15.46**	**68.75**	**29.88**	**100.0**	**1.0**

Sources: Statistics Indonesia (2021b), author's calculation

Type of Ownership

The type of ownership classification refers to the participation of domestic investment (PMDN), namely private or state-owned firms, and foreign investment (PMA). Firms that are members of PMDN and PMA ownership are firms that invest using facilities from the government and are registered. The investments that do not use the facilities are non-facility firms or Non-facilities, which according to the Presidential Decree No. 22 of 1986 is a firm that is not subject to and does not get facilities based on Law no. 1 in conjunction with Law no. 11 of 1970 concerning Foreign Investment and Law no. 12 of 1970 concerning Domestic Investment. This law has been replaced by Law no. 25 of 2007 concerning Investment, which means that the permit is issued directly by the Department/Agency in charge. Based on Table 5, 22% of food firms are PMDN, 5% are PMA, and the others are non-Facilities. PMDNs can contribute the highest share of output (47%), although the number of PMDNs is 22%.

Meanwhile, non-facility contributes the smallest share of output, even though it has more than 72% of firms. Based on the results of descriptive statistics on output share and number of firms share, the highest contributor to the food industry in the national economic recovery is PMDN. However, in terms of the ratio of output share to the share of the number of firms, PMA firms have the highest ratio. This shows

Table 5. Characteristics of the food and beverage industry by type of ownership

Type of Ownership	**Food Industry**								
	Number of firms				**The industrial output [Rp. trillion]**				*Ratio of Share*
	2010	**2018**	**Mean**	*Share*	**2010**	**2018**	**Mean**	*Share*	
F-[PMDN]	895	2252	1335	21.7	238.54	824.12	410.91	46.9	2.1
F-[PMA]	234	510	323	5.3	116.92	383.80	234.16	26.8	5.1
F-[Non-Facilities]	4119	4013	4452	72.9	89.30	406.91	230.22	26.3	0.4
Total	**5248**	**6775**	**6110**	**100.0**	**444.76**	**1,614.84**	**875.29**	**100.0**	**1.0**
Type of Ownership	**Beverage Industry**								
	Number of firms				**The industrial output [Rp. trillion]**				***Ratio of Share***
	2010	**2018**	**Mean**	***Share***	**2010**	**2018**	**Mean**	***Share***	
B-[PMDN]	109	286	166	39.0	5.27	29.96	9.73	32.6	0.8
B-[PMA]	26	53	37	8.7	5.76	18.18	9.31	31.2	3.6
B-[Non-Facilities]	193	244	222	52.2	4.43	20.61	10.84	36.3	0.7
Total	**328**	**583**	**425**	**100.0**	**15.46**	**68.75**	**29.88**	**100.0**	**1.0**

Sources: Statistics Indonesia (2021b), author's calculation that PMA is more effective and efficient in contributing to the national economic recovery.

Based on descriptive statistical analysis, trends in the number of firms and share of beverage industry output are as follows. The largest number of firms and the highest output share is owned by non-Facilities (52.2% and 36.3%, respectively). Meanwhile, PMA has the fewest number of firms and the lowest share of output (8.7% and 31.2%, respectively). The beverage firm owned by PMDN has a firm share of 39% and an output share of 32.6%. The share of output in the three owners is almost balanced so that the contributors to the beverage industry in the national economic recovery are also balanced. However, firms owned by PMA are more competitive because fewer firms exist. When viewed in terms of the ratio of output share to the share of the number of firms, PMA has the highest ratio. These results also indicate that each group requires a different policy. The choice of stimulus policy in the beverage industry in accelerating the national economic recovery is to focus on FDI firms. The number of firms is small but produces a high share of output.

EXPORTER

Export capabilities are classified into three groups; export, not export, and none. The none group is a firm that does not fill in export data, so it does not need to be analyzed even though statistics are still displayed. Firms that export represents less than 10% of the total number of firms and account for more than 18% of the output. Firms that do not export represent more than 56% of the total and account for around 30.5% share of output. The number of firms that do not export has the largest number of firms, although the contribution of the share of output is smaller than "none" firms. This shows that non-exporting firms are not as productive as other groups of firms. When viewed in terms of the ratio of output share to share of the number of firms, export firms have the highest ratio, which means that export firms are very effective and efficient in contributing to national economic recovery (Kilavuz & Topcu, 2012; Kalaitzi & Chamberlain, 2020).

Based on the results in Table 6, the trend of beverage industry firms is in line with the results obtained in the food industry. Based on the statistics descriptive of the share of output and share of the firm, the highest contributor to the beverage industry in the national economic recovery is the "none" firm. However, when viewed in terms of the share of output to the share of the number of firms, exporter firms have the highest ratio of share. This means that the "export" beverage industry is very effective and efficient in contributing to the recovery of the national economy.

In the dairy industry, GDP per capita positively affects the volume of imports of dairy cow's milk. Dairy cow's milk exports also positively and significantly impact imports. In Indonesia, the increase in imports of dairy cow's milk is in line with the increase in exports of dairy cow's milk. Indonesian milk exports are in the form of raw materials such as milk, cream, etc. In contrast, imported milk tends to be processed, such as whey, butter, fresh cheese, casein, processed cheese, powdered cheese, buttermilk, yogurt, and others. The export and import trade balance will change along with the demand and supply of dairy cow's milk (Budiraharjo, Raharjo, & Solikhin, 2021; Susanty et al., 2019).

Economic growth can be affected by several factors, including household consumption, exports, inflation, and the labor force. This fact makes the theme of economic growth still interesting to analyze, especially using Indonesian data. Export growth positively and significantly affect economic growth (Paksi, 2021; Supartoyo, Tatuh, & Sendouw, 2013; Bashir & Susetyo, 2018; Kurniasih, 2019).

Table 6. Characteristics of the food and beverage industry by exporter

Exporting?	**Food Industry**								
	Number of firms				**The industrial output [Rp. trillion]**				*Ratio of Share*
	2010	**2018**	**Mean**	*Share*	**2010**	**2018**	**Mean**	*Share*	
F-Yes	360	540	490	8.0	75.92	233.18	158.83	18.1	2.3
F-No	3251	3698	3445	56.4	144.76	461.33	266.91	30.5	0.5
F-None	1637	2537	2175	35.6	224.08	920.33	449.55	51.4	1.4
Total	**5248**	**6775**	**6110**	**100.0**	**444.76**	**1,614.84**	**875.29**	**100.0**	**1.0**
Exporting?	**Beverage Industry**								
	Number of firms				**The industrial output [Rp. trillion]**				***Ratio of Share***
	2010	**2018**	**Mean**	***Share***	**2010**	**2018**	**Mean**	***Share***	
B-Yes	9	17	14	3.2	0.75	3.63	2.62	8.8	2.7
B-No	187	283	216	50.7	4.96	17.85	8.09	27.1	0.5
B-None	132	283	196	46.1	9.75	47.27	19.17	64.1	1.4
Total	**328**	**583**	**425**	**100.0**	**15.46**	**68.75**	**29.88**	**100.0**	**1.0**

Sources: Statistics Indonesia (2021b), author's calculation

SOLUTIONS AND POLICY RECOMMENDATIONS

Stimulus policies must be realized in more detail and optimally. Identification of firms that contribute to the sub-sector of the food and beverage industry by the group of firm characteristics is a challenge for various policies. Different firm characteristics can help stakeholders or policymakers to concentrate on stimulus policies only for certain industry groups.

Based on the conclusion of this study, the practical implications that can be recommended for increasing the contribution of the food and beverage industry to the national economic recovery are as follows. **First**, the government must provide rewards or incentives to firms that have the potential to make a large and effective contribution to the national economic recovery, namely firms in the food industry sub-sector of vegetable and animal oil and fat; firms with >1000 laborers; located in Sumatra and Java-Bali; owned by a domestic investment firm (PMDN); and export-oriented firms. **Second**, the government should provide increased capitalization and subsidies to firms that tend to contribute less, namely small firms with 20–99 and 100–199 laborers; PMDN, located in the Maluku-Papua and Sulawesi regions; and not export firms to try to increase productivity. **Third**, the government must implement revitalize inefficient machines and technological changes in small-contributing firms by considering and paying attention to the specific behavior of firms in each group of characteristics of the food and beverage industry firms based on this research. **Finally**, policymakers or stakeholders must have a very strong commitment to implementing policies and achieving the desired targets, accompanied by management commitment to improving firm performance.

CONCLUSION

The conclusions of this study are outlined as follows. **First**, the stimulus policy taking into account the specific behavior of firms in the food and beverage sub-sector that contributes greatly and effectively needs to be prioritized. The findings illustrate that the manufacture of oils and fats from vegetables and animals [104] has the largest share of contribution and is also effective in contributing to national economic recovery. Thus, the policy of providing stimulus to the industry [104] is the right step. **Second**, there are only a few large firms, but the output share is high. On the contrary, many small firms only contribute a small output share. This finding shows that each character has a different contribution tendency and variability. Therefore, focusing the stimulus policy on large firms is a good step because it will reduce implementation efforts and costs. Focus on firms that are few will be more facilitated and cost-effective. **Third**, firms in Sumatra and Java-Bali have a high share of firms. Therefore, focusing the stimulus policy only on firms in the Sumatra and Java-Bali regions is a wise move because it will accelerate economic recovery. **Fourth**, PMDN firms have a large share of output compared to others, so they are responsible and contribute to economic recovery. The most effective and efficient PMA firm in contributing. Therefore, policymakers must concentrate on PMDN firms as a first step before venturing into PMA and non-facilities. **Fifth**, the number of export-oriented firms is small, but the share of output is high, so the output ratio to the firm's share is quite large. Therefore, policymakers should concentrate on export-oriented firms because it is an effective and efficient measure in accelerating the national economic recovery.

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KEY TERMS AND DEFINITIONS

Commodity: This can be defined as objects of economic value. In its broadest meaning, the word "commodity" can be used to describe any traded good, usually used for goods rather than services, but can be applied to both (Appadurai, 2014; Bain, 2013).

Economic contribution: Business or industrial events that add value to the performance of countries, which is reflected on their gross domestic products (GDP), index standard of living, industrialization, and production of goods. The industrialized countries have numerous and sophisticated ways that contribute to their economies. Economic contributions of an industry sector are often vital information in the policy-making process (Mosweunyane, 2019; Pelkki & Sherman, 2020).

Exporter: Indonesian food and beverages firm that that ship goods from the Indonesian custom area to the custom area of other countries. Usually, export process starts from an offer of a party followed by the agreement from another party in a sales contract process.

Firm characteristic: are defined as a firm internal environment that is comprised of firm's demographics and management characteristics that are part of the firm's operating environment. Firm size, leverage, firm age, revenue growth, asset growth, and turnover are all examples of firm characteristics (Zou and Stan, 1998; Ashiq et al., 2022; Salah, 2018; Mutende et al., 2017).

Firm size: firm scale measured in number of employees. It usually categorized in small, medium and large firm.

Food and beverages industry: is all companies involved in processing raw food materials, packaging, and distributing them. This includes fresh, prepared foods as well as packaged foods, and alcoholic and nonalcoholic beverages.

Industrial Cluster: A geographic concentration of interconnected firms, suppliers, and institutions in a particular field. It has the potential to affect competition by increasing the productivity of the companies in the clusters, driving innovation, and stimulating new businesses in the specific field (Christiansen, 2014).

Industrial sub-sector: The International Standard Industrial Classification of All Economic Activities (ISIC) is the international reference classification of productive activities. Its main purpose is to provide a set of activity categories that can be utilized for the collection and reporting of statistics according to such activities (United Nations-Statistical Division, 2008).

Type of ownership: This refers to the participation of domestic investment (PMDN) and foreign investment (PMA). PMDN is an investment activity to run a business in the territory of Indonesia, which is carried out by domestic investors by relying on domestic capital. PMA is the formation of business capital in Indonesia aimed at foreign investors, using foreign capital fully or partially with domestic investors.

Chapter 2
Functional Food Innovation for the Treatment of Metabolic Syndrome

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ABSTRACT

Metabolic syndrome (MetS) is a metabolic disorder characterized by central obesity, insulin resistance, hypertension, and hyperlipidemia. MetS is associated with an increase in reactive oxygen species (ROS), triggered by oxidative stress. Oxidative stress occurs when the number of free radicals in the body exceeds its ability to neutralize them, causing cells, tissues, or organs damage, and triggering type 2 diabetes mellitus (DM) and coronary heart disease. One of the ways to manage of MetS is through functional food. Various studies have shown that functional foods contain bioactive components such as dietary fibers (beta-glucans, pectin, inulin), phytosterols, oleic acid, polyunsaturated fatty acids, antioxidant vitamins, phytochemicals such as flavonoids, and bioactive peptides. In addition, functional food processing uses state-of-the-art technology that generates heat through internal transmission energy and does not use high-temperature technology. This minimizes the deterioration of sensory characteristics, nutrients, and functional foods.

DOI: 10.4018/978-1-6684-5629-3.ch002

INTRODUCTION

Metabolic syndrome (MetS) is a multiple risk factor for cardiovascular disease and develops through several interrelated factors between obesity as a factor causing insulin resistance which is associated with other cardiovascular risks, namely hypertension and dyslipidemia (Boden-Albala et al., 2008; Kurl et al., 2006). The results showed that more than 1 billion people in the world were identified as having MetS caused by central obesity (Saklayen, 2018). The prevalence of MetS in Indonesia is quite high, based on the 2007 Riskesdas data, at 5.2%, mainly caused by hypertension and central obesity (Soewondo et al., 2010). Various epidemiological studies have proven that metabolic syndrome increases the risk of cardiovascular disease almost twice as much as the non-metabolic syndrome population with obesity and insulin resistance (DeFronzo et al., 2004).

Mechanisms causing Metabolic syndrome (MetS), insulin resistance, and central (visceral) obesity due to the accumulation of fat cells, will increase free fatty acids from lipolysis, decrease insulin sensitivity, and increase gluconeogenesis resulting in increased glucose production and insulin extraction, causing hyperinsulinemia. Fat cells also secrete angiotensin, TNF, resistin, and leptin associated with a decrease in insulin resistance by inhibiting tyrosine kinase activity at insulin receptors and reducing the expression of glucose transporter-4 (GLUT-4) in fat and muscle cells (Kershaw & Flier, 2004). Meanwhile, adiponectin can reduce insulin resistance; its levels are decreased in metabolic syndrome (Weyer et al., 2001). Insulin resistance and hyperinsulinemia cause metabolic changes, resulting in hypertension, dyslipidemia, increased inflammatory, and coagulation responses through endothelial dysfunction and oxidative stress. Insulin resistance is getting worse over time, and insulin secretion eventually decreases, resulting in hyperglycemia and manifestations of type 2 diabetes (Gibson & Williams, 2000).

Intervention through lifestyle changes and physical activity to reduce insulin sensitivity or diabetes mellitus is a key factor in the success of metabolic syndrome treatment, namely by regulating food intake and functional food and physical activity so that weight loss is ideal (Tuomilehto et al., 2001). Various studies have shown that functional foods can play a role as prevention and as a therapy for MetS because it has various effective bioactive components such as dietary fibers (beta-glucans, pectin, and inulin), phytosterols, oleic acid, polyunsaturated fatty acids, antioxidant vitamins, phytochemicals such as flavonoids, and bioactive peptides. The content of these bioactive substances can be found in fruits and vegetables such as soybeans, pomegranates, cranberries, onions, tomatoes, grapes, wheat, nuts, fish, olive oil, tea, plant extracts, and fortified foods. Antioxidants contained in isoflavones can bind to endogenous receptors and are cardioprotective as antioxidants that can neutralize free radicals by increasing the up-regulating activity of LDL receptors which will then increase LDL clearances from the blood circulation and reduce LDL levels in the blood to improve the condition of MetS. Dietary fiber is useful as a cholesterol-lowering agent because it can bind bile acids in the digestive tract, reducing the re-absorption of bile acids by the walls of the small intestine which are excreted with feces. It can reduce the number of bile acids absorbed and increase the formation of new bile acids from cholesterol. The binding of bile acids decreases the absorption of fat in the intestine, and there is no accumulation of fat in the body which results in central obesity (Park et al., 2014).

Various studies on the role and ability of functional food as a therapy for MetS have been carried out and have shown optimal results (Blasa et al., 2010). Likewise with physical activity, several studies have shown that physical exercise and weight loss have been shown to increase insulin sensitivity (Knowler et al., 2002). Physical exercise can also increase lipolytic enzyme activity and HDL levels and reduce triglyceride levels (Grundy, 1999).

The functional properties of functional foods are determined by their bioactive components through the right technology in processing. Functional food processing is conducted using various advanced technologies. Instead of high-temperature technology, internal transmission energy that minimizes damage to the sensory characteristics of nutrient content and the appearance of functional foods is used to generate heat. The new technologies being developed are cold plasma treatment, electro-osmotic dewatering, and nanoencapsulation. Other widely used technologies by the food industry today are high-hydrostatic pressure, ultrasound-assisted and microwave-assisted extraction, pulsed electric field, radio-frequency drying, high voltage electrical discharge, and supercritical fluids. Various new technologies turned out to affect the components of the bioactive substances present in the food (Galanakis, 2021).

DEFINITION OF FUNCTIONAL FOODS

Food should not only be acceptable and have a high nutritional value, but it must also have functional properties. Therefore, in addition to supplying nutritional needs with delicious flavor, food serves to maintain our health. The development of functional food requires raw materials that can fulfill these goals. Functional foods are defined as foods that contain bioactive ingredients to enhance health. They not only fulfill basic energy needs, macronutrients (proteins, carbohydrates, fats), and micronutrients (vitamins and minerals) but also provide nutritional and physiological benefits for our body (Damanik et al., 2018).

Functional food is defined as foods or dietary components that may provide a health benefit beyond basic nutrition (Prasetyaningrum et al., 2019). Functional food cannot be a single well-defined/well-characterized entity. Indeed, a wide variety of food products are or will be characterized as functional foods with a variety of components — both classified and not classified as nutrients — affecting a variety of body functions relevant to either a state of well-being and health and/or to the reduction of the risk of disease. Thus, no simple, universally accepted definition of functional food exists or will (ever) exist. Functional food has thus to be understood as a concept (Gibson & Williams, 2000). Moreover, if it is function-driven rather than product-driven, the concept is likely to be more universal and not too much influenced by local characteristics or cultural traditions ("Scientific Concepts of Functional Foods in Europe Consensus Document," 1999). In scientific as well as in more marketing-oriented literature, functional food has as many definitions as the number of authors referring to it. These definitions go from simple statements, such as: 1. foods that may provide health benefits beyond basic nutrition (IFIC Foundation, 1995) and 2. foods or food products marketed with the message of the benefit to health, to very elaborate definitions such as: food and drink products derived from naturally occurring substances consumed as part of the daily diet and possessing particular physiological benefits when ingested (Annunziata & Vecchio, 2011); 2. food derived from naturally occurring substances, which can and should be consumed as part of the daily diet and which serves to regulate or otherwise affect a particular body process when ingested (Smith et al., 2015); 3. food similar in appearance to conventional food, which is consumed as part of the usual diet and has demonstrated physiological benefit and/or reduces the risk of chronic disease beyond basic nutritional functions (Health Canada, 1997); and 4. food that encompasses potentially helpful products, including any modified food or food ingredient that may provide a health benefit beyond that of the traditional nutrient it contains (Havel et al., 1994). Whatever definition is chosen, functional food appears as a unique concept that deserves a category of its own, a category different from nutraceutical, f(ph)armafood, medifood, designer food, or vitafood, and a category that does not include dietary supplements. It is also a concept that belongs to nutrition and not to pharmacology. Functional foods are and must be foods, not drugs. Moreover, their role regarding disease will, in most cases, be in 'reducing the risk' rather than 'preventing' it (Gibson & Williams, 2000).

THE MAJOR SOURCE OF FUNCTIONAL FOOD

The functional food market is increasing because people are aware of the health benefits of functional foods (Chen, 2011). As a result, even companies engaged in the agro-food sector have developed new functional food products (Annunziata & Vecchio, 2013). Functional food products by source are divided into:

Functional Foods of Plant Origin

Phytochemicals in plants are active chemical compounds that naturally have health benefits. These phytochemical compounds are secondary metabolites in plants that are antioxidant, and antimicrobial, modulate the anticancer, immune system, and affect hormone metabolism. Plants' primary metabolites include carbohydrates, amino acids, nucleic acid proteins, chlorophyll, purines, and pyrimidines. The secondary metabolites are alkaloids, terpenes, flavonoids, lignans, steroids, curcumin, saponins, flavonoids, glucosides, and phenolics (Saxena et al., 2013).

It is rare to find a single class of bioactive food components in a single plant. In contrast, bioactive components are found in mixed fruits, nuts seeds, seeds, mushrooms, spices, and tubers. Furthermore, the degree of difference may vary from one plant to another depending on the variety, processing, ripening, and growing conditions (Miękus et al., 2020).

Indonesia has very diverse types of local/traditional food, and almost every region in Indonesia has traditional food that is characteristic of the area. Therefore, traditional food products found in Indonesia can be classified based on their characteristics. These local food products use various raw materials, almost all of which are local raw materials, such as tubers and other sources of carbohydrates, fruits, spices, nuts, and others. In addition, several biological compounds in Indonesia are plant-based functional foods such as dietary fiber, phytochemicals, oligosaccharides, glucomannan, sugar alcohols, bioactive peptides, lactic acid bacteria, antioxidants, Omega fatty acids, probiotics, and prebiotics (Harini, Warkoyo, & Hermawan, 2015).

Dietary fiber and phytosterols/stanols from plants have a lipid-lowering effect by absorbing cholesterol in the intestinal tract and reducing cholesterol absorption. However, dietary fiber can also trap harmful toxins and carcinogens in the digestive tract (Capuano, 2017).

Another bioactive compound that has health benefits is glucomannan. Glucomannan is a polysaccharide composed of D-glucose and D-mannose units. Glucomannan can lower cholesterol. Glucomannan can also control spikes in high blood sugar levels and a prebiotic because glucomannan can increase the production of beneficial bacteria such as lactic acid bacteria and bifidobacteria. Glucomannan is widely contained in local Indonesian food sources, namely porang tubers (Saleh et al., 2015).

Porang processing is mainly done to get its glucomannan component. Therefore, porang products usually processed and marketed from fresh tubers are chips, porang flour (konjac flour), and glucomannan flour (konjac glucomannan). Porang flour can be used for various purposes, including functional food, water binder, thickeners, coagulation or gelling agents, and low diet foods fat and calories, mainly because of its high glucomannan solubility the water. In addition, Porang flour is also high in water-soluble dietary fiber (Wahyuni et al., 2020).

There are various ways of using functional food, one of which is as an ingredient in food fortification. Research conducted by Y.S. Darmanto et al. in 2017 succeeded in fortifying analog rice with fishbone collagen. The fortification can increase dietary fiber from analog rice (Darmanto, Riyadi, & Susanti, 2017).

Functional Foods of Animal Origin

Many biological compounds of animal origin with health benefits have been developed as functional foods, either whole or as hydrolysates. One food protein hydrolysate used in functional food is a bioactive peptide. Bioactive peptides are produced through microbial fermentation, enzyme digestion, or proteolytic enzymes in vitro and can support the physiological activities of body systems. These roles may include antioxidant, antimicrobial, antihypertensive, cytomodulatory, and immunomodulatory effects (Zhang, Chen, & Wang, 2015).

Mahfudz, L. D. et al in their research succeeded in producing chicken eggs rich in isoflavones by giving soy sauce by-product to 80-week-old hens. Isoflavones are phytosterols that can inhibit the absorption of dietary cholesterol and can help liver fat metabolism. Isoflavones are structurally and functionally similar to natural estrogens, can bind to estrogen receptors, and can act antiestrogenic effect. It is also known to act as an anticholesterol that can lower blood cholesterol and increase high-density lipoprotein, triglycerides, and low-density lipoprotein. (Mahfudz et al., 2018).

Table 1. Common animals food sources (Soumya et al., 2021)

Food Item	Bioactive Compound	Health Benefit
Milk	Whey Protein	Modulation of immune responses
Fermented Milk	Probiotics	Immunomodulators, anticancer, gastrointestinal health modulators
Egg	Phospholipid	Anti-Hypertensive activities, immunomodulatory
Meat	Peptides Fatty acids	Antihypertensive Antioxidative
Fish	Fatty acids Polysaccharides Peptides	Antihypertension Immunomodulatory Antioxidant

Marine Functional Food

The bioactive components of foods sourced from the sea are rich because they have health benefits such as anticancer or anti-inflammatory activities. The bioactive components are polyunsaturated fatty acids, sterols, proteins, polysaccharides, and antioxidants. We can find bioactive food ingredients from the sea, such as marine plants, microorganisms, and sponges (Rasmussen, 2007).

Macroalgae

Macroalgae is a source of biologically active phytochemicals beneficial for health, such as carotenoids, phycobilin, fatty acids, polysaccharides, vitamins, sterols, tocopherols, and phycocyanin (Kadam and Prabhasankar, 2010). We can find macroalgae as seaweed and identify them into three divisions, namely: brown algae (*Phaeophyceae*), red algae (*Rhodophyceae*), and green algae (*Chlorophyceae*). Proteins in macroalgae contain all the essential amino acids, but their concentrations vary. For example, leucine, valine, and methionine are commonly found in Palmaria palmata (El Gamal, 2010). In addition, concentrations of isoleucine, threonine, leucine, phenylalanine, and valine, essential amino acids, can also be found in *Ulva rigida*. Furthermore, a peptide, a bioactive compound in macroalgae, is reported

Table 2. Antioxidants from algal (Lordan, Ross, and Stanton, 2011)

Antioxidant	Algal Species	Levels (μ)
α-Tocopherol	*Tetraselmis suecica*	190-1080.
	Himanthalia elongata	12.0-33.3.
	Saccorhiza polychides	5.7±1.3
	Laminaria ocholeuca	8.9±2.1
Astaxanthin	*Chlorococcum sp*	
	Chlorella Vulgaris	
	Haematococcus pluvialis	
Lutein	*Porphyra tenera*	
	Chlorella protothecoides	4600
	Muriellopsis sp	4300
	Chlorella zofingiensis	3400
Polyphenols	*Fucus sp*	41400±400
	Laminaria sp	7300±100
	Porphyra sp	5700±100

to have an essential role in the metabolic syndrome, namely as antihypertensive, immunomodulatory, antithrombotic, antioxidant, anticancer, and antimicrobial activity (Kim & Wijesekara, 2010).

Marine algae are structurally diverse bioactive compounds and have an important role as a functional food. One of them is carrageenan in red algae which has cell walls of marine algae rich in sulfated polysaccharides (SPs). Beneficial biological activities of low molecular carrageenan are such as anticoagulant, antiviral, antioxidant, anticancer, and immunomodulating activity. This paper presents an overview of the potential health benefits of -carrageenan derived from marine algae (Prasetyaningrum et al., 2019).

Microalgae

Microalgae are found in benthic, littoral, and marine habitats as phytoplankton. Phytoplankton consists of organisms such as diatoms (*Bacillariophyceae*), dinoflagellates (*Dinophyte*), green and yellow-brown flagellates (*Chlorophyta*; *Prasinophytes*; *Prymnesiophyta*, *Cryptophyta*, *Chrysophyta*, and *Raphidophyte*), and blue-green algae (*Cyanophyta*). There are more than 50,000 species of microalgae, and most of them are untapped of valuable bioactive and biochemical compounds such as pigments, antioxidants, polysaccharides, sterols, fatty acids, and vitamins (Mata, Martins, and Caetano, 2010).

By-products of Processing

By-products are leftovers from processing, such as fish heads, shells, or parts of seafood that are not used. The production of marine functional foods from by-products is increasingly in demand because it can help reduce processing waste, especially in nutraceutical or functional foods. For example, fish heads, offal, skin, tail, offal, blood, and seafood shells have several compounds that can be developed into functional foods because they have health benefits for humans. Many studies have identified compounds from fish muscle protein residues, collagen and gelatin, fish oil, fish bones, internal organs, and shells of shellfish and crustaceans. These bioactive compounds can be extracted and purified for use, such as bioactive peptides, oligosaccharides, fatty acids, enzymes, water-soluble minerals, and biopolymers (Kim & Mendis, 2007).

Table 3. Potential marine functional food (Lordan, Ross, and Stanton, 2011)

Ingredient	Marine Source	Health Benefit
Peptides	Fish frame Fish frame Algae and fish frame	Anticoagulative Antidiabetic Antioxidative
n-3 Fatty Acids	Fish Fish mussels Fish	Anticarcinogenic Anti-inflammatory Cardioprotective
Carotenoids	Algae Algae Algae	Antioxidative Antiobesity Antidiabetic
Polyphenols	Algae Brown Algae	Antidiabetic Antioxidative

HEALTH BENEFITS OF FUNCTIONAL FOOD

Functional food can be applied to the treatment and prevention of chronic diseases; they include nonstarchy carbohydrates (dietary fiber, resistant starch, and fucoidan), antioxidants (organosulfur compounds, polyphenols, carotenoids, tocopherols, tocotrienols, phytosterols, and isoflavones), unsaturated fatty acids, bioactive peptides, sterols, and phytoestrogens.

Obesity

Obesity has become a global issue. The prevalence of obesity in the world nearly tripled between 1975 and 2020. In 2020, over two billion adults (39% of the adult world population) were overweight (BMI > 25). Of these, over 600 million were obese (BMI > 30). Functional food is used in the weight management approach, concerned with reducing nutritional activity and energy consumption, achieved via energy reduction, dietary density, appetite reduction, etc. (Contreras-Rodriguez et al., 2020). Some functional food components prove to act in the GI tract before the food is absorbed. These include chitosan, linoleic acid conjugated with it, diglycerides, triglycerides in the medium-chain, green tea, caffeine, calcium, and capsaicin (Wan et al., 2019).

Cardiovascular Disease

Diets high in plant foods and rich in polyphenols can reduce the risk for CVD and other chronic diseases. A high intake of vegetable sources and high polyphenols is associated with a reduced risk of CVD and other chronic diseases. Possible mechanisms include their anti-inflammatory, vasodilatory, anti-platelet, and antioxidant effects. Soluble fiber can affect cholesterol and lipoprotein metabolism by lowering LDL concentrations, especially in people with high LDL levels.

Functional foods have a low content of saturated fatty acids and trans-fatty acids so they optimally help lower LDL levels. Monounsaturated, such as olive oil, and polyunsaturated can reduce LDL concentrations in plasma, and some of it does this without significantly lowering the beneficial high-density lipoprotein (HDL) cholesterol (Rudkowska & Jones, 2007). Fatty acids in fish oils can be found in the long-chain (eicosatetraenoic and docosahexaenoic acids) that can decrease plasma triacylglycerols, counteract blood clotting, and promote the integrity of the vessel. Sources of fiber and antioxidants, such as tempeh gembus, can be beneficial to reduce the risk of CVD by reducing levels of hs-CRP (high sensitivity c-reactive protein) (Wati et al., 2020). Tempeh gembus contains 11.09% fiber and 48.07% antioxidant activity (Afifah et al., 2019). It can be concluded that the consumption of functional foods rich in unsaturated fatty acids can reduce the risk of CVD.

Diabetes Mellitus Type II

Evidence supports the use of whole-grain foods, vegetables, fruits, foods low in saturated fat, and starchy foods with a low glycemic index. Food sources of soluble fibers, such as psyllium and inulin, with a low glycemic index, can be beneficial. Chromium can improve the metabolism of insulin and decrease plasma cholesterol. Food containing resistant starch, such as breadfruit, is known to be beneficial for diabetic patients. It is because compact molecules prevent its breakdown by the digestive enzymes, thus avoiding blood sugar spikes (Fuentes-Zaragoza et al., 2010). Research by Fitriani showed cookies made from breadfruit flour have highly resistant starch, amylose, and amylopectin, making them suitable for consumption by diabetics (Fitriani et al., 2021). Diabetics who follow a diet high in fiber and plant protein and rich in polyphenols may benefit from the composition of the fecal microbiota and may be associated with improved glycemic control, dyslipidemia, and inflammation (Maheshwari et al., 2019).

Aging

The prevalence of chronic conditions of aging like cancer and Alzheimer's disease is increasing. These conditions can increase oxidative stress and cause aging. Therefore, if we were able to reduce this, some of these diseases may be delayed or prevented (Lange et al., 2019).

The potential useful candidates for functional ingredients are vitamin C and E, carotenoids, flavonoids, and other polyphenols. Plant food sources such as berries, mangosteen, pomegranate, tomatoes, and grapes are being explored by the food industry because of their potential as food sources high in antioxidants. Fatty acids can reduce the risk of depression and age-related dementia, whereas Ginkgo biloba can improve circulation and contribute to memory improvement (Ngo et al., 2011).

FUNCTIONAL FOOD INNOVATION FOR THE TREATMENT OF THE METABOLIC SYNDROME

Metabolic syndrome (MetS) is a variety of risk factors that cause cardiovascular diseases such as central obesity, hypertriglyceridemia, hyperglycemia, decreased HDL cholesterol, and high blood pressure (Purwaningtias & Sabini, 2020). These chronic diseases are the main cause of death worldwide. Demography and lifestyle are factors that cause MetS, and diet is the main factor that increases its prevalence

Table 4. Effects of emerging technologies on various bioactive components of food

Component	New technology	Food	Results
Protein	Ohmic heating	Seafood	Minimizes protein degradation, forming a more rigid and elastic gel
	High-Pressure Processing	Fish, meat, eggs, and soy albumin	Increase capacity and gel formation as well as digestibility of meat
	High-Pressure Processing	Tomatoes, carrots, and broccoli	Lose negligible beneficial nutrients, high glucose retardation index, and water retention
	Prolonged and high-intensity pulsed electric field	Eggs and milk	modify some proteins
	High-intensity ultrasound	Whey	Increases load, hydrophobicity, surface activity, emulsifying properties, solubility, foaming capacity, and flexibility
	Gamma irradiation	Fish, soy, eggs, and, whey	Degrade protein and decrease the viscosity
Fat	Ultrasounds	Whey cheddar cheese	Develops volatile lipid oxidation
	Cold plasma	Walnuts and peanut	Increase lipid peroxide
Vitamin	Gamma irradiation	Potato	Decreases levels of vitamin C
	High-pressure processing, pulsed electric field, and ultrasounds	Orange juice	Has higher vitamin C retention than pasteurization

Continued on following page

Table 4. Continued

Component	New technology	Food	Results
Polyphenols	High-pressure processing	Blackberries and strawberries	Preserve color, anthocyanin content, and antioxidant activity
	Ultrasounds	Pomegranate	Increases polyphenol
Glucosinolates	High-pressure processing	Broccoli	Glucosinolate hydrolysis and isothiocyanate recovery
	High-pressure processing	White cabbage	Improves isothiocyanate compared to blanching
Carotenoids	Ultrasounds	Carrot juice	Increases beta carotene which triggers a pro-oxidant effect
	High-pressure homogenization	Fruit drink	Improves my carotenoid digestibility
Enzymes	Ohmic heat	Coconut water and apple juice	Deactivate polyphenol oxidase
	Pulsed electric field	Orange juice, tomato juice, and carrot	Deactivate pectin methylesterase and lipoxygenase
Phenolic and caffeine	Japanese-style green tea process	Robusta coffee leaves	Prevent oxidation, inhibit free radicals, and inhibit fat peroxidation
Flavonoids, fiber amino acids, and polyunsaturated fatty acids	Leftover tofu fermentation	*Tempeh gembus*	Serves as an inflammatory pathway and prevents obesity and fat metabolism disorders

Sources: (Almira et al., 2020; Galanakis, 2021; Sulistyaningsih et al., 2020)

(Syauqy et al., 2018). Various studies on this disease examine the ability of functional foods to act as prevention and as therapy for the disease. Functional foods have bioactive components and, with a balanced diet, can reduce the risk of cardiovascular disease. Several bioactive substances that play an important and effective role in the pathophysiology of metabolic syndrome are dietary fibers (beta-glucans, pectin, and inulin), phytosterols, oleic acid, polyunsaturated fatty acids, antioxidant vitamins, phytochemicals such as flavonoids, and bioactive peptides. These types of bioactive substances can be found in fruits and vegetables (soybeans, pomegranates, cranberries, onions, tomatoes, grapes, etc.), wheat, nuts, fish, olive oil, beverages (tea, plant extracts), and fortified foods (Konstantinidi & Koutelidakis, 2019).

The sensory and physical characteristics of foodstuffs are influenced by their content, and the processing technique has a direct impact on their characteristics. With the increasing public demand for functional foods, researchers and the food industry are competing to enhance processing technology to improve product quality, nutritional characteristics, and product bioactive (Galanakis, 2021).

Technologies commonly used by the food industry include high-hydrostatic pressure, ultrasound-assisted and microwave-assisted extraction, pulsed electric field, radio-frequency drying, high voltage electrical discharge, and supercritical fluids. Meanwhile, new technologies are being developed such as cold plasma treatment, electro-osmotic dewatering, and nanoencapsulation. The new technology does not use high-temperature technology but generates heat through internal energy transmission which minimizes damage to sensory characteristics, nutrients, and functional foods. Various new technologies turned out to affect the components of bioactive substances as shown in Table 4 (Galanakis, 2021).

FUTURE RESEARCH DIRECTIONS

Functional food research conducted in Indonesia is mainly dominated by the keywords "effect," "extract," "addition," "application," "identification," isolation," and "characterization." Only a few studies have reached the stages of development, clinical trials, and commercialization. Researchers in the functional food sector share the same point that Indonesia has the potential for rich biodiversity and culinary arts, so most of the research uses local food ingredients as the starting material for their research. However, there are limited funds and human resources, underdeveloped infrastructure, and the absence of a functional food research roadmap in Indonesia are also challenges. Networks between researchers that have not been well established cause functional food research to run independently. Consequently, most functional food research ends at the stage of identifying bioactive compounds and their possible effects on health (Purwaningsih et al., 2021).

Clinical trials on functional foods are needed to prove the effectiveness of health claims as a form of safety guarantee when consumed by humans. However, few laboratories in Indonesia have passed clinical trials of functional food products due to lengthy and expensive procedures. In addition, product development and commercialization are required. However, reaching the industry to commercialize the product is not easy. The functional food industry in Indonesia is still dominated by large companies, both local and multinational. Introducing new research products to these companies is not easy because the companies have already created their market. In addition, companies that produce functional food products already have their R&D team.

Based on the current situation, it is necessary to synchronize between researchers regarding the direction of functional food research as an acceleration of research development in the field of functional food so that it can proceed to clinical trials. In addition, an approach to food and beverage companies is needed to facilitate the commercialization of products resulting from functional food research.

SOLUTION AND RECOMMENDATIONS

Functional foods have bioactive components and, with a balanced diet, can reduce the risk of metabolic syndrome. Several bioactive substances that play an essential and influential role in the pathophysiology of metabolic syndrome are dietary fibres (beta-glucans, pectin, and inulin), phytosterols, oleic acid, polyunsaturated fatty acids, antioxidant vitamins, phytochemicals such as flavonoids, and bioactive peptides. Therefore, those diagnosed with metabolic syndrome are recommended to consume functional foods to reduce the severity of the metabolic syndrome.

CONCLUSION

Functional foods are needed to improve the condition of people with metabolic syndrome. Bioactive substances in functional foods can be maintained through appropriate processing technology.

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KEY TERMS AND DEFINITIONS

Antioxidant: A substance that protects cells from the damage caused by free radicals.

By-products: Leftovers from processing, such as fish heads, shells, or parts of seafood that are not used.

Isoflavones: Similar to nature estrogens, and inhibit the absorption of cholesterol.

Nanoencapsulation: A technique based on enclosing a bioactive (BAC) in liquid, solid, or gaseous states within a matrix or inert material for preserving the coated substance.

Nutraceutical: Any substance that is a food or part of a food and provides medical or health benefits, including the prevention and treatment of disease.

Phytochemicals: Natural active chemical compounds from plants that have health benefits.

Tubers: The underground part of a stem or rhizome that is thickened.

Chapter 3
Health Benefits Indonesian Fermented Food of *Tempeh Gembus* Upon National Readiness for Sustainable Development Goals Achievement

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ABSTRACT

Tempeh gembus is a traditional Indonesian prepared from solid tofu waste fermented by Rhizopus oligosporus. It contained some nutritional value and bioactives from fermentation, making tempeh gembus a functional food with variety of health benefits. Previous research had investigated functional properties of tempeh gembus, such as amidolytic, antimicrobial, and antioxidant, as well as proteolytic, fibrinolytic, fibrinogenolytic, and anti-inflammation, which were linked to a variety health benefits, including atherosclerosis, diabetes mellitus, hyperlipidaemia, obesity, metabolic syndrome, and osteopenia. Tempeh gembus is sometimes underestimated because it is prepared from tofu waste and is frequently consumed by low-income people due to its low cost. Tempeh gembus intake is also low due to a lack of knowledge about its health benefits. This article reviews the health benefits of tempeh gembus as one of Indonesia's local functional foods.

DOI: 10.4018/978-1-6684-5629-3.ch003

INTRODUCTION

Producing *tempeh gembus* is one approach to achieving sustainable development goal number 2 of reducing hunger, achieving food security, and better nutrition because the main ingredients are formed from the pulp left over after making tofu. Indonesia has an estimated 84,000 tofu manufacturing units (Damanik et al., 2018) that produce roughly 1,024 million tonnes of solid waste and 20 million m^3/year of wastewaters having soybean as their main ingredient (Kurniasari et al., 2017). Adding *Rhizopus oligosporus* to tofu waste resulted in *tempeh gembus*, which was fermented for many days. *Tempeh gembus* includes protein, glucose, fiber, calcium, iron, fosfor, essential fatty acids, and bioactive compounds (Afifah et al., 2019a), even though the base material is waste-tofu.

The *tempeh gembus* fermenting process may lead to nutritional content and bioactive compound alteration. A previous study showed the variety of nutrition composition in soybean, tofu waste, and *tempeh gembus*. The carbohydrate, fat, and protein content in *tempeh gembus* are more easily digestible because the tempeh mold creates digestive enzymes. That study also indicated that fermentation may help to improve the fatty acids profile (Damanik et al., 2018).

Tempe gembus provides a variety of health benefits for humans due to its content, which is rich in nutrients and bioactives. Because *tempeh gembus* contains fibrinolytic enzymes, previous studies investigated its cardiovascular effects. Another study looked at the benefits of *tempeh gembus* for atherosclerosis, finding that *tempeh gembus* administration had a favorable association with homocysteine and malondialdehyde, though the correlation was not statistically significant. Another study revealed that *tempeh gembus* contains three times the fiber level of regular *tempeh*, which may be helpful to individuals who deal with obesity or diabetes. Another study found that *tempeh gembus* was positively connected with hyperlipidemia due to its ability to reduce cholesterol when consumed.

Because there is still limited information on *tempeh gembus*, it is necessary to write an article that explores *tempeh gembus* so that it can be useful to the community. This review article aims to investigate *tempeh gembus* nutritional and bioactive content, in addition to its health benefits.

Nutrition Content of *Tempeh Gembus*

Tempeh gembus is a soybean-based food produced from tofu waste. The nutritional value of *tempeh gembus* was investigated by Sulchan and Endang. Energy 65 kcal, total carbs 11.94 g, fiber 3.93 g, protein 3.41 g, fat 0.20 g, calcium 143 mg, iron 0.40 g, phosphorus 50 mg in 100 g *tempeh gembus*. Ruth, et al. investigated the nutritional composition of *tempeh gembus* as it changed from soybeans to tofu wastes and finally to *tempeh gembus* (Damanik et al., 2018). Vitamins, minerals, fatty acids, and amino acids, were among the nutrients examined. *Tempeh gembus*, tofu waste, and soybeans, respectively, contain 4.80%, 5.40%, and 34.12% of amino acids. Soybeans (12.01%) had the lowest saturated fatty acid content, followed by tofu waste (12.41%) and *tempeh gembus* (12.55%). Monounsaturated fatty acid levels were also observed to follow a similar pattern (34.1 percent, 36.5 percent, and 36.7 percent respectively). Soybeans, on the other hand, contained more polyunsaturated fatty acids (43.6%) significantly than others, tofu waste (38.29%) and *tempeh gembus* (30.18%) (Damanik et al., 2018). Another study revealed that two isoflavones identified in *tempeh gembus* include genistein (57.1 g/g) and daidzein (33.1g/g) (Kurniasari et al., 2017).

Transforming *tempeh gembus* into a variety of dishes, like crackers, meatballs, cookies, and nuggets will rise its value. The nutritional content of dishes whose basic ingredients have been substituted using *tempeh gembus* has been the subject of several studies. Previous research explored *gembus* crackers in 6 different formulas by modifying the *tempeh gembus* and additive ratios. It revealed that gembus crackers had a high fiber content, ranging from 38.1 to 67.4 percent, fat content ranged from 11.8 to 16.8%, protein from 0.32 to 0.84 percent, and carbohydrate from 15.05 to 44.17 percent. Based on the sensory assessment and the triangle test, the panelists preferred the *gembus* cracker with additive, however, B3 was the best formulation suggested for consumption (Afifah et al., 2019a).

A study on the results of substituting *tempeh gembus* for the ingredients in meatballs was done by Arini et al. There are four formulas: 100 percent, 75 percent, 50 percent, and 25 percent of the meat can be replaced with *tempeh.* The best formula contains 8.03 percent protein, 351.9 mg/100 gr calcium, and 5.22 percent protein digestibility with a 25% *tempeh gembus* substitution. According to the study, one serving of *tempeh gembus* (78 mg) passes the nutritional label standard for the general category, which is 13% calories, 11% protein, and 25% calcium (Arini et al., 2019).

Research on replacing wheat flour with *tempeh gembus* flour on cookies has been done by Manullang et al (2020). Comparing cookie formulas with 0% and 25% substitutions of *tempeh gembus* flour, the cookie formula with 50% substitution had the lowest glycemic index (47.01%) and glycemic load (6.90%). Cookies made with that formula also had the highest levels of protein digestibility (20.27±0.43%), dietary fiber (24.61±0.41%), and starch digestibility (48.07±0.01%). Low GI and GL were achieved with the greater *tempeh gembus* flour substitution, whereas protein digestibility, dietary fiber, and starch digestibility were all high (Manullang et al., 2020).

Sinambela et al. (2020) likewise studied cookies made with *tempeh gembus* flour instead of wheat flour, but they focused on the nutritional differences between them. In five different formulas in this study, wheat flour will be substituted with *tempeh gembus* flour to varying degrees (0, 25, 50, 75, and 100%). Cookies made with 100 percent *tempeh gembus* flour were the best for high fiber, low fat, total energy, and carbohydrate, all of which were beneficial to obese adolescent girls while cookies containing 25% and 50% *tempeh gembus* flour were acceptable and favored.

Susanti et al used *tempeh gembus* instead of fish as the main ingredient of a nugget. This study uses 5 different substitutions for the *tempeh gembus*, including 0, 20, 60, 80, and 100%. The panelists' favored nugget formulation was the replacement treatment with 20% *tempeh gembus*. Considering the nutritious content, protein digestibility, acceptance, and compliance with all quality standards of nuggets, it was advised to substitute 60% and 20% of *tempeh gembus* in the formulas. Nuggets with 60 percent *tempeh gembus* substitution had 9.71 percent protein, 10.83 percent fat, 12.85 percent carbohydrate, 17.76 fiber, and 86.23 percent protein digestibility, whereas nuggets with 40 percent *tempeh gembus* substitution had 13.53 protein, 9.85 fat, 7.85 carbohydrates, 18.00 fiber, and 86.61 protein digestibility (Susanti et al., 2021).

Functional Properties

Tempeh gembus is produced using microorganisms as part of a fermentation process. The substance content of food can be impacted by the biological activity of the microorganisms that make it, including active substances with functional properties. Some of the functional properties included in *tempeh gembus*, such as amidolytic, antibacterial, and antioxidant activity, have been demonstrated in earlier studies.

Amidolytic Activities

The term "amidolytic" describes how a protease enzyme cleaves a peptide bond in a polypeptide or protein (Winter et al., 2020). The amidolytic method is a technique for measuring the concentration of functionally active antithrombin (Abildgaard et al., 2011). *Bacillus pumilus* 2.g was found in *tempeh gembus*, along with other microorganisms known to generate enzymes with antithrombin activity. To explore the properties of enzymes that produce fibrinolytic activity, a previous study isolated *B. pumilus* 2.g in gembus (Afifah et al., 2014a). The partly purified enzyme from *Bacillus pumilus* 2.g performed as expected in the fibrinogen hydrolysis assay. The study found that the chains α and β but not the chain γ of fibrinogen were degraded (Afifah et al., 2014b).

Antimicrobial Activity

Antimicrobials are a substance generated by an organism that kills or prevents another from growing (Purssell, 2020). As a result of the hydrolysis process, soybeans have different functional characteristics. For instance, proteolytic enzymes hydrolyze protein into peptides and amino acids that can also act as antibacterial agents (Ribotta et al., 2008). The potential of *tempeh gembus* hydrolyzate to fight bacteria was investigated by Noviana et al. *Bacillus subtilis*, *Escherichia coli*, *Streptococcus mutans*, and Staphylococcus aureus were used to investigate the antimicrobial properties of *tempeh gembus* hydrolysate bromelain enzyme (TGH BE). The highest inhibition zone against Staphylococcus aureus and *Streptococcus mutans* was found for TGH BE at 8,000 ppm in the exploratory results whereas the largest *Bacillus subtilis* inhibitory zone was seen at TGH BE at 5,000 ppm. TGH BE had no antibacterial activity against *Escherichia coli*. All treatments had no statistical differences in soluble protein or inhibitory zones against *Bacillus subtilis*, *Escherichia coli*, *Streptococcus mutans*, and *Staphylococcus aureus*. TGH BE had antibacterial properties against *Bacillus subtilis*, *Streptococcus mutans*, and *Staphylococcus aureus* (Noviana et al., 2018).

Antioxidant Activity

Antioxidant activity is the restriction or prevention of food oxidation (particularly of lipids and proteins) by limiting oxidative chain reactions (Guclu et al., 2020). Protein fragments known as bioactive peptides are inert within the parent protein's sequence but may exhibit physiological action once released (Sarmadi & Ismail, 2010; Singh et al., 2014). A fermented tofu waste called *tempeh gembus* has a high protein content and bioactive peptide components that may have antioxidant properties. Diana et al investigated the antioxidants in *tempeh gembus* after several food processing methods, including fresh, fried, steaming, and bromelain-added. Fresh *tempeh gembus* has an antioxidant activity of 48.07 percent, 0.05 percent genistein, and 0.07 percent daidzein. Antioxidant activity (39.72 percent), genistein (0.07 percent), and daidzein (0.09 percent) were all found in steamed samples. Antioxidant activity (61.00 percent), genistein (0.08 percent), and daidzein (0.10 percent) were all found in fried samples. *Tempeh gembus* with bromelain added had a total antioxidant activity of 62.04 percent, 0.07 percent daidzein, and 0.06 percent genistein. Bromelain added to *tempeh gembus* resulted in antioxidant activity profiles that were compared to fresh samples, steaming, and frying (Afifah et al., 2019b).

Another study looked at the antioxidant activity of *tempeh gembus* that released the bromelain enzyme to break up peptide bonds and release amino acids and bioactive peptides (Agustina et al., 2018). The four treatment groups had significant differences in the *tempeh gembus* hydrolysate's soluble protein concentration and antioxidant activity (10.000 ppm, 8000 ppm, 5000 ppm, and 0 ppm). The ABTS test revealed that *tempeh gembus* hydrolysate has stronger antioxidant activity than the DPPH test. According to the ABTS test, the *tempeh gembus* hydrolysate's antioxidant activity improved as bromelain concentrations rose but not the DPPH test. As the concentration of bromelain enzyme rose, the hydrolysate of *tempeh gembus* contained less soluble protein (Agustina et al., 2018).

Health Benefits

The fermentation process used to make *tempeh gembus* yields fibrinolytic enzymes that can lower fibrinogen levels, one of the primary indicators of atherosclerosis. Hyperlipidemia can be treated with fiber and antioxidants from *tempeh gembus* by improving lipid profiles, such as lowering total cholesterol, LDL, and triglycerides and elevating HDL. Improving this lipid profile can prevent the oxidation of lipids, which raises the levels of cytokines linked to inflammation and oxidative stress such as MDA, homocysteine, and hs-CRP, all of which are indicators of atherosclerosis and obesity. *Tempeh gembus* has a low glycemic index, glycemic load, and high fiber content that can induce satiety while being low in calories, improving blood sugar and insulin profiles. This is advantageous for obese persons as it can help them cut back on consumption and calories. The metabolic syndrome is also prevented indirectly by *tempeh gembus* which improves lipid profiles, blood sugar, and obesity.

Atherosclerosis

Atherosclerosis is the result of hyperlipidemia and lipid oxidation which is characterized by the accumulation of lipids and fibrous elements that form plaque growth within the lumen of the arteries with a simultaneous loss of elasticity of the blood vessels (Head et al., 2017; Rafieian-Kopaei et al., 2014). Following the publishing of findings showing the deposition of fibrin and fibrin breakdown products in artery walls with atherosclerosis, a probable role for the fibrinolytic system in the development of atherosclerotic plaque was hypothesized. The fibrinolytic enzyme is a proteolytic enzyme that was initially discovered to be involved in the breakdown of fibrin and the maintenance of a patent lumen in the blood vessels (Jovin & Müller-Berghaus, 2004). The finding of fibrinolytic activity in enzymes produced by bacteria found in *tempeh gembus* motivated numerous researchers to do additional research by feeding *tempeh gembus* to experimental animals to examine how it affected atherosclerotic markers. Ratih et al. studied atherosclerotic markers such as blood malondialdehyde and homocysteine in rats given an atherogenic diet for four weeks and then given *tempeh gembus* for four weeks. This study found that feeding rats 25 grams of *tempeh gembus* per kilogram of body weight reduced serum malondialdehyde and homocysteine levels, but not considerably (Kurniasari et al., 2017).

The protein hydrolyzate produced by the bromelain enzyme breaks down protein in *tempeh gembus,* resulting in an increase in antioxidants that prevent oxidative stress from damaging the endothelium, allowing it to optimally generate nitric oxide. Nitric oxide detoxifies homocysteine by attaching and converting it to a less harmful molecule, which also serves as a thrombosis inhibitor (Pushpakumar et al., 2014). The bromelain enzyme is also involved in increasing fibrin breakdown by enhancing plasminogen to plasmin conversion (Errasti et al., 2016).

The absence of detectable homocysteine in oxidized forms such as thiolactone in the ELISA Kit, which only tests total homocysteine comprised of thiol-homocysteine, disulfide homocysteine, and cysteine homocysteine, is one plausible mechanism explaining the insignificant decrease in homocysteine. Thiolactone is a reactive thioester that combines with Low Dense Lipoprotein (LDL) to generate foam cells, which are crucial in the development of atherosclerosis. The positive control group's atherogenic diet increased the incidence of hyperlipidemia, resulting in oxidized homocysteine-like thiolactone binding to LDL. LDL-Hcythiolactone is deposited as thioco and then converted to thioretinamide. The conversion of thioco to thioretinamide generates a lot of reactive oxygen species (ROS), which might lead to endothelial dysfunction. In smooth muscle cells, thioretinamide can cause proliferation and fibrosis (Yadav et al., 2006).

An atherogenic diet increase blood lipids and inflammation, which can elevate malondialdehyde (MDA) levels (Nisa et al., 2021). The antioxidant activity of the hydrolyzed protein made from *tempeh gembus* is quite strong (Agustina et al., 2018). antioxidants can limit lipid oxidation and thereby reduce MDA production. Genistein may also affect the reduction of MDA in the *tempeh gembus* group by activating the development of the enzyme superoxide dismutase and helping superoxide dismutase in its role of converting free radicals into neutral molecules, hence reducing MDA generation (Lee et al., 2004).

Blood levels of fibrinogen and high sensitivity C-Reactive Protein (hsCRP), two additional atherosclerosis markers, were also investigated. In this study, experimental animals fed an atherogenic diet were given different types of *tempeh gembus* (*tempeh gembus* containing bromelain, fresh *tempeh gembus*, and heated *tempeh gembus.* Among different types of *tempeh gembus*, administration of *tempeh gembus* with bromelain was the most effective for serum fibrinogen and serum hsCRP levels (Dewi et al., 2018).

HsCRP decreased in the intervention group, most likely due to the presence of isoflavones such as daidzein and genistein in *tempeh gembus*. Because of its anti-inflammatory characteristics, it lowers protein levels and the activity of protective enzymes like phospholipase AZ (PLAZ), lipoxygenase (LOX), cyclooxygenase-2 (COX-2), and inducible nitric oxide synthases (iNOS), as well as suppressing the formation of pro-inflammatory contributors (Yu et al., 2016). Another potential explanation is that the presence of unsaturated fatty acids in *tempeh gembus* is linked to reduced levels of C-Reactive Protein (CRP), which is associated with the suppression of chronic inflammation (Muka et al., 2015). Linoleic acid and linolenic acid are polyunsaturated fatty acids that suppress the actions of cyclooxygenase, omega 6 desaturases, and omega-5 desaturase.

Tempeh gembus, which was given by the intervention group, is a fermented food that contains microorganisms such as bacteria. Diana et al discovered that bacteria living in *tempeh gembus* produce fibrinolytic enzymes. This fibrinolytic enzyme may have a key role in lowering fibrinogen levels in people who eat *tempeh gembus* (Afifah et al., 2014a; Afifah et al., 2014b). Fibrinolytic enzymes function as thrombolytics by activating plasminogen to convert it into plasmin, which can break down fibrin and hence remove thrombus (Afifah et al., 2014a). Another probable explanation is that the genistein in *gembus* inhibits the synthesis of thrombin and platelet activity, resulting in low fibrinogen levels (Afsaneh Bakhtiary et al., 2012).

Diabetes Mellitus

Diabetes is characterized by hyperglycemia, a metabolic condition brought on by deficits in insulin secretion, action, or both (American Diabetes Association, 2010). The most crucial aspect of diabetes mellitus is blood sugar control through meal regulation. According to previous studies, *tempeh gembus* has three times the fiber of *tempeh.* Other research has also revealed that *tempeh gembus* has a low glycemic index. *Tempeh gembus* is a functional food that diabetics can utilize as an alternative dietary ingredient because of these factors. Several gembus-based food processing modifications were created and tested for protein and starch digestion rates, dietary fiber, GI, and GL. Cookies made with 50 percent *tempeh gembus* flour have a GI of 47.01 percent, classifying them in the low GI group (<55) (Manullang et al., 2020).

Tempeh gembus has a beneficial effect on blood sugar and insulin, following studies by Isnawati et al and Nadia et al (Isnawati et al., 2020; Nadia et al., 2020). Isnawati et al. revealed in their research that the treatment group's fasting blood glucose levels were clinically lower by 4.5 mg/dl than the control group's, despite there being no statistically significant difference in fasting blood glucose levels between the two groups (Isnawati et al., 2020). Nadia et al studied insulin resistance following *tempeh gembus* intake. The study found that 28 days of daily administration of 150 grams of *tempeh gembus* reduced insulin resistance. The control group has a lower level of insulin resistance than the treatment group (Nadia et al., 2020).

Isoflavone-rich fiber diets are thought to lower insulin resistance (Charles et al., 2009; Chu et al., 2006). The high fiber content of *tempeh gembus* may contribute to the favorable impacts on blood sugar and insulin generated by its consumption. Fiber can promote glucose and insulin metabolism by lengthening the time food passes in the intestine. Fiber also has been demonstrated to improve the state of diabetes mellitus in several previous studies. Fiber intake for four weeks has been demonstrated to increase insulin secretion in overweight and non-diabetic patients in previous research (Bodinham et al., 2012). In other research, increasing fiber intake for a year has been shown to increase healthy individuals' glucagon-like peptide-1 (GLP-1) secretion (Wolever et al., 2008). Other research has found that people with Type 2 Diabetes Mellitus can reduce their HbA1c levels by eating a high-fiber diet (Mazidi et al., 2018). Fiber's high viscosity can also increase insulin sensitivity by decreasing macronutrient absorption (Clarkson, 2002). The ability of fiber to lower blood sugar levels is affected by efficient carbohydrate absorption, which causes a lower insulin response, allowing the pancreas to improve its performance because it produces insulin infrequently (Ahmed et al., 2010; Lu et al., 2013; Sedaghat et al., 2015). Furthermore, fiber can improve peripheral insulin sensitivity by causing the fermentation of fiber in the gut to produce short-chain fatty acids (Feder & Fonseca, 2017).

Hyperlipidemia

Hyperlipidemia is the medical term for an excess of fatty compounds in the blood. For the treatment and prevention of hyperlipidemia, fibers may exert a protective molecular mechanism (Nie & Luo, 2021). The high fiber content of tempeh indicates that it can be used to treat and prevent hyperlipidemia. Studies on the use of *tempeh gembus* to treat hyperlipidemia have been conducted. Hyperlipidemic women were given *tempeh gembus* for the research. In this study, there were three groups: the control group, which received no *tempeh gembus* but received nutritional education as a substitute, the group that received 103 g of *tempeh gembus* per day, and the other group received 206 g per day. These findings revealed that consuming 103 and 206 grams of *tempeh gembus* a day reduced LDL-C by 27.9% and 30.9 percent respectively (Afifah et al., 2020). The protein content of *tempeh gembus* may contribute to inhibiting cholesterol production, lowering bile acid and/or cholesterol absorption, and initiating the transcription process of LDL-C receptors, resulting in a drop in LDL-C in hyperlipidemic women using it (Greany et al., 2004). Furthermore, protein and fiber have been indicated to inhibit cholesterol absorption and enhance bile acid production in the intestine. Daidzein and genistein are phytoestrogens that boost LDL-C receptor activation (Sulchan, 2007).

Total cholesterol was also reduced by 17.7% and 19.8%. The fiber in *tempeh gembus* binds bile acids, reduces the intestinal absorption of cholesterol, and enhances fatty acid and cholesterol excretion from the liver during the creation of intraluminal micelles, allowing the liver to utilize cholesterol to produce new bile acids (Clarkson, 2002; van Bennekum et al., 2005). Fiber can also cause the gut microbiota to create short-chain fatty acids like butyrate, propionate, and acetate, which can impact lipid metabolism, synthesis of hepatic fatty acids, and bowel motility.

Contrary to theory, triglycerides increased by 2.3 and 3.1 percent, respectively. This could be attributed to serum triglyceride sensitivity and vulnerability to exogenous meal intake. Food intake has a significant impact on triglyceride levels. Food-derived triglycerides are completely absorbed, carried by chylomicrons, and circulated in the bloodstream. After 30 to 60 minutes of food ingestion, postprandial absorption of chylomicrons from the gastrointestinal tract can cause a 3- to 10-hour increase in blood triglycerides (Clarkson, 2002).

This study discovered a tiny but significant rise in HDL-C of 3.91 percent and 8.79 percent, respectively because physical activity has a bigger influence than food intake and the effect of fiber on boosting HDL-C levels is still unclear. Several kinds of research that investigated the impact of fiber on HDL-C found that it had a minor, inconsistent, or non-existent effect (Thompson & Rader, 2001).

Obesity

Obesity is a multifactorial, complex metabolic illness that is becoming recognized as a major primary health problem that lowers the quality of life due to its complications. There were studies to support the idea that inflammation and oxidative stress play a crucial role in the relationship between obesity and the complications it causes (Manna & Jain, 2015). *Tempeh gembus* is high in antioxidants, fiber, and unsaturated fatty acids, all of that can assist in reducing inflammation. Wati et al and Nadia et al were inspired to investigate the effects in hsCRP, HDL, and triglycerides caused by *tempeh gembus*. For 28 days, obese women were given up to 150g of *tempeh gembus* per day (Nadia et al., 2020; Wati et al., 2020). The findings of this study show that having *tempeh gembus* reduces hsCRP, increases HDL, and lowers triglycerides. This is consistent with recent research, which shows that meals based on soy can cut high sensitivity C-Reactive Protein levels by 25%. It is possible to detect the anti-inflammatory action in the reduction in C-Reactive Protein levels (Kim et al., 2014). Increased CRP can be protected by consuming more fiber. Previous research has found that lowering fiber intake promotes pro-inflammatory cytokines, particularly IL-6 while increasing IL-6 increases CRP levels. Fiber can also lower cholesterol levels in the body, resulting in decreased CRP levels and increased anti-inflammatory effects. Furthermore, fiber can limit fat oxidation, lowering inflammation and hence CRP (Ma et al., 2006).

Isoflavones, a kind of antioxidant can also be found in *tempeh gembus* (Afifah et al., 2019b). Isoflavone inhibits NF-κB's transcriptional mechanism, whereas NF-KB activates the transcription of pro-inflammatory cytokines and chemokines genes, along with cyclooxygenase and inducible nitric oxide synthase. Pro-inflammatory enzymes such as cyclooxygenase 2, phospholipase A2, inducible nitric oxide, and lipoxygenase, are also inhibited by isoflavones (Yu et al., 2016). *Tempeh gembus* antioxidant action is probably derived from bioactive amino acids/peptides in addition to isoflavones. Tryptophan, histidine, lysine, methionine, histidine, and cysteine are among the amino acids found in *tempeh gembus.* Antioxidant activity in soybean gembus was measured using the ABTS method and found to be 63.14±1.16% (Agustina et al., 2018).

According to previous research, giving *tempeh gembus* for 28 days can prevent weight gain in all treatment groups since the fiber in *tempeh gembus* might enhance satiety, lowering energy intake indirectly (Clarkson, 2002; Wati et al., 2020). It can also help in the elimination of cholesterol and bile acids through the feces, avoiding the return of bile acids to the liver (Jesch & Carr, 2017). The liver's ability to convert cholesterol to bile acids is increased when bile acids are produced at a lower level, which raises high-density lipoprotein (HDL) levels (Staels & Fonseca, 2009). The elevation in HDL levels in the treatment group may have been caused by the presence of flavonoids in *tempeh gembus*, in addition to fiber. Flavonoids can raise Apolipoprotein A-1 concentration in the body. In HDL tissues, apolipoprotein A-1 functions as a ligand for the lipoprotein receptor or even an enzyme cofactor for LCAT. HDL is projected to rise as Apolipoprotein A-1 levels rise (Groper et al., 2009). Several reasons contribute to increased HDL levels that do not reach ideal levels in that study, and one is exercise (Whitney & Rolfes, 2015). Regular exercise can improve Apolipoprotein A-1's ability to remove cholesterol from blood vessel walls as an HDL receptor (Kingwell & Chapman, 2013).

Because CYP51 is the first sterol intermediate in the cholesterol biosynthetic pathway, it is an important gene in cholesterol biosynthesis (Rozman et al., 2005). Previous research has found that okara consumption causes fatty acid synthetase genes to be downregulated and CYP7A1 genes to be upregulated, both of which are beneficial to obesity prevention (Matsumoto et al., 2014). CYP7A1 is a gene that controls the biosynthesis of bile acids. The fiber in *tempeh gembus* may help to accelerate fecal bile acid excretion and promote cholesterol to bile acid conversion, lowering plasma cholesterol levels. A high-fiber diet has been demonstrated to affect the expression of liver genes involved in cholesterol synthesis, such as CYP51, and that the effect of raising bile acids is most likely what causes the reduction in cholesterol (Chan & Heng, 2008).

Metabolic Syndrome

Metabolic syndrome is a risk factor that increases the risk of heart disease and other health problems, such as obesity. Inhibiting the oxidation of other molecules, antioxidants are reducing agents that can be utilized to prevent as well as treat the health issues associated with atherosclerosis and multiple sclerosis (Martins Gregório et al., 2016). According to a previous study, *tempeh gembus* is a beneficial diet rich in flavonoids, fiber, amino acids, and polyunsaturated fatty acids. These contents suggest that it can benefit in the reduction of metabolic syndrome risk via inflammatory pathways. This led Ikawati et colleagues to study the effect of *tempeh gembus* on rats with metabolic syndrome (Sulistyaningsih et al., 2020). *Tempe gembus* that was administered to metabolic syndrome rats for 28 days can significantly affect hsCRP through various processes, including the polyunsaturated fatty acid content in *tempeh gembus*, which may play a role in controlling hsCRP concentrations and other inflammatory indicators (Shen & Ordovas, 2009; Sulistyaningsih et al., 2020). The fiber in *tempeh gembus* also helps to reduce hsCRP levels by reducing lipid oxidation, balancing intestinal flora, and suppressing hyperglycemia (King, 2005; North et al., 2009).

That study also showed that giving rats with metabolic syndrome *tempeh gembus* increase adiponectin levels (Sulistyaningsih et al., 2020). Interleukin-6, TNF-a expression, hsCRP, and nitric oxide synthesis can all be inhibited by adiponectin, which is a cardioprotective cytokine (Devaraj et al., 2003, 2008). Fiber, unsaturated fatty acids, and isoflavones found in *tempeh gembus* can all influence adiponectin levels (Silva et al., 2011; Vajihe Izadi & Leila Azadbakht, 2015).

SOLUTIONS AND RECOMMENDATIONS

Tempeh gembus is a different approach to reduce waste for tofu manufacture. *Tempeh gembus* can also be used as an alternative source of protein and fiber to meet the nutritional need.

Future Research Directions

Future studies are required to determine the factors that influence the production of *tempeh gembus* in various nations, particularly those with varying climatic conditions, in order to develop this healthy alternate diet solution.

CONCLUSION

Many Indonesian traditional foods are still undiscovered in terms of their health advantages. One of Indonesia's traditional foods, *tempeh gembus*, is fermented and seems to have several functional properties like amidolytic, antimicrobial, and antioxidant activity thus *tempeh gembus* may have health advantages to aid with atherosclerosis, diabetes mellitus, hyperlipidemia, obesity, and metabolic syndrome. This article reviews the findings of different studies on *tempeh gembus* and how it affects human health.

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KEY TERMS AND DEFINITIONS

Fermentation: A process that transform complex compound in soybean dreg by Rhizopus spp. mold activity into digestible compounds.

Fibrinolytic: An activity that breakdown fibrin in blood clots.

Isoflavone: A bioactive compound with antioxidant and estrogenic activities in the body.

Peptide: A short chain of amino acids that linked by peptide bonds and it can result from protein degradation.

Sustainable Development Goals (SDGs): Actions to end poverty, safeguard the environment, and guarantee that by the year 2030 everyone lives in peace and prosperity. There are 17 SDGs that are integerated; 1. No poverty; 2. Zero hunger; 3. Good health and well-being; 4. Quality education; 5. Gender equality; 6. Clean water and sanitation; 7. Afforfable and clean energy; 8. Decent work and economic growth; 9. Industry, innovation and infrastructure; 10. Reduced inequalities; 11. Sustainable cities and communities; 12. Responsible consumption and production; 13. Climate action; 14. Life below water; 15. Life on land; 16. Peace, justice and strong institution; 17. Partnerships for goals.

Tempeh gembus**:** A food made by tempeh mold *Rhizopus spp.* from tofu waste.

Tofu waste: Soybean dreg from producing tofu.

Chapter 4
Physicochemical Characteristics of Indonesian Native Starch

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ABSTRACT

Indonesia has many local starch sources, including rice, taro, arrowroot, sago, corn, konjac, cassava, and elephant foot yam (suweg). Several uses of natural starch have been widely used as the primary raw material or as a food additive. Natural starch generally has some drawbacks limiting its use, such as color, solubility index, retrogradation, and paste stability. Starch modification is needed to improve these limitations. Starch modification is carried out physically and chemically. In this chapter, the authors will discuss the physical and chemical characteristics of several local Indonesian starches, both natural and modified, and their potential to be developed as food ingredients.

DOI: 10.4018/978-1-6684-5629-3.ch004

INTRODUCTION

Starch is a carbohydrate polymer used as the primary source of calories for consumption. Apart from being used as a food ingredient, starch may act as a gelling agent, thickener, foam and emulsion stabilizer, battered and breaded, binder, crispy texture maker, clouding stabilizer, and flavor encapsulant. Starch could also be employed in the paper, textile, and pharmaceutical industries. Various plant sources of starch, such as rice, taro, arrowroot, sago, corn, konjac, cassava, and elephant foot yam (suweg), are growing a lot in Indonesia. They respectively produce starch with different properties. This chapter reviews the physicochemical characterization of several Indonesian starch plants and their roles in controlling food processing. The scientific information from this chapter is expected to enrich the study of starch sources worldwide.

Rice (*Oryza sativa*)

Rice is a carbohydrate source and a staple food for most Indonesians. Rice is mainly consumed as cooked polished grains, whereas rice flour is used as an ingredient in many Indonesian cuisines. Starch is the most significant component in rice grains and determines the quality of rice products. The starch content in rice is in the range of 80% (Hasjim et al., 2013).

Gelatinization characteristic is considered one of the essential properties in evaluating rice starch properties. In particular, gelatinization is the most crucial rheological indicator of the quality characteristics of rice cooking and processing. Amylose content and branch chain length distribution have also been found to impact rice starch's swelling and pasting properties substantially. Rice starch granules with high amylose content act as swelling inhibitors. Amylopectin contributes to swelling, while amylose and amylose-lipid complex inhibit swelling. In addition, low swelling levels and solubility tend to increase with the increasing temperature of amylose molecules in rice. Studies show that a higher level of long chain amylopectin in rice starch is associated with firmer rice after cooking. Retrogradation was also found higher in rice starch with a longer amylopectin chain (Yoon et al., 2012).

Taro (*Colocasia esculenta*)

Taro has a starch content of about 80%. The characteristics of taro starch have been evaluated based on swelling power and solubility index. The swelling behavior of starch can be influenced by amylose and amylopectin compositions. According to Aboubakar et al. (2008), the swelling power of taro starch will increase along with starch cooking level, indicated by an increase in Water Absorption Capacity (WAC).

Temperature increase led to a significant increase in WAC to a maximum of 60–70 ºC, from which they decreased.

At 20°C, taro starch shows lower solubility and forms only a temporary suspension when stirred in water. Minimal solubility of starch at low temperatures is associated with starch semi-crystalline structure due to the hydrogen bonds formed between hydroxyl groups of starch molecules. At higher heating temperatures, taro starch solubility will increase and make it highly digestible, which is used to prepare various foods. The concept of increasing solubility while the starch granule breakdown causes heating starch in water, exposure to hydrophilic groups, and leaching of amylose (Himeda et al., 2012).

Arrowroot (*Maranta arundinacea*)

Arrowroot starch content ranged from 92.24 to 98.78%, shape spherical to elliptical granules with a size range from 7 to 16 μm (Astuti et al., 2018). Arrowroot starch extracted showed the birefringence appearance of starch granules form using a polarizing microscope. This indicated that the starch was not gelatinized. When observed using Scanning Electron Microscopy (SEM), the surface of all arrowroot starch granules appears smooth and without fissures, indicating that the granules are intact and undamaged (Rodrigues et al., 2018).

Arrowroot starch has amylose content in the range of 35% and also has low swelling power and solubility index (Gordillo et al., 2014). The solubility index of arrowroot starch suspensions increased for temperatures greater than 50°C and remained practically constant at temperatures above 70°C. The solubility of arrowroot starch will increase at temperatures above 50 and constant at higher temperatures of 70. It is related to the temperature required for starch gelatinization to occur. The thermodynamic activity of starch molecules will occur in the starch gelatinization. It causes granular mobility and water penetration, so the expansion capacity increases (Rodrigues et al., 2018). Utilization of arrowroot starch in various bakery products, gels, special binders, ice cream stabilizers, and others in substitution for other types containing gluten (Jyothi et al., 2010).

Sago (*Metroxylon sagu*)

Sago starch content was 85.08% consisting of 27% amylose and 73% amylopectin. Sago starch is contained in the stalk of the plant. Therefore, sago starch is obtained after extraction through the separating starch process from the core, then drying. This drying process was reported to affect the gelatinization temperature, water absorption, swelling power, and solubility of sago starch.

In addition to conventional drying methods, sago starch can be dried using a cross-flow fluidized bed (CFFB) dryer. The differences in characteristics of wet and dry sago starch using two drying methods can be seen in Table 1. The swelling power of sago starch dried using a CFFB dryer is lower than conventionally dried sago starch. It is influenced by several factors, including water absorption, gelatinization temperature, and amylose content. Increasing temperature and amylose content will reduce the starch swelling-power related to water absorption and gel formation. On the other hand, the higher water absorption capacity would increase starch swelling-power (Jading et al., 2011).

Table 1 also shows that sago starch dried using a CFFB dryer has a higher solubility level than sun-dried. The starch solubility is also influenced by gelatinization temperature and amylose content. According to Winarno (1997), amylose is a starch fraction soluble in hot water and can be leached out of the granules when gelatinized. Thus, when gelatinized, the amylose fraction released comes out of more granules so that the solubility level will increase. Therefore, drying sago starch using a CFFB model reduces starch swelling-power and, on the other hand, increases its solubility.

The sago starch can also be modified to increase its' solubility. One of the starch modifications is breaking the original starch granules into particles with smaller granule sizes which can affect the solubility properties and roasting process. The starch modifications can be carried out chemically, physically, biologically, or a combination of them. The starch modification of sago which is commonly used is the chemical method. Chemical modifications include acid hydrolysis, oxidation, etherification, esterification, and cross-linking (Sumardiono & Rakhmawati, 2017).

Table 1. Comparison of the characteristics of sago starch

Gelatinization Profiles	Wet Sago Starch	Dried Sago Starch with Solar-Biomass CFFB Equipment	Conventional Sago Starch
Gelatinization Temperature (^{0}C)	66,0-73,0	64,5-72,0	65,0-71,5
Absorption of starch to water (%)	11,10	50,69	51,34
Swelling power (starch 10%)			
55^{0}C	2,89	3,19	3,39
75^{0}C	30,11	32,36	35,62
90^{0}C	40,60	41,97	42,05
Solubility			
55^{0}C	0,00	0,00	0,20
75^{0}C	0,00	0,20	0,60
90^{0}C	0,60	1,00	0,90

Source: (Jading et al., 2011)

Ozone oxidation as another starch modification increases the sago starch solubility at pH 10. However, the longer oxidation time causes a decrease in swelling power (Sumardiono et al., 2021).

Corn (Zea mays)

Corn has been known to have 57% starch content. Corn starch granules are about 15 µm in size. Starch with large granules has a higher heat resistance than starch with small granules. Observations with DSC (Differential Scanning Calorimetry) showed that starch with small sizes had a lower initial gelatinization temperature than starch with larger granules (Winarno & Wirakartakusumah, 1981).

The initial temperature of gelatinization is a complex physical change in starch that is determined by several factors, including amylose/amylopectin composition and heating conditions. Increasing the initial temperature of gelatinization will increase the viscosity of starch. In addition, Subagio and Aqil (2013) reported that some local maize varieties had different gelatinization profiles. It is caused by amylose compositions difference.

The initial temperature of corn starch gelatinization of several local corn varieties can be seen in Table 2. Based on the table, the initial temperature of corn starch gelatinization ranges from 69.5 – 77.5 ºC. The higher the amylose content, the higher temperature to gelatinize at the same amount of energy. The higher amylose content causes a strong granule structure, so it takes a higher temperature to turn into a gel (Suarni et al., 2013).

Table 2. Gelatinization temperature of corn starch from several varieties

Varieties	Amylose Content (%)	Gelatinization Temperature (°C)
Pulut Takalar	5,79	70
Pulut Gorontalo	3,98	69,5
Calon varietas Pulut	6,87	72
Lokal Takalar	24,85	73,5
Anoman-1	23,26	72
Srikandi Putih-1	30,60	74
Srikandi Kuning-1	31,85	76
Palakka	45,87	75
Krisna	46,92	77,5
Bisma	47,46	74,5
Lamuru	48,29	74

Source: (Suarni et al., 2013)

CASSAVA (MANIHOT ESCULENTA)

Cassava has 25 – 30% starch content. Due to its functional properties, cassava starch has been widely applied in the food industry. Several functional properties of cassava starch have been reported, including swelling power and solubility, retrogradation, and rheology. Swelling power is the ability of starch to swell due to the gel formation process due to swelling of starch granules due to water absorption during heating (gelatinization) (Parwiyanti et al., 2015). Swelling power is determined by the amylose-amylopectin ratio, degree of branching, and conformation. Swelling power has an inverse relationship with amylopectin content in cassava starch. The swelling power of Indonesian cassava flour was reportedly 13.8 (g/g), while cassava starch was around 42 – 71 (g/g). It shows a difference between cassava flour swelling power and cassava starch (Kusumayanti et al., 2015). Swelling power values provide evidence of non-covalent bonds between starch molecules (Hasmadi et al., 2021).

Differences in amylose and amylopectin composition in cassava starch will also affect the solubility properties. The solubility of starch is inversely proportional to the amylose content. The high amylopectin content of starch will have higher solubility but lower swelling power. It indicates a weak associative force in starch granules. Another factor that causes a weak association between starch granules is starch damage that occurs during extraction (Hasmadi et al., 2021).

After gelatinization, the amylose and amylopectin chains would separate. Then they rearrange to form a more stable structure at lower temperatures (retrogradation). Retrogradation is influenced by several factors, including water content, storage temperature, storage time, and additives (carbohydrates, salts, proteins, lipids, and others). Hasmadi et al. (2021) stated that higher amylopectin short-chain content would cause slower retrogradation.

The rheological properties of starch depend on three main factors: temperature, shear rate, and gel thickness. The rheological properties of cassava starch show pseudoplastic or shear-thinning behavior. The deviation from Newton's behavior will increase if the concentration of cassava starch increases. The pseudoplastic properties of gelatinized starch are essential in many products. Associated with pseudoplastic materials have suspension properties at low shear rates, and their viscosity becomes low when processed at higher shear rates. The viscosity of a liquid is a function of the intermolecular forces constraining the molecules' motion. Cassava starch showed more pseudoplastic behavior than corn starch at the same concentration. Therefore, cassava starch is thicker than corn starch (Elizabeth et al., 2019).

The application of food technology produces new food products made from local food. Cassava native starch has a weakness that is often not applicable in food processing, so modifications to cassava starch are needed to improve it. Starch modification can be produced through physical, chemical, and enzymatic processes (Safitri, 2017) or by combining several techniques.

Modification using a combination of lactic acid hydrolysis and oxidation with hydrogen peroxide can increase the roasting expansion of cassava starch (Sumardiono et al., 2017a; Sumardiono et al., 2020). The combination of chemical and physical modification with lactic acid hydrolysis followed by microwave drying showed increased solubility and expandability of cassava starch applied to coated peanuts (Sumardiono et al., 2017b; Sumardiono et al., 2018a). Increased swellability was also found in cassava starch modified with lactic acid and ethanol, then dried with a solar dryer (Sumardiono et al., 2017c). Drying cassava starch using a sun dryer gives better results and is faster and more effective (Suherman et al., 2018; Suherman et al., 2020) compared to an oven (Sumardiono et al., 2017c) and a sun dryer (Suherman et al., 2017). Similar results were also shown by modification of cassava starch by acid hydrolysis in a rotary-UV dryer (Sumardiono et al., 2017d; Sumardiono et al., 2018b). In addition, cassava starch drying can also use a pneumatic drying system, in which the drying process can be carried out in two cycles. The higher the drying air temperature, the lower the moisture content of the solids coming out of the outlet. The thermal efficiency of the 2nd cycle was lower than the 1st cycle (Suherman et al., 2015).

Modifying cassava starch with ozone oxidation at pH 10 produces starch with smaller granule size and high amylose, increasing solubility in water (Pudjihastuti et al., 2018). Modification of cassava starch can use chemical methods through hydrolysis, esterification, or ethanol. Modification of cassava starch has been reported to positively affect the physicochemical properties of starch, including swelling and solubility. Acid-assisted hydrolysis of UV irradiation of starch causes the breakdown of amylopectin chains, thus forming an amorphous structure. Cassava starch, with these modifications, can be used as an alternative raw material in the bakery or other food industries. Modified cassava starch has good cake expansion properties and retains nutrients, which enables it to compete with commonly used ingredients (Sumardiono et al., 2021a).

KONJAC (AMORPHOPHALLUS MUELLERI)

Konjac has 78.94% starch content (Kusmiyati & Sulistiyono, 2014). In addition, starch oxalate content needs to be considered in konjac. Three days of immersion in NaCl solution with water replacement every 6 hours can reduce the calcium oxalate content in konjac tubers. The soaked tubers are sliced, placed in a drying cabinet, and ground into flour. Then added, water, separated the precipitated from Konjac flour, then dried (Koswara, 2000).

Pregelatinization is the simplest modification of starch, which aims to accelerate hydration. Pregelatinization is a physical modification of starch using the heating method at a temperature above the gelatinization range of starch, then dried. Cross-linking modification aims to inhibit starch swelling so that starch viscosity becomes stable. The principle of this method is to replace OH- group with another functional group, such as an ether, ester, or phosphate group. This modification produces starch with lower swelling power, so it can strengthen starch granules and make the starch more resistant to acid. The starch is also resistant to heat, so it is more applicable to products with heating treatment. In addition, the cross-linking method can improve texture, viscosity, paste clarity, gel strength, and adhesiveness. However, the weakness of this method is that it reduces the solubility, sediment volume, gel elasticity, and freeze-thaw stability of starch (Raina et al., 2006).

In konjac starch, the combination of pre-gelatinization and cross-linking modifications showed an effect on functionality, viscosity, pH, and organoleptic characteristics compared to native starch. The results of testing the impact of pre-gelatinization and cross-linking on konjac starch can be seen in Table 3. The pregelatinized and cross-linked modified starch produced good flow properties in konjac native starch. Modified konjac starch has a better flow rate between 4-10 g/s (Aulton, 1988).

The pregelatinized and cross-linked modified starch produced good flow properties in konjac. In addition, the material flow velocity can also be seen from the compressibility index, which shows the particle density. The high compressibility index makes the powder hard to flow. Simek. et al. (2016) reported that the excellent

Table 3. Effect of pregelatinization and cross-linking modifications on konjac starch

Test Parameters	Native	Modification of pregelatinization and cross-linking
Angle of Repose (°)	13.8473	0.20045
Flow Speed (g/s)	0.1379	6.25003
Compressibility Index (%)	0.663	6,541
LOD (loss on drying)	5.09	2.625
pH of starch gel	4.3	6.7
Viscosity (cP)	13040	19680
Homogeneity	Homogeneous	Homogeneous
Organoleptic		
Color	Light brown	Dark brown
Aroma	Typical of starch	Typical of starch
Form	Semi-solid	Semi-solid

Source: (Haeria et al., 2017)

compressibility index is less than 30%. The modified pre-gelatinization and cross-linking treatments increased the compressibility index value compared to the natural starch. However, this modified konjac starch still meets the criteria of being easy to flow because the compressibility index value is 6.541%. Therefore, pregelatinized and cross-linked modified konjac starch has the potential to be used in processing processes that require good flow properties, such as direct compression techniques native starch.

Weight loss due to the heating process is called Loss On Drying (LOD). Pregelatinization and cross-linking prevent water loss or other components that evaporate during heating. The LOD value of modified konjac starch is in accordance criteria for a good pregelatinized starch LOD, which is below 5% (Kibbe, 2000). This modification affects the increased modified starch gel pH compared to native starch.

Konjac starch gel has a semi-solid texture and a starchy aroma. However, the native starch gel was light brown, while the modified starch gel was dark brown. It is related to the non-enzymatic browning reaction during modified starch heating.

Viscosity is a liquid's resistance to flow, which is related to the average molecular weight of starch (Masuelli, 2018). The existence of a cross-linking process will increase the molecular weight of the starch, so the viscosity is higher than native konjac starch. The konjac starch gel appears homogeneous and stable, both native and modified starch.

In addition, pre-gelatinization and cross-linking, hydrolysis modification by alpha-amylase also affects its functional properties. During hydrolysis, it is observed that starch granules absorbed water and swelled, becoming gelatinized starch. This may be due to the shearing effect of stirring, removing the gelatinized outer layer, and the long-chain starch molecules will dissolve in the solution, resulting in hydrolysis. As the endo-enzyme at this stage, amylose will randomly break off the inside. Dextrin will be formed at the beginning, and continuous maltose will accumulate. One of the glucose molecules has a free glucoside group to reduce its properties.

The hydrolysis rate of amylase enzyme on konjac starch was influenced by stirring speed, enzyme concentration, and solid-to-liquid ratio. Increasing the stirring speed, amount of enzyme, and solid-to-liquid ratio will increase the production of reducing sugar. Starch conversion is more influenced by solid-to-liquid ratio, substrate concentration rather than stirring speed, and enzyme amount. Triplicating the solid-to-liquid ratio from 3.33 g/L to 10 g/L will increase the reducing sugar by 4.6 times. While increasing the stirring speed from 400 rpm to 600 rpm only increased the concentration of reducing sugar up to 1.5 times, and increasing the amount of enzyme added four times only gave 1.24 times higher yield (Fadilah et al., 2015).

ELEPHANT FOOT YAM (AMORPHOPHALLUS PAEONIIFOLIUS)

Elephant foot yam (suweg) contains 69% starch as one of the macro components. Granule size, retrogradation, texture, swelling power, and solubility are the functional properties studied in elephant foot yam starch. Natural native starch is a small granule insoluble in water at room temperature. Elephant foot yam starch granules have a glossy white color, odorless and tasteless, with round, elliptical, and polygonal shapes with smooth surfaces. However, it will deteriorate after cooking, debranching, or drying (Reddy et al., 2014).

The size distribution of starch granules will affect the swelling power. Small starch granule size has small swelling power. The swelling power of the native elephant foot yam starch at 85°C was 8.14%. The modification of elephant foot yam starch can affect its swelling power. The retrogradation enzyme hydrolyzed elephant foot yam starch at the same temperature and showed a swelling power of 5.6%. While the retrogradation enzyme hydrolyzed elephant foot yam starch was 5.4% (Reddy et al., 2014). The difference in swelling power value after treatment confirms a change in magnitude of interactions between starch chains in crystalline and amorphous regions. Swelling power measures the ductility (capacity to resist deformation) of bonds in crystalline parts of starch granules, indicating starch's palatability to cook. Granules with larger crystalline areas will have stronger bonds, swelling slightly in cold water and under heat. Gels formed from crystalline areas are weak and tend to reverse due to these bonds. Molecular weight distribution, degree of debranching, branch length, molecular conformational size, and amylose: amylopectin ratio play an essential role in the interaction of water and starch (Reddy et al., 2014). Table 4

Table 4. Physicochemical properties of Elephant foot yam starch retrograded enzyme hydrolyzed native starch and retrograded enzyme hydrolyzed gelatinized starch

Parameter	Elephant foot yam starch	The retrograded enzyme hydrolyzed native starch	Retrograded enzyme hydrolyzed gelatinized starch
Amylose (%)	24.21 ± 0.983^{c}	46.78 ± 1.454^{b}	50.18 ± 1.171^{a}
RS (%)	17.98 ± 0.382^{c}	30.67 ± 1.632^{b}	36.27 ± 1.167^{a}
SP (%)	8.14 ± 0.201^{a}	5.67 ± 0.108^{b}	5.48 ± 0.168^{b}
WAC (%)	3.59 ± 0.176^{c}	5.46 ± 0.415^{a}	6.04 ± 0.185^{a}
WSI (%)	2.57 ± 0.110^{b}	12.06 ± 1.010^{a}	13.89 ± 1.249^{a}
RC (%)	19.37 ± 0.633^{c}	25.12 ± 0.949^{b}	27.84 ± 1.201^{a}

RS, resistant starch; SP, swelling power; WAC, water absorption capacity; WSI, water solubility index; RC, relative crystallinity. All data were means of triplicates. Values with the same superscripts in a row did not differ significantly ($P < 0.05$) by DMRT.

Source: (Reddy et al., 2014)

shows the amylose composition, resistant starch, swelling power, water absorption capacity, water solubility index, and relative crystallinity of elephant foot yam starch.

The starch modifications, retrogradation, and enzyme hydrolysis in native starch affect the texture of elephant foot yam starch. Elephant foot yam starch paste, which was incubated for 24 hours at 4°C, will be retrograded and analyzed using a texture profile analyzer. The data obtained are presented in Table 5. Native elephant foot yam starch showed significantly higher viscosity and hardness values than retrograded enzyme hydrolyzed native starch and retrograde enzyme hydrolyzed gelatinized starch. It could be because native elephant foot yam starch has a larger starch granule size and a lower amount of amylose. Due to partial hydrolysis of starch granules and granule destruction, hardness and gelling ability decreased in hydrolyzed native starch. They retrograded enzyme hydrolyzed gelatinized starch samples due to partial hydrolysis of starch granules and granule destruction enzymatic hydrolysis and autoclaving process. The results showed significant differences in texture between all samples, including hardness, cohesiveness, adhesiveness, gumminess, springiness, chewiness, and stringiness. The rigidity influenced textural properties, amylose content, and interaction between dispersed and continuous phases. It, in turn, depended on the structure of amylose and amylopectin (C. K. Reddy et al., 2014). The enzymatic hydrolysis of elephant foot yam starch using a mixture of alpha-amylase and glucoamylase enzymes can reduce heat requirements in the conventional hydrolysis process (Hargono et al., 2019).

Elephant foot yam starch treated by modified heat moisture treatment (HMT) using various heating sources, including hot air oven (HAO), microwave (MW), and

Table 5. Textural properties of elephant foot yam starch: hardness, cohesiveness, adhesiveness, gumminess, springiness, chewiness, and stringiness

Parameter	Elephant foot yam starch	The retrograded enzyme hydrolyzed native starch	The retrograded enzyme hydrolyzed gelatinized starch
Hardness (N)	0.506 ± 0.051^a	0.113 ± 0.005^b	0.093 ± 0.005^b
Cohesiveness	0.323 ± 0.041^b	0.523 ± 0.035^a	0.536 ± 0.025^a
Adhesiveness (Ns)	-13.04 ± 0.632^b	-3.963 ± 0.241^a	-4.04 ± 0.07^a
Gumminess (N)	0.17 ± 0.01^a	0.046 ± 0.011^b	0.046 ± 0.005^b
Springiness (s)	1.14 ± 0.026^a	0.876 ± 0.096^b	0.903 ± 0.06^b
Chewiness (Ns)	0.127 ± 0.092^a	0.04 ± 0.01^a	0.0366 ± 0.005^a
Stringiness	5.973 ± 0.935^a	6.17 ± 0.238^a	5.476 ± 0.434^a

All data were means of triplicates. Values with the same superscripts in a row did not differ significantly ($P < 0.05$) by DMRT.

Source: (Reddy et al., 2014)

autoclave (AL), showed changes in starch characteristics. Microwave and autoclave modifications showed similar effects on swelling power, solubility, and volume. The hot air oven provides more effective results than other heating methods. It had been explained previously that amylose content and short-range molecular order strongly influenced swelling power and solubility. However, swelling volume did not have a significant relationship with other parameters. However, this study also showed that the solubility facilitated the increase of rapidly digestible starch (RDS) components in elephant foot yam. In addition, the modified elephant foot yam starch with a hot air oven also had the lowest glycemic index value, making it suitable for use as an ingredient in diabetes-friendly products (Barua et al., 2021).

FUTURE RESEARCH DIRECTIONS

Starch modification can be explored to provide further information on improving its natural characteristics.

The modification process can develop specific physicochemical characteristics, improving the application of modified starch into food products. Further research is also needed on the effect of modified starch on human health after its application in food products.

CONCLUSION

One of the essential properties in rice evaluation starch are gelatinization characteristics. This attribute is also the most crucial rheological indicator in corn and cassava starch. Meanwhile, amylose-amylopectin composition and structure also affect starch characteristics. The swelling power of taro starch will increase with the degree of starch, as indicated by the increase in Water Absorption Capacity. Arrowroot starch has low swelling power and solubility index, which will increase when the temperature is above 50°C and be stable at 70°C. The properties of sago starch are affected by the drying process, using the cross-flow fluidized bed model can reduce the swelling power of starch but increases its solubility compared to conventional drying. Modification of konjac starch through a combination of pre-gelatinization and cross-linking showed positive effects on flowability and viscosity. Starch modification through retrogradation and enzyme hydrolysis of elephant foot yam starch significantly increased the amylose content, resistant starch, water absorption, water solubility index, relative crystallinity, cohesiveness, and adhesion. However, it significantly decreased swelling strength and hardness.

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KEY TERMS AND DEFINITIONS

Amylopectin: A polymer of alpha-glucose units and linked linearly with α-l,4 glycosidic linkages, as well as α-l,6 glycosidic linkages occurring at intervals of 24 to 30 glucose subunits.

Amylose: A straight linear chain of glucose molecules linked by α-l,4 glycosidic linkages.

Gelatinization: A process of breaking down the intermolecular bonds of starch molecules in the presence of water and heat, allowing the hydrogen bonding sites to engage more water.

Pregelatinized: Physical modification of starches which are accomplished by heating and by mechanical shearing resulting in cold-water-swelling capacity.

Retrogradation: A process in which disaggregated amylose and amylopectin chains in a gelatinized starch paste reassociate to form more ordered structures.

Solubility: The ability of a substance, the solute, to form a solution with another substance, the solvent.

Starch: A carbohydrate polymer consisting of two types of polysaccharides: amylose and amylopectin

Starch viscosity: The thickness, or resistance to shear, agitation or flow of starch. Measuring the viscosity of starches gives a direct assessment of their processability in terms of pumping and mixing.

Swelling power: The ability of starch granule to inflate due to weakened hydrogen bond during the heating process causes water hydration.

Chapter 5
Animal-Based Fermented Foods in Tropical Countries: Functional Aspects and Benefits

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ABSTRACT

Tropical countries are rich in fermented animal foods, such as meat paste, shrimp paste, ronto, dadih, Nem chua, and chin som mok. The salt addition (2.4-3.0%) and carbon sources resulted in fermentation process at room temperature in tropical countries. The abundance of Salinococcus spp. during dough preparation and Lentibacillus spp. during fermentation contributes to the distinctive taste and umami of the shrimp paste. Lactic acid bacteria isolated from fermented animal foods have the potential as probiotics. Probiotics can play a role in increasing antioxidant activity and antimicrobial properties. Corynebacterium sp, Bacillus subtilis, and Lactobacillus plantarum were designated as functional starter cultures that could inhibit the growth of pathogenic bacteria (Staphylococcus aureus, Salmonella sp. and Escherichia coli). Animal based fermented foods in tropical countries are very diverse and have functional properties for health, related to antioxidant, probiotic, and antimicrobial properties.

DOI: 10.4018/978-1-6684-5629-3.ch005

INTRODUCTION

Currently, a healthy lifestyle is becoming a trend in the world community. Therefore, the existence of fermented foods is needed. The fermented foods and their modifications continue to grow. In tropical countries, traditional fermented foods are very varied, both plant-based and animal-based fermented foods. Most fermented animal-based foods are sourced from livestock meat and seafood. Some examples of fermented animal foods that are well known in tropical countries are meat paste (*Petis*), shrimp paste, *Ronto*, *Cincalok*, *Dadih* (Indonesia), *Nem Chua* (Vietnam), and *Chin Som Mok* (Thailand). Indonesia is a maritime country with two-thirds of its territory consisting of water. As a maritime country, Indonesia has enormous fishery potential. Indonesia's marine fisheries potential is 6.4 million tons annually, with an average production of 4.88 million tons annually (76.3%) (Rinto, 2018). This paper aims to describe various examples of animal-based fermented foods that are developed in tropical countries, their fermentation technique, and their functional properties and benefits for health and product quality.

BACKGROUND

This chapter describes various types of fermented animal food from tropical countries, which are sourced from livestock, fish, and other marine products. The themes presented in this chapter include the types and names of fermented foods, fermentation techniques, and their functional properties. Functional properties include the benefits for health when the food is consumed or benefits for the product development, specifically on flavor and sensory characteristics of the product.

The diversity of processed products contributes to the culinary richness of tropical countries, the majority of which are developing countries. This processed product is also an original ethnic food in tropical countries. Knowledge of the product contributes to food sustainability and serves as a consideration for the authorities in food policy. Therefore, the theme of this chapter is closely related to the theme of the proposed book, namely Food Sustainability, Environmental Awareness, and Adaptation and Mitigation Strategies for Developing Countries.

FERMENTED MEAT (PETIS)

Meat fermentation is quite popular so far, this product is a product of microbial activity in meat-based media that produces distinctive aroma or flavor characteristics. In America, it is known as pepperoni, which is a fermented sausage for pizza, which is the manufacturing process at the time of mixing raw materials at a temperature of 2-3°C, while the fermentation process is at a temperature of 20-28°C. In Europe, it is known fermentation of meat sausages derived from beef, pork, or poultry, the manufacture of which there is one with dry or semi-dry fermentation.

Types of Fermented Meat

In Indonesia there is a fermentation called *Petis* as fermented meat, this product is in the form of a sweet, salty, or sweet-salty taste pasta (according to taste) with the addition of salt, sugar, and spices or spices. Petis products are usually used as seasonings or flavorings, as a complement to food or raw materials for chili sauce, and also as side dishes. The way it is made is that the meat is finely ground and then salted as much as 15 – 20% (w/w), then cooling is carried out at a temperature of 40 °C for 6 hours. After that fermentation takes place spontaneously at room temperature for 48 hours. After fermentation is separated between solids and liquids, it is this liquid that is then added with spices and flavors (salty, sweet, or salty-sweet) and thickened with starch flour by heating at a temperature of 70–80 °C for some time until cooked (Anonym, personal communication, 2004).

Based on the fermentation process and the types of meat fermentation products that exist today, they are divided into 3 parts namely dry fermentation, semi-dry fermentation, and fermentation without drying.

Dry fermentation is characterized by Aw ranging from 0.82 – 0.86 and a final pH of less than 5.3. In this fermentation, dehydration occurs so that the water content becomes about 20 – 30% (w/w), usually, if the fermentation takes place both the bioamines formed are less than fermentation without any addition. In this dry fermentation, there must be the addition of salt, the content of which varies depending on the taste of the maker. Other ingredients added are sugar (some are without the addition of sugar), spices, and some are given nitrite or nitrate to maintain the color to make it more attractive. In the drying process, some use fumigation or without fumigation, and there is a ripening process with molds or maturation without molds. The duration of the fermentation process has three variations in time, namely short fermentation between 1-4 weeks, medium fermentation between 12 – 14 weeks, and long fermentation, which is more than 4 months. This long process depends on the magnitude of the fermented material (meat), the larger the material it takes the longest. For fermentation temperature depends on the process and duration of fermentation carried out, in a short fermentation process without fumigation the temperature is less than 15 °C, while those without fumigation range from 15-26 °C. In the medium-time fermentation process without fumigation, the fermentation temperature ranges from 20 – 25 °C, while in fermentation with fumigation between 32 – 38 °C, the fermentation process takes a long time the temperature is maintained at 25 °C. In dry fermentation this usually has physical properties that can be cut before consumption (sliceable), examples of products that often exist are *Salamis* (Germany, Denmark, and Hungary), *Genoa* (Italy), *Chorizo* (Spain), Summer Sausage (USA), *Thuringer* (Germany), *Sausion Sec* (France), *Thai Nam* (Thailand), and large-shaped ones such as whole meat cured ham (Hammes et al., 2003).

Semi-dry fermentation is characterized by Aw ranging from 0.92 – 0.94 and the pH at the end of fermentation is less than or equal to 0.53. In this semi-dry fermentation, dehydration also occurs but the water content is more than that of the dry system, which is around 40% (w/w). Just like dry fermentation in semi-dry fermentation, the bioamine content will also decrease if the fermentation takes place properly when compared to the fermentation process without any additives. As in dry fermentation the temperature and duration of fermentation depend on the fermentation system carried out, but in this semi-dry fermentation, there are three divisions of time, namely short, medium, and long fermentation. At short fermentations between 1 – 4 weeks, the fermentation temperature is less than 15 °C in the process by fumigation, while the one with fumigation ranges from 15 – 26 °C. The fermentation process is medium in time between 12 – 14 weeks, with a temperature of 20 – 25 °C in fermentation without fumigation, while those with fumigation range from 32 – 38 °C. For a long fermentation time usually months (more than 4 months) at a temperature of 25 °C, the fermentation time depends on the magnitude of the fermented meat. In this semi-dry fermentation, the same as other fermentations of meat, there is always the addition of salt, due to its properties that can serve as an agent for microbiota selection during fermentation. In this process, there is also the addition of spices, sugar (without sugar), and nitrites or nitrates which function to maintain the color to remain attractive, in addition to being a preservative. Examples of products are the same as those with dry fermentation at short fermentation times, namely summer sausage (US) and *Thuringer* (Germany), while for medium fermentation *Salamis, Genoa, Saucision,* and *Chorizo*. An example of a longtime process is cured ham whose basic ingredients can be beef or pork (Hammes et al., 2003).

Fermentation without drying is characterized by high water content and very minimal dehydration occurs, the water content ranges from 34 – 42% (w/w), with Aw between 0.95-0.96, and the pH at the end of fermentation is less than 0.5. The fermentation time is very short only 2 – 4 days with a fermentation temperature of less than 25 °C, in the process without maturation with molds as well as physical properties can be smeared or flattened (spreadable). Examples of products that are already known in Europe are *Streech Mectwurst* (Germany), *Sobrada* (Spain), and *Petis* (Indonesia) (Pramono, et al, 2009)

Lactic Acid Bacteria as a Functional Starter Culture in Meat Fermentation

The use of functional starter culture in the fermented food industry is currently being developed (De Vuyst, 2000). The term functional starter culture is a starter that has several functional properties when used. The functional properties in question can play a role in increasing product safety and or improving organoleptic properties, technology, nutritional aspects, or health-added value. The application of this functional culture starter must show these functional properties but can maintain the natural properties of the product, as well as its health aspects (De Vuyst and Leroy, 2004).

Fermentation of meat has a purpose (1) to increase product safety through the inactivation of pathogenic bacteria, (2) to increase product stability, namely being able to extend shelf life and inhibit putrefactive bacteria, (3) product diversification; and (4) to improve functional properties (Lucke, 2000). One of the functional starter cultures in meat fermentation is lactic acid bacteria that can improve nutritional aspects, namely increasing bioactive peptides and suppressing bioamine production. Meanwhile, from the aspect of food safety, it can produce components that can play a role in extending storage. For the functional properties of organoleptic, that is, it plays a role in suppressing the formation of "off-flavor" (De Vuyst and Leroy, 2004).

In spontaneous fermentation of meat, there is a very large variation of the microbiota, resulting in a very high variety of quality, resulting in unstable quality. On the other hand, the modern fermented meat industry requires high and stable product quality, minimal risk of quality variation, and the sensory characteristics of the product are getting better, this cannot be met by spontaneous fermentation. For this reason, it is necessary to develop the potential for controlled fermentation of meat with starter cultures whose properties are known.

The research that Santos et al. (2001) carried out showed fermentation of pork sarcoplasmic muscle protein with starter yeast *Debaryomyces hansenii* CECT 12487 isolated from sausages could increase the amount of carnosine. Fermentation was carried out with a salt content of 0.5% (w/w) at pH 6.5 with a temperature of 27 °C for 4 days there was an increase in the amount of carnosine 28.54 g/500 L of extract. This shows the potential for the use of fermentation to increase the amount of carnosine in meat-based media.

Jae-Young et al. (2005) conducted a study on the spontaneous fermentation of oyster sauce at a temperature of 25 °C with a salt content of 25% (w/w), and there was an increase of 18.7% in the amount of carnosine for 4 months. In this study, there was no mention of the type of microbe that played a role in the amount of quantitative increase, but it was suspected to be a halophilic lactic acid bacterium that played a role in increasing the amount of carnosine because it was able to survive at high salt conditions (25%).

Fermentation of the koji system in mackerel fish was performed by Yin (2005) using *Aspergillus oryzae* BRCC 30118 and *Aspergillus sojae* BRCC 30103 with 0.5% NaCl at a temperature of 25 °C for 4 days. Fermentation conditions are carried out with a combination of 50% chopped mackerel (mince), 3% rice flour, as well as 47% water. The fermentation results showed that there was a 10-fold increase in the amount of carnosine which from the beginning was not detected to 10.08 mg/100g with the starter *Aspergillus oryzae* BRCC 30118, while in fermentation with starter *Aspergillus sojae* BRCC 30103 there was an increase in the amount of carnosine by 9.74 times from the beginning also undetected to 9.74 mg/100g.

The increase in the number of carnosine also occurred in a study conducted by Yin et al. (2005) on mackerel-based fermentation. Fermentation is carried out by combining with proteases from *Aspergillus oryzae* which are then fermented with *Pediococcus pentasaceus* type S and L. In the fermentation of *Pediococcus pentasaceus* type S, carnosine was increased by 17 times from the initial amount of only 8.33 mg/100g to 140.91 mg/100g, while in the combined fermentation of type S and L, carnosine was increased by 25x from the beginning of 8.33 mg/100g to 206.19 mg/100g. Utilization of lactic acid bacterial fermentation can increase the amount of carnosine as a bioactive peptide beneficial to health.

The results of research by Pramono, et al., (2009) showed that isolates of *Pediocoocus acidilacticii* YDA3 and *Pediococcus pentosus* YDA4 can be used as starter cultures for fermentation of petis liquid because they can improve quality and maintain stability, maintain product safety, and have the potential to improve the functional properties of *Petis*.

The ability of the two isolates to improve quality and maintain stability because it can suppress the growth of putrefactive bacteria and suppress the formation of "off-flavor" component indicators, namely TVN (total volatile based-nitrogen) and TMA (trimethyls amin), maintaining guaranteed product safety because they can suppress the growth of pathogenic bacteria and histamine-producing bacteria, as well as playing a role in increasing the amount of carnosine so that it has the potential to improve the functional properties of the *Petis* produced.

NEM CHUA

Nem Chua is a processed pork product originating from Vietnam which is fermented for 2 to 4 days at room temperature. *Nem Chua* is a meat paste shaped into cubes, topped with sliced onions, and wrapped in banana leaves and *Psidium guajava*. Packaging aims to create anaerobic fermentation conditions and prevent contamination from pathogenic microbes. *Nem Chua* is usually homemade, in rural Vietnam. The shelf life at room temperature is 5 days, while at refrigerator temperature it is up to a month. *Nem Chua* fermented products produce lactic acid bacteria (LAB) isolates, including the genus *Lactobacillus*, *Coccus*, *Kocuria spp*, and *Staphylococcus*. These lactic acid bacteria are useful in producing antimicrobial compounds and bioactive components. These antimicrobial compounds will inhibit the growth of spoilage microorganisms and pathogens. In addition, lactic acid bacteria also contribute to the development of the unique and distinctive sensory characteristics of *Nem Chua* (Nguyen et al., 2013).

Staphylococcus and *Kocuria spp* play a role in the development of the color and taste of *Nem Chua*. This is due to the degradation of free amino acids during the fermentation process and inhibition of the oxidation of unsaturated free fatty acids.

FERMENTED PRODUCTS BASED ON FISH

Fish contain high water content ranging from 70-80%. Fish also contains food components in carbohydrates, proteins, fats, and minerals. The high water content and composition of the fish cause the fish to experience a deterioration in quality (perishable foods) easily. Protein is the largest component after water found in fish. In addition, the high water content in fish and the nutritional components of fish cause fish to be easily damaged by microbial activity. As a result, numerous attempts were undertaken to handle and treat fish to increase their shelf life. Efforts to extend the shelf life of fish have been carried out both traditional and modern. Several attempts to extend the shelf life of fish include drying, salting, and fermentation.

Fermentation can be done spontaneously or by adding a certain microbial starter. Microbes that play a role in fish fermentation are lactic acid bacteria. Fermentation breaks down complex organic compounds such as carbohydrates, proteins, and fats into simpler forms without oxygen (anaerobic). Fishery fermented products are spread all over the territory of Indonesia, with different characteristics in each region. The fermentation process aims to extend the shelf life while at the same time producing a product with a different taste from the raw material. As a result, fermented products tend to have a more sour taste.

Various fermentation techniques are applied to various types of fish to produce the characteristics of fermented products. Types of fish and different fermentation processes in each region such as Wood Fish (Aceh), *Bisasam* (South Sumatra), *Budu* (West Sumatra), *Naniura* (North Sumatra), *Cincalok* (Riau), *Rusip* (Bangka Belitung), Picungan (Banten), Terasi, Peda (Java), Wadi (Kalimantan), and Bekasang and *Tembalo* (Sulawesi) produce different fermented products. Therefore, the fresher or better quality of the fish used to make fermented products, the better the quality.

Budu

Budu is made from mackerel, but other fish types can also be used. Huge sea fish with white flesh, such as Talang-Talang Fish (*Chorinemus tala*), Mackerel (*Scomberomorus guttatus*), and other types of fish are used. *Budu* fish products are named after the type of fish used such as *Talang budu* fish, *Tenggiri budu* fish, or other *Budu* fish. The purpose of hanging this fish is to allow the blood from fresh fish to drop, lowering the fish's liquid weight. Mackerel used as a preserved product of *Budu* fish must meet several criteria. Mackerel, for instance, cannot be used if it has been mixed with ice if the *Tenggiri* fish has been cooled down with ice.

The process of making *Budu* fish in the community has traditionally been unregulated since the amount of salt and spices utilized varies. Equally, the place and conditions used during the manufacturing process vary based on the habits of each fish processor. According to Marrysa Derec, (2022) the process of making *Budu* fish is as follows:

1. Cleaning The mackerel is cleaned from head to tail. Because putrefactive bacteria in fish are mostly found in the digestive tract, specifically the stomach and gills, cleaning the fish's stomach is intended.
2. Hanging. The hanging process is carried out for 24 hours until the fish meat is swelling. The purpose of hanging is so that the fish's blood goes down until it disappears. If the blood is still present in the fish, it will cause itching for consumers who have eaten fish when it has become a culinary product. The time in hanging this fish must be considered because the fish should not go through the swelling; eventually, the meat will not stick together or break. On the other hand, dividing the fish flesh will be difficult if the fish is less than optimal inflating. The resulting product will not be as expected because the organoleptic value is not good.
3. Fish meat cleavage. The purpose of cleaving the fish meat is to remove all of the bones from the fish. By removing all types of bones found in fish, boneless fish is produced, resulting in only pure fish meat in *Budu* fish products.
4. Giving salt to the fish that has been evenly split. There are several specialized techniques for applying salt to salt. The first aspect is the composition of the salt given to the fish. If the *Budu* fish makers are familiar with or competent in determining the level of salt to be given, this salt will usually produce an optimal product. Aside from that, the size of the fish used for processed products influences the salt composition used during salting. The second consideration is the type of salt used. Sand salt is the type of salt used. Sand salt has been mashed and dried in such a way that it is in the form of sand.

5. Seasoning. The provision of cooking spices on processed products of *Budu* fish depends on the expertise of the local community. Each community has its secret in giving seasoning to *Budu* fish. Some people provide seasonings such as Ajinomoto to add to the taste. After giving the Ajinomoto, it is combined with the addition of a little sugar so that the salty taste of the salt is not too prominent in the *Budu* fish products.
6. Incubation (fermentation). Incubation of fish products takes time, depending on the fermented fish's size. In general, if the size of the fish used is large and thick, incubation is carried out for 3 hours. On the contrary, if the size is small and thin, the time required only reaches 1 hour. The purpose of incubating fish is so that the salt that has been given can dissolve and spread to all parts of the fish meat, and the salty taste of fish products can be achieved. In addition, salting also aims to make the resulting product more durable and durable due to a microbiological process in *Budu* fish products, where salt will inhibit the growth of spoilage microbes and pathogens in fish.
7. Cleaning II. Cleaning the fish from the remaining salt left on the surface of the fish meat during fermentation. Increase the organoleptic value of the resulting product, where the fish will look clean like fish products without salt.
8. Drying fish. Drying fish aims to make fish products dry, free from the water content contained in the product during fermentation. Apart from that, drying also aims to make the fish meat and fish together. Drying is also related to the shape of the product to be produced. The time required for drying depends on the quality of the existing sun. Optical drying generally takes 48 hours according to the sun's state at the drying time.

The use of sufficient salt (certain concentration) aims to absorb the glucose liquid contained in the fish and inhibit the growth of unwanted bacteria. Appropriate temperature settings must also be considered during fermentation to maintain the viability of lactic acid bacteria.

The aroma of *Budu* is produced by methyl ketone, butyraldehyde, ammonia, amino, and compounds other anonymous compounds due to fat oxidation. Even though fat oxidation can cause rancidity, if the process is not too continuous, it will produce a distinctive aroma that consumers prefer.

Lactic acid fermentation is the process used in *Budu* fish production. According to Susalam et al. (2022), lactic acid bacteria isolated from *Budu* fish have the potential as probiotics. Lactic acid bacteria are the dominant bacteria in the fermentation process, which occurs spontaneously. Microorganisms release a variety of metabolites during fermentation, including protease, which hydrolyzes the proteinaceous raw materials. Some manufacturers cook the resulting sauce at the end of the fermentation period, while others do not (Ilyanie et al., 2022).

Maslami et al. (2018) found that lactic acid bacteria isolated from *Budu* can produce glutamic acid, improving broiler carcasses' quality by increasing broiler meat's color and aroma. Aisman et al. (2019) added that lactic acid bacteria from *Budu* can produce gamma amino butyric acid (gaba), which can reduce the effect of stress on broilers with high cage densities. Liasi et al. (2009) asked lactic acid bacteria isolated from *Budu* fish in the form of *Lactobacillus* (*Lactobacillus casei* LA17, *Lactobacillus plantarum* LA22, and *L. paracasei* LA02), and the highest population was *Lactobacillus paracasei* LA02. The lactic acid bacteria showed antimicrobial activity. *Lactobacillus plantarum* and one strain of *Streptococcus faecalis* are also lactic acid bacteria isolated from *Budu* fish. These lactic acid bacteria have the potential to produce lactate which is a group of antibiotics that act as antimicrobials (Ohhira, 1990). *L. plantarum* and *L. paracasei* are potential probiotic lactic acid bacteria isolated from *Budu* (Ilyanie et al., 2022).

The well method can evaluate the *Budu* lactic acid bacteria's ability to fight against microbes. The isolates were grown in MRS broth at 37 °C and centrifuged at 12,000 x g for 10 minutes at 4 °C to create cell-free culture supernatants for antibacterial tests. The antimicrobial activity of the cell-free culture supernatant was determined using agar.'s well diffusion assay. Aliquots of supernatants (100 L) were placed in wells (6 mm diameter) cut in cooled soft nutrient agar plates (25 mL) that had been seeded with the appropriate indicator strains (1 percent v/v). The diameters of the growth inhibition zones were measured after 24 hours. The agar-well diffusion assay was used to determine the inhibitory spectrum of *Lactobacilli* isolates. The plates were incubated in an optimum condition for the growth of the target microorganism. After 24 hours, the growth inhibition zones' widths were assessed. To ascertain the inhibitory spectrum of *Lactobacill*i isolates, the agar-well diffusion experiment was utilized.

Lactic acid bacteria isolated from *Budu* fish showed antibiotic resistance, according to Liasi et al. (2009). According to Liasi et al. (2009) lactic acid bacteria isolated from *budu* fish were resistant to aminoglycoside antibiotics (amikacin, kanneomycin, neomycin, and streptomycin). In addition, lactic acid bacteria are also resistant to gram-negative spectrum antibiotics (nalidixic acid). Resistance to these antibiotics is usually intrinsic, so the genes are not transferred to pathogenic or bacterial flora.

Marlida et al. (2021) stated that microorganisms such as yeast *Saccharomyces cerevisiae* were also found in *Budu* fermentation. Another use for yeast is as a probiotic is known. Using universal yeast agar, which contains 3.0 g.L.-1 of malt extract, 3.0 g.L.-1 of yeast extract, 10.0 g.L.-1 of glucose, 5.0 g.L.-1 of peptone, and 15.0 g.L.-1 of agar, it was possible to isolate the yeast from *Budu*. Following procedures were used to isolate the *Budu* yeast.; the *Budu* (1 g) was added to 9 mL of 0.9% NaCl (saline) solution and mixed thoroughly for 60 s. Serial dilution was then carried out in saline solution and spread plated onto universal yeast agar. The yeast universal agar was composed of 3.0 g.L-1 malt extract, 3.0 g.L-1 yeast extract, 10.0 g.L-1 glucose, 5.0 g.L-1 peptone, and 15.0 g.L-1 agar. The spread-plated yeast universal agar was incubated for 72 h at 28 °C. Presumptive yeast showed white-to-yellow colonies under the microscope. Such isolates were randomly selected and further purified on yeast universal agar. Yeasts showing the typical appearance of *Saccharomyces* (white-to-yellow colonies) were selected. The selected yeast strains were purified by successive streaking on the universal media. Three isolates were maintained at -80 °C in 20% (v/v) glycerol (Hi-Media) (Marlida et al., 2021).

Naniura

Naniura is a fermented fish product from North Sumatra and one of the typical foods of the Toba Batak tribe. *Naniura* is a traditional food that is different from other traditional foods. The difference between *Naniura* and other fermented fish products is that if other foods have a cooking process, either boiled, steamed, fried, or baked, *Naniura* does not go through a cooking process.

Naniura is made using carp (*Cyprinus carpico*) based on the fermentation process, namely the use of microorganisms in food processing. This food is served at major ceremonies such as weddings and funerals. But some make it at gatherings, birthday celebrations, and other family events. *Naniura* is a fermented food product that uses microorganisms in food processing.

Naniura is served without going through cooking using fire, but only with the addition of the prepared spices and *asam jungga* until it becomes soft. Soaked asam jungga (*Citrus jambhiri*) can make raw fish less fishy and tough like raw fish (Silalahi, 2006). The type of acid used to make *Naniura* is *jeruk jungga* (*Citrus jambhiri*).

The Batak people generally make goldfish *Naniura*, using three pieces of asam jungga in 1 kg of carp. Several other types of acids that can be used as alternative acids are *jeruk nipis, jeruk kasturi*, and *jeruk purut*. Because the price of *asam jungga* is also relatively high and difficult to find on the market. The acidic conditions in *Naniura* allow the growth and development of acid-fast bacteria that can prevent the development of spoilage microbes.

Jeruk jungga or some call it *unte jungga* has a shape similar to *jeruk purut*, and tastes almost the same as lime (*jeruk nipis*). The aroma of oranges is also more fragrant than lime. The Batak tribe uses *jeruk jungga* in *Naniura* cuisine because of the high acidity by applying the juice of jungga jungga to fresh carp or *mujair* and allowing them to ripen (Febrian et al., 2016). The dominant acid in orange juice is citric acid, with a pH of 2.2 - 2.5, which can inhibit growth or kill bacteria by damaging bacterial cells to reduce microbial growth, especially pathogenic microbes.

The addition of orange juice in the manufacture of *Naniura* aims to reduce fish's pH value and microbial growth so that *Naniura* is safe for consumption. A low pH in food (<4.5) can inhibit the growth of pathogens so that food can be stored longer than food with a neutral pH (Aloysius et al., 2019).

The length of the soaking process is one of the crucial factors in making *Naniura*. The immersion time is related to the penetration time of the acid into the fresh carp. Soaking fish in acid can affect the nutritional components of carp as the main raw material in the manufacture of *Naniura*. During immersion, there will also be physical changes in goldfish color, aroma, taste, and texture. In addition, ceding carp into *Naniura* fish can inhibit and kill pathogenic bacteria that cannot survive (Haro, 2019).

According to Haro (2019), the manufacture of *Naniura* is done by first preparing the essential ingredients and spices. Then, the carp is washed, scaled, cut in half wide, and removed from the entrails and gills. The carp is washed with cold boiled water and then drained until the water no longer drips. Oranges are also cleaned, cut in half crosswise, squeezed with an orange squeezer, and filtered, and the juice is taken. The spices used to make *Naniura* are shallots, garlic, ginger, *kencur* (*Kaempferia galanga*), and turmeric. Shallots, garlic, and candlenuts are roasted separately until the aroma is fragrant, then mashed. Ginger, *kencur*, and turmeric are grated and squeezed to get the juice. Next, cayenne pepper and *andaliman* are blended. After being steamed, *rias* is mashed. Except for cosmetics and candlenuts, all spices are evenly combined and stirred.

The drained fish is placed in a container and then doused with tamarind juice in a ratio of 1g of jungga acid juice to 1.8 g of carp meat, and 3% salt is added. The fish was soaked for 7 hours. Then, the fish is added with all the spices and allowed to stand for 1 hour after adding the spices. The immersion of fish is done in a container that is not tightly closed. Fish meat soaked in orange juice or acid has a pH of up to 4, most likely not to be overgrown by bacteria, so the fish is safe for consumption (Febrian et al., 2016). *Naniura* is usually consumed without going through the cooking process after fermenting raw carp-based ingredients for 3 hours.

The processing of carp *Naniura* occurs by acids which can cause changes in protein structure with specifications for the color of the fish flesh to be pale white, and myotomes are visible. Myotomes that are visible indicate the presence of protein decomposition due to enzymatic processes that cause changes in texture and appearance of fish and affect pH. The hydrolysis of fish meat protein occurs because the acid causes fish to be consumed without cooking (Indah Turnip, 2017). Febrian et al. (2016) stated that the total microbes of the goldfish *Naniura* will decrease during the immersion time due to the more organic acids from the orange juice penetrating the fish meat tissue as the soaking time increases.

Aloysius et al. (2019) showed that *Naniura* contains lactic acid bacteria with probiotic potential and inhibits pathogens *S. aureus*, *E. coli*, and *S. typhi*. However, the concentration of acid is also different and the length of stay on the total bacterial colonies in the manufacture of carp *Naniura*, resulting in the total bacterial colonies decreasing and maintaining the life of *Lactobacillus sp* while the *Streptococcus sp* bacteria will die (Pasaribu et al. 2015). Total microbes of fresh carp used in the manufacture of carp *Naniura* were 5.5563 log CFU/g. The results of the research by Febrian et al. (2016) stated that the total microbes of goldfish *Naniura* up to 6 hours of immersion still met the requirements of SNI. Based on SNI 01-2779.1-2006, it is indicated that the total plate number in fresh fish is a maximum of 5 x 10^5 colonies/g or 5.6990 log CFU/g (BSN, 2006).

The longer the immersion time, the lower the protein content of the *Naniura* carp. Due to the ability of the acid to penetrate the carp meat, the free water contained in the fish meat is pushed out, and the amount of acid that enters the fish meat increases as the length of immersion of fish meat in acid and spices *Naniura* (Febrian et al., 2016). The acid in fish meat will denature protein which can cause coagulation and release water so that water in fish meat will decrease. The decrease in protein content of carp *Naniura* is influenced by the pH of carp *Naniura*, which decreases along with the longer immersion time. Acidic conditions can accelerate the breakdown of protein into short-chain peptide groups or amino acids easily soluble in water, causing the protein content of the material to decrease (Febrian et al., 2016).

All the lactic acid bacteria isolates had inhibition activity against the α-glucosidase enzyme. The enzyme has the role of degrading polysaccharides into monosaccharides. Thus inhibition makes the isolates can be an alternative way of treating type 2 diabetes. Furthermore, the exopolysaccharide produced by the lactic acid bacteria protects the lactic acid bacteria from hard conditions such as dehydration and acidity, even bile acid.

Bekasam

Bekasam is a traditional fermented fish that tastes sour and is widely known in various parts of Indonesia, especially in South Sumatra (Rusmana, Suwanto, and Mubarik, 2012; Rinto et al., 2015). In addition, *Bekasam* is a source of animal protein, so it has the potential to be used as food that is suitable for consumption by the people of Indonesia. *Bekasam* has other names that are different in some areas, including Pedas, Bekasang, Peda, and Wadi.

Bekasam is generally made from fresh or brackish water fish such as catfish, snakehead fish, tilapia, carp, wader fish, and mujair. The process of making *Bekasam* is still done traditionally by applying spontaneous fermentation. *Bekasam* is made by fermenting fish using high salt content with the addition of rice as a carbohydrate source with a specific ratio and fermenting for 5-7 days. The addition of salt generally ranges from 15-20% of the weight of fresh fish. There is no standard process for making excavate, so each region has its process stages.

In principle, the process of making *Bekasam* is carried out in 3 stages, namely; (1) salting, (2) addition of carbohydrates, and (3) fermentation. Making *Bekasam* begins with preparation, including cleaning the gills and washing the stomach contents. Furthermore, salting is done; the fish is mixed with mixed ingredients, then the fermentation is continued for 5 to 7 days. *Bekasam* is thought to have antihypertensives due to the formation of bioactive peptides resulting from protein degradation during the fermentation process of the *Bekasam* (Wikandari et al., 2012).

The container for making *Bekasam* is generally by placing fish that has been added with salt and a source of carbohydrates in a jar. The jar is closed, so there is only a small cavity between the lid and the fish to be fermented. Because lactic acid bacteria are expected to ferment, fish can grow in low oxygen conditions. In addition to rice as a source of carbohydrates, the maker of *Bekasam* also uses other carbohydrate sources, including roasted rice, cassava, sticky rice, flour, and so on (Omega, 2016). The addition of carbohydrates in the manufacture of *Bekasam* aims to stimulate microbial growth.

Microbes that play a role in the fermentation of *Bekasam* include lactic acid bacteria. Lactic acid bacteria involved in the fermentation of acid reflux include the genera *Streptococcus, Lactobacillus*, and *Staphylococcus* (Lestari et al., 2018). *Lactobacillus plantarum*, *Lactobacillus pentosus* and *Pediococcus pentosaseus* (Wikandari et al. 2012).

Carbohydrates are broken down by lactic acid bacteria producing lactic acid, acetic acid, propionic acid, and ethyl alcohol. These compounds are beneficial as preservatives and give the tamarind product a sour taste and distinctive aroma. Rice is widely used in making *Bekasam.* Lactic acid bacteria have proteolytic enzymes that can degrade fish protein into peptides and amino acids. Lactic acid bacteria are also included in the amylolytic microorganism group, so starch, the primary substrate, will serve as the initial substrate for lactic acid bacteria. Adding a significant carbohydrate source allows lactic acid bacteria to grow well on these foodstuffs.

Salt is a microorganism selector that can minimize the presence of spoilage microbes to extend the shelf life of used products. However, salt can bind water materials and indirectly increase the material's osmotic pressure, so only certain microorganisms can grow. This phenomenon is a selector for several spoilage microbes that cannot tolerate salt (Priyanto and Djajati. 2018).

During the fermentation process, Lactic acid bacteria also produce bioactive components that function for health. Lactic acid bacteria, as in the manufacture of *Bekasam* can be used to improve the nutritional quality (digestibility) of the *Bekasam* and increase its functional value of the *Bekasam*. The functional properties of *Bekasam* as a cholesterol-lowering agent can be seen from the lovastatin content in *Bekasam.*

Lactic acid bacteria isolated from seluang fish shells produce lovastatin as an inhibitor of cholesterol synthesis (Rinto et al. 2015; Wikandari & Yuanita 2014).

Lovastatin belongs to the statin compound known as monacolin K or mevinolin. Rinto and Thenawidjaja (2016) stated that lovastatin acts as a competitive inhibitor for the enzyme HMG-CoA (3-hydroxy-3 methylglutaryl Coenzyme A) reductase. This enzyme determines cholesterol biosynthesis to help reduce cholesterol levels in the blood. Seluang fish extract contained lovastatin on average, ranging from 165.08 to 248.27 ppm (Lestari et al. 2018). Lactic acid bacteria metabolites from fermented tamarind act as antimicrobials, so *Bekasam* products have a longer shelf life when compared to fresh fish (Rusmana, Suwanto, & Mubarik, 2012).

Bekasam is also known to have antihypertensive activity caused by the activity of Angiotensin Converting Enzyme (ACE) inhibitor peptides resulting from proteolytic degradation during fermentation. Lactic acid bacteria and their fermentation products can lower blood pressure and produce bioactive peptides that can inhibit the activity of Angiotensin I Converting Enzyme (ACE). This enzyme plays a role in regulating blood pressure in the Renin-Angiotensin system. The activity of ACE inhibitors produced by lactic acid bacteria is in line with the increase in the number of peptides resulting from proteolytic degradation of lactic acid bacteria (Wikandari et al., 2012). ACE inhibitory activity is thought to be related to the formation of oligopeptides. Proteolytic lactic acid bacteria produce dipeptides, and tripeptides can influence the ACE inhibitory activity. Lactic acid bacteria isolated from *Bekasam* can produce ACE inhibitor activity of 51.77% - 65.75% (Wikandari et al., 2012). ACE inhibitory activity's magnitude correlates with the increase in peptides formed during fermentation.

Lactic acid bacteria isolated from tamarind are also known to have antimicrobial abilities, thereby increasing the product's shelf life. This durability is due to lactic acid bacteria inhibiting spoilage and pathogenic bacteria. Lactic acid bacteria can produce metabolites such as organic acids (lactic and acetic acid), hydrogen peroxide, diacetyl, and bacteriocins (Rusmana, Suwanto, & Mubarik, 2012).

Bacteriocin is an antimicrobial protein produced by lactic acid bacteria. The bacteria closely related to the bacteria that produce the bacteriocin can kill by bacteriocin. Therefore, bacteriocins are safe if consumed and can be applied as food preservatives. Bacteriocins have antagonistic properties against several pathogenic bacteria such as *Listeria*, *Clostridium*, *Staphylococcus*, *Bacillus spp*, *Brochotrix*, *Aeromonas*, and *Vibrio spp*. Therefore, bacteriocins can potentially be used to control bacterial contaminants in food products (Darbandi et al. 2021).

Organic acids are preservatives commonly used in food, and GRAS has a broad spectrum as an antibacterial agent. Organic acids are effective in preserving food because, in addition to antibacterial activity, organic acids also act as a sour taste enhancer (Rusmana, Suwanto, & Mubarik, 2012). Crude extract of bacteriocin isolates of lactic acid bacteria was able to inhibit *Staphylococcus aureus*, *Escherichia coli*, and *Salmonella sp*.

Ronto

Ronto is a traditional fermented shrimp product popular on the coast of South Kalimantan, made from a mixture of *Rebon* (*Acetes sp.*), salt, and rice, fermented for two weeks at room temperature. Comparing *Rebon*, salt, and rice 7:1:2. Fermentation has been performed anaerobically for two weeks (Khairina et al. 2016). *Ronto* processors use different types of doses in determining the ratio between salt shrimp: and rice so that the quality of the product between processors also varies (Khairina et al., 2013). *Ronto* is a chili sauce mixture's side dish, flavoring, and ingredient.

Ronto has a characteristic pungent sour, salty and strong smell of salt with the aroma of fermented shrimp. The taste of *Ronto* is a mixture of sour, salty, and savory flavors with a robust fermented shrimp flavor. *Rebon* has a light pink, acidic taste with a strong savory flavor of fermented shrimp. The texture of the *Ronto* is like porridge with a suspension of crushed rice and shrimp meat.

Processors of *Ronto* use different doses to determine the ratio between shrimp and salt and rice so that the product quality between processors is also various. Small-scale *Ronto* processing (<5 kg) uses a small bowl as a measure. While processing with a capacity of more than 10 kg, the dose used is buckets or cans with a volume of 1 – 3 kg, the difference in the amount used will affect the ratio of salt and rice added so that it will impact the quality of the resulting product (Soetikno, et al. 2018)

Small-scale *Ronto* processing (<5 kg) uses a small bowl as a measure. While processing with a capacity of more than 10 kg, the dose used is buckets or cans with a volume of 1 – 3 kg, the difference in the dose used will affect the ratio of salt, and rice added so that it will affect the quality of the products produced. The addition of carbohydrates in fish processing helps the growth of lactic acid bacteria (Rhee et al. 2010; Adams 2011). The percentage of salt and rice used in *Ronto* processing with a ratio of rebon: salt: rice = 7:1:2 is about 11.47% salt and 19.67% rice (Khairina et al. 2016b). The difference in salt and rice given affects the Aw loss value. The water content and water activity in the material affect the growth and metabolism of microbes that play a role in *Ronto* fermentation.

Various processed fishery products always use salt as a preservative. The amount of salt given other than as a preservative affects the sensory quality of the *Ronto*, especially the taste. High salt is a barrier for consumers because of the very salty taste, but high salt products tend to have a better shelf life. Therefore, determining the optimum amount of salt for the *Ronto* fermentation process needs to be known to obtain durable *Ronto* with sensory properties acceptable to consumers.

The decrease in pH is an indicator of the success of the fermentation process. The pH of *Ronto* generally decreases rapidly if the raw material is easily fermentable carbohydrates. Rice is the most commonly used carbohydrate source. Rice or roasted rice allows the saccharification process by amylolytic bacteria and other bacteria.

The color change of *Ronto* during Fermentation is related to the content of carotene and astaxanthin in the skin and flesh of rebon shrimp. Protein binding and Shrimp shell binding compounds decompose during fermentation causing carotene and astaxanthin bonds to be released, resulting in a color change. During Fermentation, shrimp protein undergoes proteolysis by a group of indigenous protease bacteria that decompose protein into short chain peptides and free amino acids (Chaijan & Panpipat, 2012). These compounds form specific flavors and flavors in fermented shrimp products (Faithong et al., 2010). Various biochemical reactions occur during shrimp fermentation, resulting in the development of color, aroma, taste, and texture of the shrimp fermented product. Proteolysis and hydrolysis cause the release of astaxanthin from protein bonds. Releasing astaxanthin produces a color change from pink (reddish-pink) to orange. When the rebon prawns are still fresh, the color is gray to pale white, and then the color will slowly change to pale pink with increasing intensity until it becomes light pink. Astaxanthin, also known as red xanthophyll with the chemical formula (3,3'-dihydroxy-i,i-carotene-4,4'-dione), plays a role in forming specific colors of crustaceans (Rodriquez et al. 2010).

The difference in salt concentration affects the resulting fallout's total acid and pH value. The pH value generally will decrease rapidly if the raw material is easily fermentable carbohydrates. Rice is the best carbohydrate source. Rice or roasted rice allows the saccharification process by amylolytic bacteria and other bacteria (Fernandez, 2009). High total acid affects the taste of *Ronto*, so it will be less sensory favorable.

Protein decomposition during fermentation is related to forming a total volatile basis that produces *Ronto* aroma. Khairina et al. (2017) reported an increase in the total volatile base value during 12 days of fermentation, namely 150 mg N/100 g sample. The total volatile base value was in line with the Sik-Khae study (Rhee et al., 2011)

The difference in salt and rice affected the Aw *Ronto*. The results of the analysis of diversity showed that there was a significant difference between treatments. The lowest Aw value was indicated by the control treatment. The *Ronto* fermentation process causes a decrease in the water activity and occurs significantly starting on the 4th day of fermentation and the 12th day, reaching 0.83 (Khairina et al., 2016). A w value drops influenced by the salt and water content of the product during fermentation (Abbas et al. 2009). Professionals use water activity in foodstuffs in product development, quality control, and food safety, making it an essential criterion for evaluating and controlling food safety and quality. Water activity decreases during the *Ronto* fermentation process. The water content and water activity in the material influence the growth and metabolism of microbes that play a role in fermentation.

The optimum Aw value for bacteria is 0.8 – 0.9, yeast 0.7-0.8, and mold < 0.7 if the Aw value is lower than this value, the metabolic system and growth of spoilage and pathogenic microbes will be disturbed because it is unable to grow at low Aw. This condition is very beneficial in food preservation, including fermented foods such as *Ronto*.

Thus, the fermentation process in animal-based fermented food must pay attention to the water activity conditions of the ingredients. Water activity can be adjusted by adding sugar, salt, flour or reducing the water content. This is important for the success of the fermentation process and prevention of contamination.

FUTURE RESEARCH DIRECTIONS

Exploration of the potential of animal fermented food is still very broad to be done. Especially for traditional and local fermented products in tropical countries. Examples of such foods are Nem Chua and Cin Som Mok.

CONCLUSION

Fermented animal-based foods in tropical countries are very varied and have the potential to be observed further. The fermentation results produce bioactive components that act as antioxidants, anti-hypertensives, and antibacterial.

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Section 2

Environmental Awareness

Chapter 6
Modified TiO2 Nanomaterials as Photocatalysts for Environmental Applications

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ABSTRACT

Since the water splitting breakthrough using semiconductor reported in 1972, titanium dioxide (TiO2) has been extensively investigated as a promising material used in broad range of research areas. TiO2 is a transition metal oxide semiconductor with three distinct polymorph crystalline structures. With that alone TiO2 established remarkable performance as photocatalyst for organic photodegradation in the irradiation of UV. However, improvement on the light absorption properties that support the excellent photocatalytic activity still needs to be pursued for wider environmental application. In this book chapter, the limitations of TiO2 as photocatalyst were discussed especially in the industrial wastewater treatment application. The strategies in overcoming the limitation by TiO2 morphology and surface modification were also presented. The modified TiO2 nanomaterials proves to have excellent photocatalytic activity in dyes (Rhodamine B, Methyl Orange and Methylene Blue) as representative of organic pollutant degradation and Cu (II) reduction as representative of inorganic pollutant.

DOI: 10.4018/978-1-6684-5629-3.ch006

INTRODUCTION

Water pollution is one of the dangerous problems threatening the world's environmental system. Climate change, population growth, fast economic development, and change in consumption patterns are the main cause of water scarcity. Meanwhile, enormous human activities lead to contamination concerns with detrimental effects on human health and ecosystems. Major sources of water pollution are human settlement and industrial and agricultural activities. Globally, over 80% of wastewater is discharged without prior treatment. It consists of sewage that is discharged directly into water bodies and an estimated 300-400 MT of polluted waste dumped by industries every year (World Water Assessment Programme (United Nations et al., 2021).

The release of untreated wastewater remains a common practice, especially in developing countries, due to a lack of infrastructure, technical and institutional capacity, and financing (World Water Assessment Programme (United Nations) et al., 2021). Developing countries, home of most large-scale agriculture products harvested and giant industries such as textile and other products release polluted water consisting of fertilizers and pesticides, organic waste, heavy metals, pathogens, and other emerging pollutants. Polluted water increases the environmental threats leading to eutrophication and water scarcity with potentially serious threats to human health (Unesco et al., 2020).

Wastewater consists of various colloidal particulates, pathogenic microorganisms, and organic and inorganic pollutants. Organic pollutants include dyes, colourants, pesticides, fertilizers, hydrocarbons, phenols, plasticizers, biphenyls, detergents, oils, greases, pharmaceuticals, proteins, and polysaccharides. Wastewater with a large number of organic pollutants (suspended solids) can reduce the light available to photosynthetic organisms and organic oxidation in the water (Rashed, 2013). Meanwhile, inorganic pollutants come in the form of chemical pollution, including heavy metals (Cu, Cr, Pb, Ni, etc.) (Liang et al., 2021). The removal of organic pollutants become an important task in the water treatment industry as they associate with the formation of disinfection by-products (DBPs). For instance, trihalomethanes (THMs) and halo acetic acids (HAAs) can be formed when certain organic species react with chlorine or chloramine which is a threat to public health. The discharge of untreated effluent in water bodies not only leads to eutrophication and human health risks but also contributes significantly to Green House Gas (GHG) emissions in the form of nitrous oxide and methane. In addition, the presence of heavy metals and other inorganic compounds with a concentration above the minimum level could have detrimental effects on human health and ecosystems as it is poisonous, non-degradable and, easily accumulates (Tomczyk et al., 2020; B. Yu et al., 2000). Therefore, the development of wastewater treatment technology that is technically and economically feasible is the only way to solve the environmental issues on water quality.

The treatment of such wastewater is based on various mechanical, biological, physical, and chemical processes. The advanced oxidation process (AOP) represents one of the promising technologies for the degradation of organic pollutants in water. (Kanakaraju et al., 2018; Loddo et al., 2018). AOP is typically characterized by the generation of highly reactive hydroxyl radical (•OH) that can mineralize organic pollutants. There are various types of AOP, such as ozonolysis, ozone/H_2O_2 peroxone process, UV/ozone, UV/H_2O_2, Fe^{2+}/H_2O_2 fenton process, irradiation with electrons, vacuum ultraviolet and ultrasonic, photocatalysis and combinations of the above-stated methods (Sillanpää et al., 2018).

Photocatalysis with various semiconductor materials has been the focus of investigations in recent years. Photocatalysts such as ZnO (Ge et al., 2009; Gonçalves et al., 2022; Rouzafzay et al., 2020; Sampaio et al., 2017; Zaidi et al., 2019), Fe_2O_3 (Gao et al., 2015; Nalbandian et al., 2016; Sheikholeslami et al., 2019), CdS (Guo et al., 2012; Nasir et al., 2020; Z. Yu et al., 2014), WO_3 (Murillo-Sierra et al., 2021; Tahir et al., 2017; Yang et al., 2018), Cu_2O (Choi et al., 2017; Domagała et al., 2020; X. Yu et al., 2018) and ZnS (Jabeen et al., 2017; J. Lee et al., 2018; Yan et al., 2015) were successfully applied to degrade a wide array of organic and inorganic pollutants. Among these semiconductors, TiO_2 remains the most widely used photocatalyst, due to its high photocatalytic activity, good stability, non-toxicity, and relatively cheap. In the UV/TiO_2 photocatalytic oxidation process, hydroxyl radicals (•OH) are generated when a catalyst (TiO_2) is illuminated by ultraviolet (UV) light. As a result, organic compounds are mineralized to CO_2, H_2O and inorganic constituents (Saravanan & Sasikumar, 2020). TiO_2 photocatalysis can be stated as a "green" process as it has several advantages such as (i) it can be conducted in mild operating conditions; (ii) it does not use dangerous heavy metal catalysts (TiO_2 is relatively safe); (iii) it uses mild oxidants (O_2, in some cases from the air); (iv) it does not produce harmful chemicals; (v) it offers a good alternative to the energy-intensive conventional treatment methods; and (vi) it can be combined with other physical and chemical technologies (e.g. membrane separations) (el Nemr et al., 2019).

The limitation of employing TiO_2 as a photocatalyst for organic and inorganic pollutant removal from water is that TiO_2 is a wide band-gap semiconductor, which makes the photocatalytic activity limited only to the use of ultraviolet radiation, not to the visible light, solar and fluorescent light (X. Wang et al., 2013) Crystal phases of TiO_2 (anatase, rutile, and brookite) are reported to have a large bandgap of ~3.2 eV which limits their optical absorption only in the ultraviolet region (290-400 nm) of the solar light spectrum (Z. Wang et al., 2002). To trigger its photocatalytic activity, TiO_2 needs to be illuminated by photons with energy larger than its band gap which means it can only be activated by UV light irradiation (below 400 nm).

It is common knowledge that a UV spectrum only accounts for ~5% of the full spectrum of solar energy. Even if TiO_2 is very efficient in utilizing energy from UV light, its overall photocatalytic activity in solar light is relatively low (Chen et al., 2015). In large-scale wastewater treatment applications, it is desirable to use new types of catalysts that can utilize not only UV light but also the overall solar radiation spectrum to get an efficient photocatalytic process.

To overcome these limitations and improve the photo-efficiency and organic degradation efficiency of TiO_2, several chemical and structural modifications were carried out to enable light absorption in the visible region. In this regard, various nanostructured TiO_2 materials were also developed, including nanoparticles and nanofibers, nanotubes, nanosheets, and nanowires. Alongside the structural changes, several chemical modification schemes were also reported which mainly consist of doping TiO_2 with non-metals (such as C, N, S or F), metals (such as Fe, Cr or V) or metal oxides (such as V_2O_5, ZrO_2 or WO_3). Hybrid materials combining TiO_2 with carbon materials such as carbon nanotubes, activated carbons or TiO_2-carbon microspheres were also investigated for the same purpose (Nakata & Fujishima, 2012).

The intrinsic photocatalytic activity of TiO_2 results from multi-competitive steps, including catalyst bandgap, the generation and recombination of electrons and holes, interfacial charge transfer, the mobility of electrons and holes, and charge carrier travelling time. Many strategies can be used to maximize photoactivity in terms of quantum efficiency. These include: (a) bandgap engineering, which extends the usable sunlight spectrum and increases the electrons/holes yield per unit of sunlight irradiation; (b) electrons/holes recombination rate reduction, which is normally achieved by the presence of impurity elements functioning to increase the holes trapping and delay the electron/holes recombination; (c) increase of the charge carrier transfer rate in the bulk solution or on the surface by reducing the internal resistance; and (d) reducing charge carriers travel time by decreasing the particle size or thin film thickness (Li et al., 2009; Zhang et al., n.d.). Thus, modification of its surface chemistry or morphology is worth studying further.

MORPHOLOGY MODIFICATION OF TIO_2

As stated previously, TiO_2 remains the most widely used photocatalyst, due to its high photocatalytic activity, high stability, non-toxicity, and relatively cheap to be applied in the wastewater treatment field. New photocatalytic materials developments are being intensively explored to achieve higher activities than TiO_2-based photocatalysts but the success cases for practical applications are very few. One of the most viable and practical approaches to developing better photocatalysts is to self-modify TiO_2 with various methods including morphology and surface modification (Park et al., 2013).

The first approach that can be used to improve the properties of TiO_2 is morphology modifications. Advanced research has proved that TiO_2 can be engineered in various types such as 0, 1, 2 and 3-dimensional nanostructures. The widely used 0D nanostructured TiO_2 (powder) is having some drawbacks such as fast recombination of electrons and holes, and slow charge carrier transfer. Meanwhile, the synthesis of 2D and 3D nanostructured materials was comparably complex and required high maintenance experimental conditions. Recently, 1D nanostructure has been extensively studied due to its unique advantages. It had a high aspect ratio with a diameter ranging from 1 to 100 nm, in the form of a tube, rod, wire, fibre or belt/ ribbon shape. 1D TiO_2 nanostructured materials possess all the typical features of TiO_2 nanoparticles and displayed a large specific surface area favourable for photo-generated carriers transfer and photocatalytic activity (Ge et al., 2016; Nakata & Fujishima, 2012). The nanostructured TiO_2 can be synthesized via hydrothermal, solvothermal, electrochemical anodization, sol-gel, electrochemical deposition, and electrospinning.

Kasuga et al. reported the fabrication of TiO_2-based nanotubular materials by the hydrothermal method for the first time in 1998 (Kasuga et al., 1998). In this process, amorphous TiO_2 powder was treated at high temperatures in a highly concentrated NaOH solution. This method can 100% convert the precursors to 1D TiO_2 nanostructured materials such as tubes, wire, rods, belts and plates. *The solvothermal method* is also a common synthesis method with some similarities to the hydrothermal process to produce TiO_2 nanostructures. It is usually conducted in a stainless-steel vessel with high temperature and pressure. These two methods generally use TiO_2 nanoparticles as the precursor. Only the solvothermal method is usually conducted in an organic solvent (ethanol, ethylene glycol, n-hexane, etc.), while the hydrothermal method usually reacts in water solutions. Choosing an appropriate solvent is the key to the solvothermal method, which also limits its wide applications (Ge et al., 2016). *The electrochemical anodization method* can be used to synthesize 1D TiO_2 nanostructured arrays (TNAs) on a Ti metal substrate. In general, the type, pH and temperature of the electrolyte, applied anodization voltage and time, affect the morphology and structure of TiO_2. Hydrofluoric acid-based water aqueous electrolytes with some organic solvents are most widely used in titanium anodization to produce TiO_2 nanostructures(Dong et al., 2014). *Chemical vapour deposition methods (CVD)* have been developed to construct high-quality 1D TiO_2 nanostructures which formed on a silicon substrate coated with Ti, $TiCl_4$ or $Ti(OC_3H_7)_4$ in a sealed chamber at a high temperature. *Template-assisted method and sol-gel method* are widely used in the fabrication of 1D TiO_2 nanotubes and nanorods. An anodic aluminium oxide (AAO) nanoporous membrane, made of an array of parallel straight nanopores with controllable diameter and length, is usually used as a template. The template was removed by chemical etching after

TiO_2 was deposited onto the template. The sol-gel method is representative of wet chemistry methods to synthesize 1D TiO_2 nanostructures with low temperatures and easy control of the process. The general route to preparing TiO_2 sol-gel is to mix tetrabutyl titanate or titanium isopropoxide in acetic acid. The solution is then heated to a high temperature with vigorous stirring. The nanostructured TiO_2 is formed by undergoing hydrolysis and condensation reactions. The electrospinning method is where the polymer solution is injected from a small nozzle under the influence of an electric field. The solution is then subjected to stretching by the continuous accumulation of electrostatic charges, forming ultra along and hollow nanofibers. Single-phase and highly crystalline TiO_2 nanofibers can be obtained through the calcination of the as-prepared samples (Ge et al., 2016).

A hydrothermal method is the most common method used for the fabrication of 1D TiO_2 nanostructures. It is usually conducted in a stainless-steel vessel with moderately high temperature and pressure. The hydrothermal method has attracted much attention due to its simple procedure and low production cost. TiO_2 with nanoribbons morphology (1D) has been reported to have high photocatalytic activity with kinetics constant of 0.0820/min for the photodegradation of dyes pollutants. By using alkaline hydrothermal methods at 150-180°C with an additional post-annealing process at a certain extent of temperature 500°C, TiO_2-based nanoribbons derived from TiO_2 nanoparticles with dimensions several microns in length and 200-300 nm in width can be produced (Ariyanti et al., 2018). It is also claimed that the modified TiO_2 possesses high surface area and pore volume which extend the utilization of TiO_2-based nanoribbons to the fair adsorption capacity over dyes such as Rhodamine B and Methyl orange with their respective adsorption capacity considering its large surface area and high pore volume (Ariyanti, Mo'ungatonga, et al., 2020). Different types of 1D morphology such as hierarchical structures of coated TiO_2 nanoribbons also can be prepared through a two-step hydrothermal process. The structures consist of $H_2Ti_3O_7$ nanoribbon as a core with TiO_2 anatase nanoparticles as a second layer. The coated nanoribbon has a good photocatalytic activity with a degradation rate of 0.0269/min for Rhodamine B as a representative dye pollutant. The presence of TiO_2 nanoparticles as the second layer of hierarchical structures can improve photocatalytic activity by providing additional surface area for light absorption and contact area with dye pollutants (Ariyanti et al., 2019). 1D TiO_2 nanostructures can also be prepared from Ti foil to create an immobilised type of photocatalyst. The hydrothermal process at 180°C for 18 hours in the presence of acetone can be used to form nanorods TiO_2 that grow on the surface in the vertical direction. The nanorods type successfully degrade almost 40% of bromothymol blue in the black light irradiation as well as organic pollutants including dyes and phenolic compound in Batik wastewater, confirming its effectiveness as a photocatalyst (Ariyanti et al., 2021; Ariyanti, Purbasari, et al., 2020).

SURFACE MODIFICATION OF TIO_2

The photocatalytic reaction involving TiO_2 depends on the number of working electrons and holes (excited by light irradiation) available on the surface to trigger the reduction and oxidation reaction in the surrounding environment. Upon light irradiation, the excited hole and electron possess several de-excitation pathways such as charge carrier recombination, trapping and migration to the surface of the catalyst. There are several ways to improve photocatalytic activity including (i) bandgap engineering, which extends the usable sunlight spectrum and increases the electron holes yield per unit of sunlight irradiation and (ii) reducing the holes recombination rate (H.-I. Lee et al., 2010). The approach to improve the properties of TiO_2 mentioned is surface modification. The modification of the TiO_2 surface can be done in many ways such as metal deposition (Pt, Pd, Au, Ag, etc); heterogeneous composites (CdS, WO_3, SNO_2, SiO_2, Al_2O_3, etc); hybrid nanomaterials (CNTs, graphene, zeolite, etc.); and doping (metal ion, non-metal ion, co-doping, and self-doping or defect engineering). Defect engineering is the feasible method to improve the optical properties of TiO_2 (Chen et al., 2015). In terms of the optical absorption properties, larger optical absorption can increase the amount of light absorbed, and generate more electrons and holes, which is favourable for photocatalytic activity (Zhuang et al., 2010). Various synthetic methods such as hydrogen thermal treatment, hydrogen plasma, chemical reduction, chemical oxidation, and electrochemical reduction have been developed to make engineered TiO_2 with different shapes, particle sizes, morphologies, holes recombination rate reduction, and extend the light absorption towards the visible light region (Chen et al., 2015).

A model of surface modification through defect engineering is reported in (Ariyanti et al., 2017). The defected TiO_2 nanoparticles were prepared by $NaBH_4$ reduction at 300-450^oC under an argon atmosphere on pristine TiO_2 nanoparticles. The process can create some amount of defect concentration in the form of oxygen vacancies that enhance visible light absorption. The controllable defect introduction can lead to better photocatalytic activity performance of Rhodamine B degradation under simulated solar light. Theoretical calculations conducted in another report (Ariyanti, Mukhtar, et al., 2020) confirmed the presence of extra energy states created by oxygen vacancies (Vo). The reduction of bandgap value was observed in the TiO_2 with Vo defects in comparison to the pristine TiO_2. The phenomena lead to a disordered layer and broad visible light absorption.

Meanwhile, surface modification by the formation of hybrid materials such as rGO-TiO_2 composite was also investigated to improve the photocatalytic activity through the synergetic effect of the two components. The rGO-TiO_2 composite was synthesized via the hydrothermal method under specific conditions. The hybrid materials are then used to perform photodegradation of organic pollutants (dyes) and photoreduction of inorganic pollutants (Cu (II)). The result shows there is a synergetic effect of each component to improve the organic removal performance involving adsorption-desorption followed by photocatalysis. Therefore, it leads to the improvement of the organic removal activities in comparison to the pristine TiO_2. A slightly different trend was observed in the inorganic pollutant removal (Cu (II)) by using the rGO-TiO_2 composite. The reduction of (Cu (II)) was hardly seen as the presence of rGO triggered faster electron and hole recombination leading to the lack of hydroxyl and oxygen radicals to perform photodegradation. The result also confirms that hybrid materials such as rGO-TiO_2 composite have excellent photocatalytic activity for organic pollutant degradation and fair photocatalytic activity for inorganic pollutant photoreduction.

SOLUTIONS AND RECOMMENDATIONS

The superiority of TiO_2 among photoactive materials has been established, but still, there are some spaces related to its performance and efficiency that can be improved further. TiO_2 possess wide band-gap energy, which makes the utilization of sunlight becomes low. It also possesses high charge recombination and low adsorption capacity. The photocatalytic reaction involving TiO_2 largely depends on the number of working electrons and holes (excited by light irradiation) available on the surface to trigger the reduction and oxidation reaction in the surrounding environment. Upon light irradiation, the excited hole and electron possess several de-excitation pathways such as charge carrier recombination, trapping and migration to the surface of the catalyst. High charge recombination and low adsorption capacity are not favourable for photocatalytic activity. The engineered TiO2 through morphology as well as surface modification are expected to have lower band-gap energy so that the catalyst can utilize more sunlight irradiation, or either has low charge recombination with high adsorption capacity that supports the excellent photocatalytic activity.

FUTURE RESEARCH DIRECTIONS

Modified TiO_2 for environmental application still have many sides to be developed. As discussed in the previous section, from a catalyst point of view the materials can be modified in many ways using many different methods to improve their photocatalytic activity. Apart from that, the materials also should have feasibility when applied for organic or inorganic degradation in the real wastewater treatment plant. Many technical data should be provided for those purposes. Research in the development of modified TiO_2 that has excellent photocatalytic activity as well as reusability is also important to support its industrial application.

CONCLUSION

The modified TiO_2 nanomaterials via morphology and surface modification have successfully improved the properties related to the excellent photocatalytic activity in pollutant removal from the water body. The morphology modification includes various TiO_2 nanostructures that can be synthesized via hydrothermal, solvothermal, electrochemical anodization, sol-gel, electrochemical deposition, and electrospinning. While surface modification can be conducted via metal deposition, heterogeneous composites formation and hybrid materials preparation.

Morphology modification improves the surface area and pore volume which can increase the number of sites for initial adsorption of the pollutant before the photodegradation process. On the other hand, surface modification engineered either bandgap adjustment or adding site to prolong the charge recombination and accelerate the reduction and oxidation reaction for organic and inorganic pollutant degradation. From the photocatalyst material point of view, modified TiO_2 nanomaterials still have many sides for further exploration and development to improve their photocatalytic activity, especially for environmental applications.

ACKNOWLEDGMENT

This research was financially supported by Deputy for Research Strengthening and Development, Ministry of Research and Technology / National Research and Innovation Agency of Indonesia, Indonesia for the financial support No: 257-24/ UN7.6.1/PP/2021 and World Class University Ptogram of Universitas Diponegoro, Semarang, Indonesia.

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KEY TERMS AND DEFINITIONS

Band Gap: This is the gap energy between the valence band of electrons and the conduction band in semiconductor such as TiO_2

Modified TiO_2 Nanomaterial: This is TiO_2 in the form of nanomaterial that experience changes in the morphology and/or in the surface state due to chemical and physical modification process that lead to the change in its properties.

Photocatalyst: This is a material commonly semiconductor which has ability to absorbs light that higher than its bandgap to excite charges to make a chemical reaction occur.

Photocatalysis: This is a photo-activated chemical reaction occurring when free radical charges is excited from the compound with the favour of photons that have sufficiently high energy levels.

Photodegradation: This is the degradation process of components wide range of organics triggered by the radical charges excited from the compound with the favour of photons that have sufficiently high energy levels.

Chapter 7
The Recent Design of Ag3PO4-Based Photocatalyst for Renewable Energy and Environmental Applications

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ABSTRACT

Green energy and environmental awareness have grown because human activities have an impact and are harmful to the environment. Recently, renewable energy and the environment are hot issues in the world that are facing serious challenges. A new photocatalyst, Ag3PO4, has great potential to be applied in producing renewable energy and the environment. The recent design of Ag3PO4-based photocatalysts and their applications are discussed in this book chapter. Modifications of Ag3PO4 photocatalysts are carried out to increase photocatalytic activity and stability. Surface modification and composite design into binary, ternary, and quaternary have given very important results in increasing the capability of this photocatalyst. The application of Ag3PO4-based photocatalyst is very prospective for hydrogen/oxygen production, organic pollutant degradation, antibiotic degradation, antibacterial, and environmental sensors.

DOI: 10.4018/978-1-6684-5629-3.ch007

INTRODUCTION

The world is currently facing big challenges, especially in the fields of energy and the environment. The use of fossil fuels produces carbon dioxide gas, which influences global climate change. Fossil fuel combustion could have multiple threats to child health due to the emission of toxic particles and gases (Perera, 2017). The toxic air pollutant and climate change affected the developing fetus and young child. Therefore, a future energy source such as hydrogen is very important to replace fossil fuels. Environmentally friendly energy should be provided for our next generation.

To achieve such goals, the photocatalyst is one of the materials that can be chosen to solve energy and environmental problems. Photocatalysts can be applied for hydrogen production under solar irradiation (Wang et al., 2016), converting CO_2 to methanol (Wu et al., 2019), and converting biomass to electricity (W. Liu et al., 2014). These materials can also be applied for wastewater treatment (Arifan et al., 2018; Borges et al., 2016), organic pollutant degradation (Kusworo et al., 2021; Pasini et al., 2021), organic dye oxidation (Ariyanti et al., 2018; Wibowo & Sutanto, 2016), gas pollutant elimination (Sulaeman et al., 2010), and bacteria inactivation (N. Liu et al., 2021; Sutanto et al., 2015). The highest challenge of this material is to produce a highly active photocatalyst under solar light irradiation. With this approach, more sunlight energy could be harvested. The modification of iron-doped TiO_2 (Ebrahimi et al., 2021; Nasralla et al., 2018), nitrogen-doped TiO_2 (Asahi et al., 2001; Hidayanto et al., 2017; Pandiangan et al., 2018; Sutanto et al., 2017; S. Yin et al., 2003), and defect TiO_2 nanomaterials (Ariyanti et al., 2017), have been attempted to achieve this purpose. However, low activity has been found in these materials. Therefore, alternative photocatalysts such as Ag_3PO_4 should be explored. This chapter gives an overview of the latest developments of Ag_3PO_4-based photocatalysts for energy and environmental applications.

Ag_3PO_4-based materials are potential photocatalysts for energy and environmental applications. Ag_3PO_4-TiO_2 heterojunction (C. F. Liu & Perng, 2020), Z-scheme g-C_3N_4/Ag_3PO_4 nanocomposite (Raeisi-Kheirabadi & Nezamzadeh-Ejhieh, 2020), and Ag_3PO_4/MXene (Zhao et al., 2020), have been successful in initiating the water-splitting experiments. These Ag_3PO_4-based photocatalysts could be promising for producing hydrogen as renewable energy in the future. Besides the energy creations, the Ag_3PO_4-based photocatalysts could also be applied for organic pollutant degradation. Colour substances such as methylene blue, methyl orange, and rhodamine B could be easily oxidized by this modified photocatalyst (Yan et al., 2017). Other organic pollutants of phenol (Song et al., 2018), bisphenol (T. Li et al., 2019), and polyaromatic hydrocarbon (Yang et al., 2018) also could be degraded into carbon dioxide and water. For health and sanitary purposes, the Ag_3PO_4-based photocatalysts could potentially be applied as antibacterial agents (Seo et al., 2017).

The modification of Ag_3PO_4 through Ag_3PO_4/α-Fe_2O_3 (Su et al., 2020), Fe_3O_4/SiO_2/ZnO/Ag_3PO_4 (Mao et al., 2020), and Bi_2MoO_6/Ag_3PO_4/Silk fibroin (Wang et al., 2021), led to excellent antibacterial photocatalysts.

DESIGN OF Ag_3PO_4-BASED PHOTOCATALYST

Modifications of Ag_3PO_4 photocatalysts are carried out to increase the photocatalytic activity and stability. The photocatalytic reaction of Ag_3PO_4 can be suppressed by the recombination of electron and hole pairs. This phenomenon is found in many photocatalysts due to defect formation on the surface which could act as a center of recombination. Besides electron and hole recombination, poor stability of Ag_3PO_4 has been found. This phenomenon has limited the successful application in the environment. The cause of poor stability might be associated with the photo-corrosion of silver ions in Ag_3PO_4. In photocatalytic reactions, the Ag^+ in Ag_3PO_4 might be reduced into metallic Ag (Sulaeman et al., 2022).

To handle these problems, the modification of Ag_3PO_4 should be done. Some new methods have been published to enhance the photocatalytic reaction such as surface modification and composite design. Surface modifications using platinum complexes (Sulaeman et al., 2020), metallic gold and gold complexes (Sulaeman et al., 2021), and alginate (Sulaeman et al., 2022), have been attempted to improve the photocatalytic activity. These modifications can facilitate the reduction of oxygen to generate superoxide radicals which produce a significant role in organic pollutant degradation.

Composite design in Ag_3PO_4 modification has been widely attempted by many researchers worldwide. The designs can be binary, ternary, and quaternary photocatalysts. The recent progress of these designs is listed in Table 1. Binary photocatalyst is widely developed to achieve high photocatalytic activity and stability. PEDOT/Ag_3PO_4 and MoS_2/Ag_3PO_4 binary composites were successfully designed using ion exchange and chemisorption (Sari et al., 2021). The PEDOT/Ag_3PO_4 hybrids showed a Z-scheme mechanism. This mechanism can convert oxygen to superoxide radicals on the surface of PEDOT, whereas the hydroxyl radical generation occurs on the surface of Ag_3PO_4. On the surface of the binary MoS_2/ Ag_3PO_4, the 1T-MoS_2 could act as a co-catalyst to receive the photoinduced electrons from the Ag_3PO_4. Because of its metallic character, the 1T-MoS_2 decreases the resistance of charge transfer (Sari et al., 2021). This binary composite has a superior photocatalytic ability for methylene blue and tetracycline degradation.

The ternary composite of Ag_3PO_4/$Co_3(PO_4)_2$/g-C_3N_4 material was successfully designed using the precipitation method for tetracycline photodegradation (Shi et al., 2020). The enhanced photocatalytic activity was due to the synergistic effects of $Co_3(PO_4)_2$, g-C_3N_4 and Ag_3PO_4. This structure led to a Z-scheme and Type II heterojunction mechanism for the effective separation of holes and electrons. This

Table 1. The composite design of Ag_3PO_4-based photocatalyst with mechanism and application

Structure	Mechanism	Application	References
Ag_3PO_4/TiO_2	band-band transfer	hydrogen production	(C. F. Liu & Perng, 2020)
g-C_3N_4/Ag_3PO_4	Z-scheme	water splitting	(Raeisi-Kheirabadi & Nezamzadeh-Ejhieh, 2020)
Ag_3PO_4/ Ti_3C_2	the electron "pool" effect Ti_3C_2 and its hydrophilic effect	oxygen evolution	(Zhao et al., 2020)
Ag_3PO_4/C_3N_5	Z-scheme	tetracycline hydrochloride removal	(H. Yin et al., 2021).
PEDOT/Ag_3PO_4	Z-scheme	methylene blue and tetracycline degradation	(Sari et al., 2021)
Ag_3PO_4/α-Fe_2O_3	band-band transfer	antibacterial	(Su et al., 2020)
Ag_3PO_4/MoS_2	Z-scheme	degradation of the dyes (MB, RhB, and MO) and phenol	(Zhu et al., 2016)
Ag_3PO_4/SnO_2	the p-n junction between Ag_3PO_4 and SnO_2	Rhodamine B dye oxidation	(Silva et al., 2021).
ZrFe2O5/Ag3PO4	cyclical oxidation of phenolic to ketones and electrons reduces Ag+ to Ag^0	sensor for tetracycline detection	(Abraham et al., 2020).
TiO_2/Ag_3PO_4/g-C_3N_4	Z-scheme	metronidazole (MNZ) decomposition	(Abbasi-Asl et al., 2021)
$Ag_3PO_4/Co_3(PO_4)_2$/g-C_3N_4	Z-scheme and Type II heterojunction	tetracycline degradation	(Shi et al., 2020)
g-$C_3N_4/Ag_2MoO_4/Ag_3PO_4$	Z-scheme	water splitting	(W. Liu et al., 2018)
Bi_2WO_6/BiOI@Ag_3PO_4	n-p-n heterojunction	bisphenol A (BPA) and cefepime degradation	(Chu et al., 2021).
Bi_2WO_6/BiOI@Ag_3PO_4	Z-scheme	BPA degradation	(Chu et al., 2021).
BiO_2–x/Ag_3PO_4/CNT	band-band transfer	naphthalene and pyrene degradation	(Jin et al., 2020)
$CeO_2/Co_3O_4/Ag/Ag_3PO_4$	S-scheme and SPR effect	MB degradation	(Sabzehmeidani et al., 2022)
g-$C_3N_4/Ag/Ag_3PO_4$/AgPd	Z-scheme	formic acid dehydrogenation	(Altan & Metin, 2021)
g-$C_3N_4/Fe_3O_4/Ag_3PO_4/Co_3O_4$	accumulated electrons in CB of Ag_3PO_4 and Co_3O_4 are transferred to O_2 resulting in H_2O_2	RhB degradation	(Mousavi & Habibi-Yangjeh, 2017)
$Ag_3PO_4/BiPO_4$/MIL-88B(Fe)/g-C_3N_4	core@shell	navy Acid Blue 92 degradation	(Khasevani et al., 2017)

phenomenon could be defined as a multilevel electron transfer mechanism. Another ternary composite that follows the Z-scheme mechanism is g-C_3N_4/Ag_2MoO_4/Ag_3PO_4 heterojunction photocatalyst (W. Liu et al., 2018). In this composite, the formation of metallic Ag led to a plasmonic effect and created a new Z-scheme. Therefore, a dual Z-scheme system was formed and it increased the separation of electrons and holes leading to high photocatalytic activity.

Quaternary composite of g-C_3N_4/Fe_3O_4/Ag_3PO_4/Co_3O_4 could be fabricated under ultrasonic irradiation for RhB degradation (Mousavi & Habibi-Yangjeh, 2017). The highest photocatalytic activity was achieved after the sample was calcined at 300 °C for 2 h with 20 wt% of Co_3O_4. The band-band electron transfer improved the photocatalytic activity. The addition of Fe_3O_4 to the photocatalyst led to magnetical separability. Quaternary of g-C_3N_4/Ag/Ag_3PO_4/AgPd could be successfully designed for formic acid dehydrogenation (Altan & Metin, 2021). This photocatalyst enhanced the reaction by inducing more positive holes and improved the electrons and hole separation of the two different semiconductors. Its mechanism is a Z-scheme where Ag nanoparticle acts as a recombination center. The CeO_2/Co_3O_4/Ag/Ag_3PO_4 quaternary composite could be synthesized via electrospinning, calcination, and precipitation (Sabzehmeidani et al., 2022). The high photocatalytic ability of this composite was due to the extension of the absorption in the visible light range, the plasmonic effect, and the formation of the S-scheme mechanism.

THE PROSPECTIVE APPLICATION OF Ag_3PO_4-BASED PHOTOCATALYSTS

Hydrogen and Oxygen Production

Ag_3PO_4-based photocatalysts could be excellent candidates for hydrogen and oxygen production from water splitting. To generate the ability of water splitting, many researchers have utilized g-C_3N_4 for composite design. For example, g-C_3N_4 nanotube/Ag_3PO_4 synthesized under the precipitation method exhibited excellent photocatalytic activity for O_2 production (D. Li, Liu, Xu, et al., 2022). This composite showed an excellent inorganic-organic S-scheme photocatalyst with an O_2 evolution rate of 370.2 $\mu molL^{-1}h^{-1}$. In this mechanism, the electrons of Ag_3PO_4 recombine with holes of g-C_3N_4. This improves the charge separation and maintains the strong oxidizing ability. The shape of g-C_3N_4 could also be prepared in a nanorod. A g-C_3N_4 nanorod/Ag_3PO_4 composite material was successfully designed (Tian et al., 2018). This composite with 600 mg rod-like g-C_3N_4 showed higher efficiency for oxygen evolution compared to the bulk Ag_3PO_4. The Ag/g-C_3N_4-Ag-Ag_3PO_4 composite with Ag_3PO_4 crystal plane of (110) exhibited strong oxidizing ability and large hydrogen production (Li et al., 2020). It was due to the presence of Ag nanoparticles with a Z-scheme mechanism. Ag nanoparticles could be conductive channels that can transfer the electrons from the CB Ag_3PO_4 to the VB g-C_3N_4 (Z-scheme). This phenomenon can effectively retain electrons on CB g-C_3N_4 leading to large hydrogen production. Ag nanoparticles bound to g-C_3N_4 can act as cocatalysts and increases the active site. This phenomenon can also improve the efficiency of hydrogen production.

Besides g-C_3N_4, Ti_3C_2 and WO_3 can also be applied for Ag_3PO_4-based composite for water splitting. An Ag_3PO_4/Ti_3C_2 composite could be synthesized by the in-situ deposition of Ag_3PO_4 particles on the exfoliated Ti_3C_2 nanosheets. This composite could enhance the photocatalytic O_2 evolution in the absence of a sacrificial electron acceptor. The improvement of O_2 generation was caused by the electron "pool" effect of Ti_3C_2 and the hydrophilic functionalities on the Ti_3C_2 surface (Zhao et al., 2020). An Ag_3PO_4/WO_3 composite was also successfully prepared using a simple deposition-precipitation method (D. Li, Liu, Yang, et al., 2022). This composite exhibited high photocatalytic activity of oxygen production (306.6 μmol$L^{-1}h^{-1}$), higher than pristine Ag_3PO_4 (204.4 μmol$L^{-1}h^{-1}$). Based on the characterization, an S-scheme mechanism was found in the composite of Ag_3PO_4/WO_3 that improved photocatalytic reaction. The Ag_3PO_4-Bi_2WO_6-TiO_2 nanostructures were successfully designed by anchoring Ag_3PO_4 on a binary catalyst of Bi_2WO_6-TiO_2 using the hydrothermal method (Mandari et al., 2021). This design leads to an increased electronic effect of Ag_3PO_4 which improves the oxygen evolution reaction (OER) capacity.

Organic Pollutant Degradation

Ag_3PO_4-based photocatalysts are potentially applied for organic pollutant elimination under solar radiation. Dye molecules, phenol, bisphenol A (BPA), and polyaromatic hydrogen (PAH) are successfully degraded using the modified Ag_3PO_4. An Ag_3PO_4/MoS_2 composite synthesized under ethanol-water solvents exhibited excellent photocatalytic ability and stability for the degradation of methylene blue, rhodamine B, methyl orange, and phenol degradation (Zhu et al., 2016). These degradations occurred on the surface through a Z-scheme mechanism. The formation of metallic Ag could assist the Z-scheme mechanism because it can act as the charge separation center. With this modification, photo-corrosion could effectively be inhibited leading to higher stability. Rhodamine B was also effectively degraded using the Ag_3PO_4/SnO_2 composites (Silva et al., 2021). Superoxide radicals are significant species in this photocatalytic reaction that are generated via a p-n junction between Ag_3PO_4 and SnO_2. For phenol pollutants degradation, A W–Ag_3PO_4 photocatalyst was successfully designed (Ma et al., 2021). This preparation showed that W^{6+} could enter the Ag_3PO_4 lattice, replacing the position of P^{5+} forming WO_4^{2-}. In this photocatalyst, the phenol oxidation was mainly carried out by h^+ species.

Bisphenol A (BPA) and cefepime organic pollutants were successfully degraded using the Bi_2WO_6/BiOI@Ag_3PO_4 composite that was prepared by a one-step hydrothermal process (Chu et al., 2021). This composite provided a double-heterojunction structure that enhanced photocatalytic activity. The BPA oxidation mainly involves the superoxide anion radical (•O_2–), whereas the cefepime degradation mainly involves the hydroxyl radical and holes species. The bisphenol A could also be degraded using Biochar@$CoFe_2O_4$/Ag_3PO_4 composite under visible light irradiation (Zhai et al., 2020). The high activity of this composite was induced by the Z-scheme mechanism.

The polyaromatic hydrogen (PAH) pollutants were successfully degraded using the BiO_2–x/Ag_3PO_4/CNT composite (Jin et al., 2020). This multi-heterostructure composite having oxygen-rich defects can be prepared by two-step deposition. This new photocatalyst provided an effective photocatalytic activity for pyrene and naphthalene compound degradation. The BiO_{2-x} component could absorb a large wavelength of light to produce holes and electrons. The holes in VB Ag_3PO_4 could effectively transfer to VB BiO_{2-x} forming a built-in potential field. The presence of CNT can improve the transfer efficiency of electrons and holes. This phenomenon can significantly enhance photocatalytic ability.

Antibiotic Degradation

Nowadays, antibiotics are increasingly used that can contaminate the water. The antibiotic compounds of tetracycline hydrochloride (TCH), ciprofloxacin (CIP), and metronidazole (MNZ) can be oxidized using Ag_3PO_4-based photocatalysts. The antibiotic of tetracycline was effectively degraded using the composite of Ag_3PO_4/C_3N_5, Ag/Ag_2S/Ag_3PO_4, and 0D/2D-Ag_3PO_4/nickel-aluminum layered double hydroxide (Alshamsi et al., 2021; Fan et al., 2021; H. Yin et al., 2021). Ag_3PO_4/C_3N_5 nanocomposite showed excellent photocatalytic activity toward tetracycline hydrochloride removal (H. Yin et al., 2021). The Z-scheme system on the surface of Ag_3PO_4 and C_3N_5 was the main role in improving photocatalytic ability. The nanocomposite of Ag/Ag_2S/Ag_3PO_4 can be designed for the degradation of tetracycline antibiotics using simulated sunlight exposure (Alshamsi et al., 2021). This heterojunction material exhibited better photodegradation efficiency (~95%) than single Ag_2S or Ag_3PO_4. The high photocatalytic activity was mainly due to higher superoxide and hydroxyl radicals. The nanocomposite of 0D/2D-Ag_3PO_4/nickel-aluminum layered double hydroxide showed the photocatalytic ability for tetracycline hydrochloride degradation under visible light exposure (Fan et al., 2021). This design provided a Z-scheme photocatalytic mechanism that was caused by Ag formation during photoirradiation. Metallic Ag is known to act as the center for hole and electron recombination sites to boost the effective role of oxidation and reduction in the surface of VB and CB of hybrid material.

The morphology of Ag_3PO_4 can influence the photocatalytic activity of antibiotic degradation. The tetrahedral and cube shapes of Ag_3PO_4 with facets {111} and {100} respectively were prepared to evaluate the relationship between facets and the photocatalytic properties (He et al., 2021). The results showed that the samples of Ag_3PO_4 tetrahedrons had superior antibiotic ciprofloxacin (CIP) oxidation compared to the Ag_3PO_4 sphere and cubes under visible light exposure. The holes in Ag_3PO_4 tetrahedrons with higher {111} facets exhibited faster mobility, which was effective for CIP oxidation. The degradation rate of antibiotics depends on the shapes of Ag_3PO_4.

The $TiO_2/Ag_3PO_4/g\text{-}C_3N_4$ ternary composite synthesized using calcination and precipitation methods showed superior photocatalytic activity for metronidazole (MNZ) decomposition (Abbasi-Asl et al., 2021). The high activity is induced by a Z-scheme mechanism, plasmonic effect, and high hole-electron separation compared to pristine and binary photocatalysts. Hydroxyl radicals are the main role in the degradation of this antibiotic molecule.

Antibacterial Application

The Ag_3PO_4-based photocatalyst could also be applied for antibacterial activity. The nanostructure of Ag_3PO_4 showed high potential for killing bacteria such as Staphylococcus aureus and Escherichia coli. The mechanism of antibacterial in nanostructured Ag_3PO_4 was proposed as follows (Dânoun et al., 2021): (a) the photocatalyst material can interact with the cell wall and membrane because there is an electrostatic interaction with sulfur proteins. (b) The interaction of photocatalyst with the cell wall can increase the cytoplasmic membrane permeability leading to the destruction of the bacterial envelope. (c) After the membrane was broken, the Ag_3PO_4 could enter the cells. (d) Ag_3PO_4 can directly bind to lipids, proteins, DNA, and enzymes, and the oxidation occurred due to the formation of reactive oxygen species (ROS).

To improve the ability of antibacterial properties, Ag nanoparticles were embedded on Ag_3PO_4 using a flow microwave reactor (Długosz & Banach, 2022). This composite material possessed excellent antibacterial activities. Another approach to improve the antibacterial activity is through Ag_3PO_4-based composite design. The binary composite of Ag_3PO_4/TiO_2 heterojunctions could completely collapse bacterial cells (Lyu et al., 2021). These heterojunctions show a more pronounced antibacterial performance in Gram-negative than in Gram-positive bacteria. A quaternary composite of $Fe_3O_4/SiO_2/ZnO/Ag_3PO_4$ nanocomposites could also have an antibacterial effect on E. coli and S. aureus (Mao et al., 2020). Fe_3O_4 can act as the magnetic core and SiO_2 can act as the protective layer. The high activity was caused by the synergistic effect between ZnO and Ag_3PO_4.

Sensor Application

The most interesting role of Ag_3PO_4-based photocatalyst is its application in sensing. The ammonia (NH_3), hydrogen sulfide (H_2S), and tetracycline could be detected using the Ag_3PO_4-based photocatalyst sensor. The Ag_3PO_4 showed the performance of ammonia sensing at room temperature using the exposure of an LED lamp (Shao et al., 2021). The response value was higher under LED exposure compared to dark conditions with a detection limit of 10 ppm. It is because the oxygen species generated during illumination enhance gas sensing performance, and showed high selectivity for NH_3 under mixed gases due to interacting lone pair electron of NH_3 with the empty orbital of a silver atom.

An Ag_3PO_4-doped SnO_2 material has been successfully synthesized under hydrothermal and chemical precipitation methods (Sun et al., 2020). This material can effectively be applied for H_2S gas sensing. This phenomenon is attributed to the increased oxygen vacancy and facile electron transfer process in the conduction band.

A binary composite of $ZrFe_2O_5/Ag_3PO_4$ was applied to a sensor for tetracycline in small concentrations (Abraham et al., 2020). It had a detection limit of 6.38 nanomolar and a dynamic range of 10–90 nanomolar. This finding was very important for future industrial applications. The sensor mechanism can be described as cyclical oxidation of phenolic to ketones, and the generation of the electron is transferred to Ag_3PO_4 that reduces Ag^+ to Ag^0. The small particle aggregation of $ZrFe_2O_5$ offered sufficient sites for the mobility of the electrons and was responsible for an excellent electrochemical sensor.

SOLUTIONS AND RECOMMENDATIONS

In the last decade, research on Ag_3PO_4-based photocatalysts has developed very rapidly. However, this photocatalyst cannot be commercialized yet because there are still weaknesses including low stability due to the photo-corrosion reaction during the photocatalyst reaction. Possible measures to increase the stability and activity of Ag_3PO_4 are surface modification and a composite design. The surface modification can use metal, non-metal, and functional groups. This preparation is expected to capture photogenerated electrons and thereby reduce photo-corrosion. It can also improve the separation of electrons and holes. This method can improve stability and activity. Modification of Ag_3PO_4 through a composite formation can also prevent photo-corrosion and increase the separation of electrons and holes.

Composites can consist of two components (binary), three components (ternary), and four components (quaternary). To obtain the effective composite, the band-band electron or Z-scheme transfer reaction must occur. In this modification, the selection of the semiconductor bandgap energy as a composite material is very important. For the Z-scheme mechanism, providing metal nanoparticles is very helpful to bridge the electron and hole reactions of the two connected semiconductors.

FUTURE RESEARCH DIRECTIONS

Future research directions for Ag_3PO_4-based photocatalysts are very challenging. The first focus of research is how to make nano-sized Ag_3PO_4 particles. A very promising method is the manufacture of nano-sized Ag_3PO_4 particles using polymers, both natural and synthetic polymers. These polymers will control the rate of Ag_3PO_4 crystal growth which prevents agglomeration. Nano-sized Ag_3PO_4 particles have the advantage due to possessing a very large surface area. This characteristic is very useful for photocatalytic applications. The larger the surface area, the greater the reaction that occurs on the Ag_3PO_4 surface. The second focus is how to immobilize Ag_3PO_4 and design a thin layer on the substrate. This design is used to avoid catalyst filtration processes in environmental applications. The third focus is how to expand the absorption spectrum of Ag_3PO_4. Currently, Ag_3PO_4 particles are only active in blue light. By extending the absorption of wavelength, Ag_3PO_4 will have activity in red light. This research is very important because it will harvest a lot of solar energy in the future.

CONCLUSION

The improvement of Ag_3PO_4 photocatalytic activity and stability can be achieved through surface modification and composite design. Ag_3PO_4-based photocatalysts are potentially applied for hydrogen/oxygen production, organic pollutant elimination, antibiotic degradation, antibacterial activity, and sensor. A g-C_3N_4 for Ag_3PO_4-based composite can exhibit an excellent activity, particularly for water splitting to generate hydrogen and oxygen production. Dye molecules, phenol, bisphenol A (BPA), and polyaromatic hydrogen (PAH) could be degraded using modified Ag_3PO_4. The antibiotic compounds of tetracycline hydrochloride (TCH), ciprofloxacin (CIP), and metronidazole (MNZ) have been demonstrated to be oxidized using the modified Ag_3PO_4. These photocatalysts showed high potential for killing bacteria such as Staphylococcus aureus and Escherichia coli. Also, the most interesting recent application of an Ag_3PO_4-based photocatalyst is in environmental sensing. Ammonia

(NH_3), hydrogen sulfide (H_2S), and tetracycline were shown to be detected using the sensor of an Ag_3PO_4-based photocatalyst.

ACKNOWLEDGMENT

This work was financially supported by the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia, in the Scheme of World-Class Research [024/E5/PG.02.00.PT/2022].

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KEY TERMS AND DEFINITIONS

Binary Composite: A mixture of two materials that results in new properties such as high catalytic ability or novel mechanisms.

Photocatalyst: Catalysts that work when exposed to light. The catalysts have semiconductor properties, in which the light can excite the electrons in the valence band to the conduction band, resulting in oxidation and reduction reactions.

Photo-Corrosion: Reduction reaction of silver ion on Ag_3PO_4 due to exposure to light. The reaction can degrade Ag_3PO_4 and decrease the photocatalytic activity.

Quaternary Composite: A mixture of four materials that results in new properties such as high catalytic ability or novel mechanisms.

Surface Modification: Design to change the surface structure through surface doping or the formation of surface defects that can lead to favorable properties.

Ternary Composite: A mixture of three materials that results in new properties such as high catalytic ability or novel mechanisms.

Z-Scheme Mechanism: The mechanism that occurs when two materials interact, in which the photogenerated electrons in the conduction band of one material encounter holes in the valence band of their partner materials to enhance reactions in the valence band and conduction band, respectively.

Chapter 8
Betung Bamboo-Based Magnetic Biochar for Dye Removal

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ABSTRACT

Water is one of the vital resources of human life. The rapid development of the industrial sector in developing countries is one of the main factors that contribute to water pollution, due to a lack of environmental awareness. Therefore, it is very important to remove the pollutants from industrial wastewater before being discharged into water bodies. Adsorption using inexpensive and high availability materials such as magnetic biochar is a promising alternative. Embedding magnetite (Fe3O4) into biochar not only aims to solve the separating problem, but also to strengthen the adsorption performance of the biochar. This book chapter introduces the preparation and characterization of magnetic biochar derived from betung bamboo. Furthermore, a discussion was conducted to provide a perspective on the use of magnetic biochar in adsorption technology, particularly in the removal of dyes in an aqueous solution. Finally, the isotherm models for the magnetic biochar-dye system are discussed at the end of this chapter.

DOI: 10.4018/978-1-6684-5629-3.ch008

INTRODUCTION

Water is one of the vital resources of human life. The availability of water on earth is very large, covering 70% of the earth of which 3% is available as freshwater. However, among these, only 0.06% are accessible. Unfortunately, most of the world's population lives in developing countries with the provision of clean water is still a serious problem. The rapid development of the industrial sector in developing countries is one of the main factors that contribute to water pollution due to a lack of environmental awareness. The discharge of wastewater into the stream without prior treatment has reduced the self-cleaning capacity of the water and increased the pollution of water bodies. It is further exacerbated by the fact that some synthetic dyes, heavy metals, and organic compounds contained in the wastewater are toxic, teratogenic, mutagenic, carcinogenic, and nonbiodegradable (Wang et al., 2022; Astuti et al., 2011). Therefore, it is very important to remove the pollutants from industrial wastewater before being discharged into the water bodies. Several researchers have developed biological and physicochemical methods to remove pollutants from wastewater, including electrocoagulation (Prasetyaningrum et al., 2018), coagulation-flocculation (Badrus, 2018), ultrafiltration membrane (Aryanti et al., 2015), UF membrane (Istirokhatun et al., 2015), micellar-enhanced ultrafiltration (MEUF) membrane (Aryanti et al., 2017), anaerobic sequencing batch reactor (Rahayu et al., 2015), biosorption (Hadiyanto et al., 2014), phytoremediation using microalgae (Soeprobowati and Hariyati, 2017), anaerobic baffled reactor (Sumantri et al., 2015), advanced oxidation processes (Azizah and Widiasa, 2018), and adsorption (Astuti et al., 2016). The adsorption process with the advantages of simple process, easy operation, high efficiency, and low cost is a great alternative (Chafidz et al., 2018). Coal fly ash (Astuti et al., 2017), coal bottom ash (Kusmiyati et al., 2017), zeolite (Imandiani et al., 2018), clay (Darmawan et al., 2019), composite (Chen and Tseng, 2022), chitosan (Wang et al., 2022), activated carbon (Al-Latief et al., 2015; Arnelli et al., 2018; Arnelli et al., 2019), and biochar (Meng et al., 2022) have been used as adsorbents. Among these materials, biochar is an environmentally friendly adsorbent and has high economic value for removing organic and inorganic pollutants in aqueous solutions, including dye (Astuti et al., 2022).

Biochar, a black carbonaceous material, can be produced through the pyrolysis process under limited or no oxygen conditions (Medeiros et al., 2022) at a temperature of 300-1000 ^{o}C from various types of biomass such as sludge (Liu et al., 2022), organic waste (Zhang et al., 2022), agricultural waste (Ajeng et al., 2022; Murad et al., 2022), algae (Sun et al., 2021), forest residue (Aghababaei et al., 2017), and animal manure (Hossain et al., 2021). Besides biochar, pyrolysis of biomass also produces bio-oil and syngas. Therefore, the operation condition needs to be considered to obtain high-yield biochar. As a carbon-rich material and highly aromatic solid substance, biochar has a high adsorption capacity in removing pollutants such as dyes and heavy metals in wastewater due to the properties of biochar associated with specific adsorption mechanisms such as hydrophobic and electrostatic interaction. In this sense, several characteristics of biochar such as rich organic carbon, high porosity, large specific surface area, and abundant functional groups are influential. Biochar can be engineered by surfactant (Y. Li et al., 2018), acid (Awasthi, 2022), base (Awasthi, 2022), and magnetic (Li et al., 2019), depending on the desired properties. Embedding magnetite (Fe_2O_3) into biochar (hereinafter referred to as magnetic biochar) not only aims to solve the problem of separating biochar from effluent which is sometimes difficult but also to strengthen the adsorption performance of the biochar (Yi et al., 2021).

On the other side, betung bamboo (*Dendrocalamus asper*), a member of the grass family, commonly grows in many regions, including Indonesia. This bamboo has better fiber morphology and physical-chemical properties compared to other bamboos such as andong, ampel, and black bamboo, with cellulose content of 45.02%, hemicellulose of 10.81%, and lignin of 28.35% (Astuti et al., 2022). It allows betung bamboo to be used as a raw material in biochar preparation. This book chapter introduces the preparation and characterization of magnetic biochar derived from betung bamboo stem. Furthermore, a discussion was conducted to provide a perspective on the use of magnetic biochar in adsorption technology, particularly in the removal of dyes in an aqueous solution. Finally, the isotherm models for the magnetic biochar-dye system are discussed at the end of this chapter.

PREPARATION AND CHARACTERIZATION OF MAGNETIC BIOCHAR

Biochar is a type of carbonaceous material having a large specific surface area. It can be obtained by pyrolysis of biomass. In general, the process of biochar preparation consists of two stages, namely dehydration and pyrolysis. Dehydration is the process of removing water contained in the precursor or main raw material. The dehydration stage can be carried out by drying the raw materials in the sun or heating them in the oven at a temperature of 110-120 ^{o}C to a constant weight. Meanwhile, pyrolysis is a thermochemical process of organic material through a heating process without or with a little oxygen or other reagents, resulting in an increase in carbon content and a decrease in the number of heteroatoms. Extreme pyrolysis that leaves only carbon as a residue is called carbonization. In solid-phase carbonization, the precursors, which are macromolecules, decompose with increasing temperature, accompanied by the evolution of gases and low molecular weight liquids as a result of decomposition in the pyrolysis process. In the preparation of biochar from betung bamboo, the pyrolysis process was carried out in a tubular furnace at a temperature of 500 °C under a stream of N_2 for two hours.

As previously explained, biochar is a carbon-based material having high porosity and abundant surface functional groups, which is made through the pyrolysis process of biomass waste (Qu et al., 2022). However, the separation of biochar powder from wastewater often requires complex centrifugation and filtration steps, which can result in limited biochar application and cause secondary pollution. Recently, relevant research has been directed towards the exploration of magnetism and its application as an effective adsorbent for the removal of contaminants. Magnetic biochar can be synthesized with a combination of magnetic materials (eg Fe, -Fe_2O_3, and Fe_3O_4) and biochar through pyrolysis and chemical coprecipitation processes (Qu et al., 2022). Compared with conventional biochar, magnetic biochar retains outstanding biochar properties and has magnetic separation characteristics. In the coprecipitation method, 3.33 g $FeCl_3.6H_2O$ was mixed with 1.83 g $FeSO_4.7H_2O$ in 300 mL distilled water and heated until the temperature reached 65 °C for 20 minutes. Then 10 g biochar was added and mixed properly. While stirring, the NaOH (2M) solution was added dropwise at 40 °C to increase the pH to 12 and precipitate iron (II) hydroxide from the aqueous solution. The stirring was continued for 1 hour and allowed to stand for 24 hours. After cooling, the solids were washed with HCl and distilled water until the pH of the filtrate was around 7 and dried in an oven at 80 °C to constant weight.

Before being used for adsorption, an analysis of the adsorbent material can be carried out to determine the physicochemical characteristics, including crystallographic structure, surface groups, surface morphology, and specific surface area. X-ray diffraction analysis (XRD) is a method for determining the crystallographic structure of a material that is commonly used in materials science. XRD works by irradiating a material with x-rays and then measuring the intensity and angle of scattering of x-rays coming out of the material. The XRD patterns of betung bamboo magnetic biochar showed that biochar was approaching the amorphous-like structure, while magnetite (Fe_3O_4) was identified through the presence of peaks at 2θ of 29°, 35°, 43°, 54°, and 62.9° which correspond to magnetite peak standards (JCPDS No. 96-900-2321). Surface morphology analysis was performed using a scanning electron microscope (SEM). The morphological structure of biochar shows the presence of shallow cylindrical pores of varying sizes. Some of the pores appear to be clogged with tar as a product of the carbonization process. After the magnetite embedding process into the biochar, it appears that some of the pores are filled and covered by Fe_3O_4 which causes a decrease in the specific surface area although the decrease is insignificant, from 325 m^2/g to 230 m^2/g. FTIR spectrum analysis was carried out to identify different surface groups on the biochar and magnetic biochar surface that function as active sites in the adsorption process. The biochar spectrum showed peaks at wavenumbers 3789.29, 3661.49, 3410.89, 2138.79, 1586.81, and

872.86 cm^{-1}. The peaks at wavenumbers 3789.29 cm^{-1}, 3661.49 cm^{-1}, and 3410.89 cm^{-1} indicate the presence of stretching vibrations of the octahedral O-H group from alcohol (Imran et al., 2020). The absorption band at 2138.79 cm^{-1} indicates the presence of weak transmission of C-C vibrations while the absorption band at 1586.81 cm^{-1} indicates the formation of carboxylate groups with the occurrence of C-H vibrations. Meanwhile, the peak in the absorption band of 872.86 cm^{-1} indicates an absorption stretch in the C-O vibration of the carboxylate group (Astuti et al., 2020). Meanwhile, in the biochar-magnetite spectrum, the absorption peaks were seen at wavenumbers 3789.25, 3659.75, 3433.31, 2133.20, 1616.50, 1054, and 579.50 cm^{-1}. Peaks at wavenumbers 3789.25, 3659.75, and 3433.31 cm^{-1} indicate the presence of hydroxyl group vibrations in the biochar magnetite (Imran et al., 2020) while the band at 2133.20 cm^{-1} can be attributed to C-C vibration. The C-O vibration of the carboxylate group was identified by the peak at wavenumber 1054 cm^{-1}. The presence of magnetite in biochar is seen by the presence of a peak at a wavenumber of 579.50 cm^{-1} which indicates the presence of the Fe-O bond vibrations (Astuti et al., 2019).

MAGNETIC BIOCHAR FOR DYE REMOVAL

As previously explained, dyes are a common source of water contaminants, which are widely applied in the paper, batik, textile, and printing industries. Water contaminated with dyes causes serious health problems, even small amounts of dyes in water harm the environment. In this case, magnetic biochar is effective in dye removal from an aqueous solution. There are several key factors on pollutant adsorption by magnetic biochar, including pollutant concentration, pH, and interfering ions. The adsorption efficiency generally increases with increasing initial pollutant concentration. In the remazol brilliant blue-magnetic biochar system, the amount of remazol brilliant blue adsorbed per unit adsorbent mass increases with increasing initial remazol brilliant blue concentration, and faster equilibrium was attained at a lower concentration. It may be related to the abundance of vacant sites at lower concentrations. In addition, the percentage removal of remazol brilliant blue by magnetic biochar was higher than that of biochar. It may be due to an increase in the number of active sites from magnetite. The adsorption of remazol brilliant blue dye by betung bamboo biochar increases from 75 to 96% with increasing dye concentration from 10 to 500 mg/L at a solution pH of 1 for 180 minutes. The embedding of magnetite into biochar increases the adsorption ability from 89 to 98% at an increase in the initial concentration of remazol brilliant blue from 10 to 500 mg/L at pH 1 for 180 minutes.

The solution pH greatly affects adsorbent surface charge, contaminant species forms, and the protonation degree of surface functional groups. When $pH < pH_{pzc}$

(zero charge point), a large number of H^+ or H_3O^+ ions fill the active site and form a positively charged adsorbent, which weakens the nucleophilicity of the functional group, resulting in electrostatic interaction with the negatively charged remazol brilliant blue dye, thereby increasing the adsorption effectiveness (Qu et al., 2022). When $pH > pH_{pzc}$, magnetic biochar having a negatively charged surface gives electrostatic repulsion to the remazol brilliant blue dye, thereby reducing the adsorption efficiency. In addition, the protonation rate of the material decreases with increasing pH, which allows more oxygen and nitrogen-containing adsorption sites, thereby significantly lowering the adsorption performance. Thus, the higher adsorption performance of remazol brilliant blue is relevant to the formation of more positively charged groups at low pH, which allows the interaction between the positively charged adsorbent functional groups and the negatively charged remazol brilliant blue dye stronger. The removal ability of remazol brilliant blue decreases from 93 to 10% with an increase in the solution pH from 1 to 11 at an initial concentration of remazol brilliant blue of 100 mg/L for 180 minutes, due to competitive adsorption of negatively charged remazol brilliant blue with the hydroxide complex. Thus, pollutant adsorption by magnetic biochar is highly dependent on solution pH and pH_{pzc} due to the protonation of functional groups on the biochar surface. It is important to determine the optimal pH and pH_{pzc} to maximize the removal of pollutants from wastewater.

It is known that water bodies are complex systems with both cationic and anionic substances. Thus, the ionic strength of the solution is an important factor influencing the adsorption of contaminants in wastewater. In the adsorption of remazol brilliant blue dye, the presence of other anions can reduce the adsorption efficiency due to competitive adsorption. The presence of competitive ions in this solution can not only limit the available adsorption sites but also change the surface properties of the adsorbent.

ADSORPTION ISOTHERM MODELS

The adsorption isotherm which describes the equilibrium of adsorbate molecules in the liquid and solid phase at constant temperature is used to estimate the adsorption capacity of the adsorbent. The adsorption isotherm models that are often used especially for practical purposes are Langmuir and Freundlich. Langmuir isotherm follows the assumption that adsorbate molecules are adsorbed by active sites in the adsorbent surface having homogeneous energy, each site only can bind one molecule. Adsorption allows monolayer adsorption, which only occurs until all active sites are occupied, and there is no migration of the adsorbate molecules to the other sites. In addition, no interaction between adsorbate molecules. The Langmuir isotherm can be expressed as Eq. (1) with the value of q_e is described as Eq. (2) (Astuti et al., 2019):

$$q_e = q_m \frac{K_L C_e}{1 + K_L C_e} \tag{1}$$

$$q_e = \frac{(C_i - C_e)V}{1000\text{m}} \tag{2}$$

with q_e (mg/g) is the amount of dye adsorbed per unit mass adsorbent, q_m is the monolayer adsorption capacity of the adsorbent (mg.g^{-1}), K_L (dm^3.mg^{-1}) is the Langmuir constant indicating the adsorption energy, C_i (mg/L) is the initial dye concentration, C_e (mg/L) is dye concentration in solution at equilibrium, V (L) is the volume of dye solution, and m (g) is adsorbent mass. Eq. (1) is solved by optimizing the correlation coefficient between the value of q_e data and q_e predicted from Eq. (1). The isotherm parameters are observed using the solver add-in feature of Microsoft Excel software by minimizing the difference between the experimental data and the model.

The Freundlich isotherm is an empirical equation describing the adsorption system in an aqueous solution very accurately. Moreover, the Freundlich isotherm model allows multilayer adsorption. The saturation in the adsorbent surface is ignored, leading to an increase in the amount of adsorbate adsorbed with an increase in the initial concentration of the solution. In addition, no interaction between adsorbate molecules. The Freundlich isotherm is formulated as (Astuti et al., 2019):

$$q_e = K_F C_e^{\frac{1}{n}} \tag{2}$$

with K_F (mg.g^{-1})(mg.dm^{-3})$^{-n}$ is the Freundlich constant indicating adsorption capacity, while n is an empirical parameter indicating the adsorption intensity or the bonding energy between the adsorbate molecules and the adsorbent. The parameters in Eq. (2) are observed by optimizing the correlation coefficient between the value of q_e data and q_e predicted from Eq. (2) using the solver add-in feature of Microsoft Excel software.

To evaluate the validity of the models, the sum of the square of the errors (SSE) defined as Eq. (3) and the non-linear chi-square test (χ^2) defined as Eq. (4) are used (Astuti et al., 2019).

$$SSE = \sum_{i=1}^{N}\left(q_{e,calc} - q_{e,meas}\right)^2 \quad (3)$$

$$\chi^2 = \sum_{i=1}^{N}\left(q_{e,calc} - q_{e,meas}\right)^2 / q_{e,meas} \quad (4)$$

with $q_{e,meas}$ is the value of q_e measured from the experiment, $q_{e,calc}$ is the value of q_e calculated from the isotherm models, while N is the number of measurements. On the betung bamboo magnetic biochar-remazol brilliant blue system, the Langmuir model is suitable for the experimental data due to it having the lowest error function value with a K_L value of 39.574.

SOLUTIONS AND RECOMMENDATIONS

One of the promising methods for overcoming the current pollution of water bodies is the application of biochar as an adsorption agent. Carbon-rich materials help reduce various pollutants while maintaining a sustainable environment. In this case, the type of raw material, operating conditions during the pyrolysis process, biochar modification, and targeting of certain pollutants greatly affect the efficiency of the adsorption process. This relationship can be identified through the use of various raw materials with the same preparation and pyrolysis methods to produce biochar with certain physicochemical characteristics and properties. Finally, the effect of the surface area is very important to consider because it is the most important parameter in the adsorption mechanism. Selectivity and sensitivity reviews also need to be studied in depth. Biochar can act as an adsorbent due to the presence of surface functional groups, suitable structure and pore size, and high surface area. Therefore, modifications are needed to increase its selectivity to certain contaminants. The addition of magnetite to biochar increases the adsorption ability although the specific surface area decreases. Thus, the surface functional groups have a greater influence on the adsorption of the dye than the surface area. On the other hand, pH, dose, adsorption time, and initial concentration of the solution affect the optimization of the process.

FUTURE RESEARCH DIRECTIONS

There are several aspects of potential future research, which should be considered in the use of biochar for the removal of contaminants in water, especially dyes:

- Many low-cost adsorbents are being developed by researchers, but the efficiency of the adsorbent is still limited at the laboratory scale. Research and applications in the field have not been widely explored.
- Biochar characterization plays an important role in influencing the efficiency of the adsorption process. The results of the characterization can be combined with the results of adsorption to develop a new isotherm model.
- Another neglected issue is the regeneration and disposal of residual waste from the adsorption process. The desorption of adsorbed contaminants on biochar needs to be considered for adsorbent recycling purposes. Regeneration can be carried out using heat treatment and biochar modification, but both methods may have adverse effects on the environment, so the research direction should focus on developing environmentally friendly techniques.
- Since the focus is on developing low-cost adsorbents to solve environmental problems, economic analysis should be considered.

CONCLUSION

One of the promising methods for overcoming the current pollution of water bodies is the application of magnetic biochar as an adsorption agent. In this sense, betung bamboo magnetic biochar has been successfully prepared and used to remove remazol brilliant blue dye. Embedding magnetite into biochar not only aims to solve the problem of separating biochar from effluent but also increases the adsorption ability up to 98%. The removal of remazol brilliant blue by betung bamboo magnetic biochar is following the Langmuir isotherm model.

ACKNOWLEDGMENT

The authors are grateful to the Ministry of Research and Technology/National Research and Innovation Agency of Republic Indonesia for the financial support of this research (Grant number: 32.25.3/UN37/PPK.6.8/2021) and to the Post-Doctoral WCU (World Class University) Program 2021 for the financial support of this publication.

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KEY TERMS AND DEFINITIONS

Adsorbate: The substance or contaminant which adsorbed by porous solid materials.

Adsorbent: A solid substance used to remove contaminants from liquid or gas that can harm the environment. A good adsorbent must have pores, cavities, and or active sites.

Adsorption: The adhesion of atoms, ions or molecules from a gas, liquid, or dissolved solid to a solid surface. This process creates a film of the adsorbate on the surface of the adsorbent. This process differs from absorption, in which a fluid is dissolved by or permeates a liquid or solid.

Adsorption isotherm: The relationship between the adsorbate in the liquid phase and the adsorbate adsorbed on the surface of the adsorbent at equilibrium at a constant temperature.

Betung bamboo: Betung bamboo (Dendrocalamus asper) is a type of bamboo that has a large stem circumference and belongs to the grass tribe. This bamboo has better fiber morphology and physical-chemical properties compared to other bamboos such as andong, ampel, and black bamboo.

Biochar: A carbon-enriched biomaterial generated in the combustion of biomass through a process called pyrolysis. It has a large specific surface area.

Magnetic biochar: Biochar which is easily attracted by the magnetic field.

Pyrolysis: a process of chemically decomposing organic materials at elevated temperatures in the absence of oxygen.

Chapter 9
Recent Trend of Renewable Energy From Agricultural Wasted Biomass

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ABSTRACT

The environmental issue occurs along with the waste released from the agricultural or agroindustrial sector. Biomass waste from agricultural or agroindustrial activities has potential value due to its composition and cost. The extraction and treatment of biomass could convert the organic compound into valuable material or energy source. A pretreatment or preprocessing needs to be applied before the application of biomass waste. Biogas, biohydrogen, and bioethanol are the most energy-providing source products from agricultural waste biomass. The technology is developed to obtain successful fermentation and generate optimum biogas and bioethanol. Biopellet production from biomass waste is also promising for a solid energy sources that recently developed. Conversion and utilization of biomass waste from agricultural or agroindustrial sectors not only promote environmentally friendly process results, but also deliver a circular economy.

DOI: 10.4018/978-1-6684-5629-3.ch009

INTRODUCTION

Waste is defined as an unavoidable by-product and a consequence of most human activity. It is classified into two main groups, municipal solid waste (including industrial and commercial waste) and agricultural waste (UNECAP, 2003). Biomass includes a variety of materials such as wood, sawdust, straw, seed waste, fertilizer, paper waste, household waste, sewage, etc. Agricultural biomass, a single-carbon renewable energy source, can store solar energy, which can be converted into various forms of fuel as well as chemicals through a sequential conversion process (Deb et al., 2019).

Massive agricultural biomass waste is commonly produced in a large-scale agricultural plantation and processing, for instance, cocoa and coconut husk (Campos-Vega et al. 2018; Akolgo et al, 2021), paddy straw (Zong et al., 2022) sugarcane bagasse (Kumar, Kumar, and Singh, 2021), etc. This causes an environmental problem if not processed properly. In addition, to solve the environmental problem, recent technology of biomass treatment proposes potential materials (Hakeem, Jawaid, aand Alothman, 2015) and renewable energy (Choiron et al., 2020a). The use of biomass waste as a renewable energy resource is projected to increase by 6% per year. One of the main features that make biomass a suitable energy source is that it can be burned directly in a waste conversion plant to generate electricity, or it can generate heat on an industrial and residential scale in a boiler (Perea-Moreno, 2019). Instead of direct burning, thermochemical or biochemical processes can be used to generate bioenergy from biomass in the form of heat, electricity, or biofuels (solid, liquid, or gas) (Clauser et al., 2021). Therefore, bioenergy from biomass waste is more environmentally friendly compared with fossil energy. On the economic potential side, the large-scale production of bioenergy from biomass waste will be feasible and very profitable in some scenarios for the next decade (Winchester and Reilly, 2015; Tomberlin and Mosey, 2013; Reid et al., 2020)

Utilizing agricultural biomass waste as a bioenergy source is facing challenges. Low caloric value and low energy density are the disadvantages of biomass. Most lignocellulosic materials have high water content and must be vaporized before they ignite and indirectly reducing the efficiency of the boiler. It also requires the preparation of individual materials such as compression, pre-treatment, etc. (Sivabalan et al., 2021). Bulky volume and low energy density of fresh biomass affect storage costs and transport efficiency.

The economic aspect cannot be separated from the application of technology to ensure its sustainability. The utilization of agricultural waste as renewable energy directly or indirectly can have a positive economic impact. Economics, Environment, and Energy are 3 main areas that can be interrelated. A circular economy is important in the application of technology for converting agricultural biomass into energy.

Potential Energy From Agricultural Waste

Agricultural biomass waste has various properties. Thermochemical techniques are most effective for the use of dry biomass. Biochemical process engineering for the production of biogas or liquid biofuels is most effective for moist biomass. The utilization of biomass through the conversion process. Process conversion of biomass to fuels, energy, or heat can go through direct combustion, gasification, pyrolysis, hydrolysis and fermentation, and anaerobic digestion (Ness and Moghtaderi, 2007). Except for direct burning, agricultural biomass waste requires pre-processing and pre-treatment before being fed into the conversion system. The degree of pre-treatment depends on the type of conversion, biochemical or thermochemical. Pre-treatment helps to change the physical, rheological, and chemical properties of the biomass, making it more suitable for conversion (Tumuluru, 2018). The preprocessing technologies for biomass conversion to energy are classified into three groups, those are mechanical preprocessing, thermal preprocessing, and chemical preprocessing. After preprocessing step, the production of bioenergy follows the anaerobic digestion process, biological process, chemical process, and thermochemical process (Cheng, 2017). Anaerobic digestion has been developed in the last decades. To achieve a successful anaerobic digestion process, several factors should be considered such as environmental factors (temperature, pH, nutrient, physical parameters), toxic substances, substrate and inoculum, and reactor design.

Temperature is one of the major influences on all of the above. The optimum temperature for an anaerobic reactor is 35^{o}C or greater. The optimum temperature will affect on degradation process, microorganism adaptation, the sensitivity of methanogenic bacteria, and the conversion of carbon-energy substrate to cell mass. pH is an important factor in anaerobic digestion. The acidity and alkalinity influence the methanogens microorganisms because they will grow in a neutral pH range (Stronach et al., 1986). Other factors (physical and nutrient) has various effect on the anaerobic digestion process. A well-identified specific nutrient requirement can enhance biogas production. Anaerobic digestion process using a single-phase generates methane and carbon dioxide as the final product. Anaerobic digestion also can be conducted using two-phase or two reactors. This process will separate the anaerobic digestion degradation stage into two stages. The first stage will promote hydrolysis, acidogenesis, and acetogenesis, whereas in the second stage/second reactor methanogenesis will occur (Srisowmeya et al., 2020)

A recent bioenergy product from agricultural biomass waste treatment is biohydrogen. Contrary to common commercial hydrogen that produces from the gasification of fossil sources, biohydrogen is produced from natural resources via fermentation. Some dominant hydrogen-producing bacteria are the genera *Clostridium*, *Enterobacter*, *Klebsiella*, *Citrobacter*, and *Bacillus*. As an energy carrier, hydrogen has 2.75 times greater than hydrocarbon value, 122 kJ/g (Chandrasekhar et al., 2015). The combustion of hydrogen will generate only water as output, this makes hydrogen an environmentally friendly energy source and becomes one of the future energy sources. The problem of hydrogen production via fermentation (dark fermentation) is low hydrogen yield and low energy efficiency.

Many studies were conducted with the purpose to enhance the hydrogen yield. One recent study is the application of hot compressed water (HCW) to the inoculum and substrate (Choiron et al., 2020b). The result showed that the hot compressed water condition 130^{o}C, 0.3 MPa for 60 minutes obtain the highest yield of hydrogen 112.07 mL H_2/g COD of biomass. Hydrogen production improved in several ways. First, the HCW will degrade the complex structure of biomass into a monomer through some pathways. This monomer (monosaccharide) will be easily consumed by hydrogen-producing bacteria and promote bacterial growth. Second, the HCW suppresses the methanogens from the inoculum and remains the hydrogen-producing bacteria. Third, the HCW also influence the ionic release from the substrate, some ion will support bacterial growth. This experiment was conducted on a lab scale as well as in other studies.

From an economic perspective, due to limitations on biohydrogen yield and production scale (limited to lab-scale only), the hydrogen production cost could vary in each study. The cost of hydrogen production is around $2.6/kg for dark fermentation using biomass as substrate. Hydrogen production costs for other processes showed in Table 1.

Table 1. Comparison cost data for hydrogen production

Processes	**Energy Source**	**H_2 cost ($/kg)**	**References**
Dark Fermentation	Biomass	2.6	Bartels et al., 2010
Photo Fermentation	Solar	2.8	Demirbas, 2006)
Steam Methane Reforming	Natural Gas	1.8 – 3.0	Acar and Dincer 2013; Acar and Dincer 2015; Kalamaras and Efstathiou, 2013; Penner, 2006; Baeyens et al., 2020
Gasification	Biomass	1.0-2.0	Acar and Dincer 2013; Acar and Dincer 2015; Baeyens et al., 2020
Photovoltaics and electrolysis	Solar	6.1-9.0	Acar and Dincer 2013; Acar and Dincer 2015; Baeyens et al., 2020

Increasing the hydrogen production scale and optimizing hydrogen yield can be a strategy to improve hydrogen production efficiency.

Bioethanol is one example of renewable energy that produce on a commercial scale. The United States and Brazil are the leader in bioethanol production using biomass as raw material. Molasses and corn are the main raw materials for bioethanol in the U.S, and sugarcane is commonly used in Brazil. The bioethanol process includes pretreatment, hydrolysis, and bioethanol conversion from sugar (Tse et al., 2021). Similar to biohydrogen production, bioethanol production involves microorganisms in its process. Most yeasts can convert many hexose sugars to ethanol by glycolysis. However, *Saccharomyces cerevisiae* is the most commonly used yeast for alcoholic fermentation due to its robustness and tolerability (Krantz et al., 2004). Fermentation efficiency and bioethanol yield depend on the raw materials, varieties, and organisms used. Biological and abiotic factors must also be addressed to ensure optimal fermentation rates and degrees. Different types of fermentation can be used to address some of these concerns (and help reduce yeast stress. In addition, additional supplements and adaptive responses improve yeast stress resistance (such as heat shock and ethanol shock) and improve fermentation performance (Tse et al., 2021)

Evaluating Energy Generated from Agricultural Waste

Organic solid waste is the residue from human activities in the form of solids and contains the main components in the form of carbohydrates, proteins, and fats. Organic solid waste can be generated by household activities, agriculture, animal husbandry, or the agricultural industry. The solid waste generated by households is generally in small quantities and is distributed according to the distribution of community settlements. The solid waste generated by agriculture, livestock, and the agricultural industry has a large amount and is usually concentrated. Organic waste that is returned to the environmental ecosystem in small quantities generally will not disturb the environmental balance. However, large amounts of organic solid waste will disrupt the environmental balance because the decomposition process in nature exceeds the carrying capacity of the ecosystem. Environmental issues regarding organic solid waste will be the topic of discussion in this paper.

Organic solid waste generally still contains macronutrient elements that cannot be utilized by humans. The tofu industry is one example of the agricultural industry that carries out the process of extracting protein components from soybeans as a source of human food. Solid waste produced by the tofu industry is in the form of tofu waste which still contains 17.4% protein content, 5.9% lipid content, and 16.8% crude fiber content (Mahardika et al., 2018). Environmental problems that arise when tofu waste is discharged into the environment are the process of protein decomposition (by bacteria and fungi) into odorous volatile components. However, how big is the effect? An overview of the amount of organic solid waste produced by the agricultural sector is presented in Table 2.

Table 2. Waste based on the amount of agricultural production in Jember regency

Commodity	Waste Yields	Waste Amount (ton)
Paddy	20	194.019,20
Cassava	30	14.340,90
Corn	47	193.570,91
Coconut	14	984,79

Source: (Rusdianto, 2014)

Alternative utilization of organic solid waste, among others, is used as raw material for energy production such as biogas and fuel. Organic kitchen waste has the potential to be converted into a source of biogas with a mixture of cow dung. Organic solid waste from the kitchen with a mixture of cow dung and diluted with water can produce methane gas as much as 65% to 69% (Srinvasa et al., 2017). The model for developing biogas originating from households is carried out using vegetable waste combined with cow dung and EM4 starter. The decomposition results produce less methane gas compared to other organic wastes due to the cellulose content which is more difficult to decompose by decomposing bacteria (Mukti et al., 2021).

The potential for biogas development with abundant organic waste resources can be found in landfills. The potential for developing biogas reactors in landfills is indicated by the amount of methane gas that can be produced in the waste heap. The results of the measurement of the amount of methane gas produced at the Klotok I Kediri garbage dump which was carried out in the morning and evening with three measurement locations, namely cell 1 (a pile aged 13 years), cell 2 (a pile aged about 8 years) and cell 3 (a pile aged about 8 years). less than 5 years) (Hariyanto et al., 2019). The most methane gas is produced in the waste heap in cell 2, which is an 8-year-old pile. In the long term, landfills have the potential to be developed as a source of biogas, as shown in cell 3 (13 years old pile) which still produces a large amount of methane gas.

The problem that is quite challenging in the development of the biogas industry is the reactor or methane gas catcher. The manufacture of reactors that can be installed in residential areas and maintenance of biogas installations by the general public is a challenge in itself because of the nature of methane gas that easily escapes through small gaps so that even the slightest leakage can reduce the effectiveness of the existing biogas reactor. The problem with industrial biogas installations at landfills is the area of land that must be covered to capture the methane gas that appears. The installation of gas distribution from the landfill to the final consumer is also a challenge because the location of the landfill, which is generally far from residential areas, will cause the installation of pipelines to reach consumers to belong.

Another alternative to the utilization of organic solid waste is as a solid fuel such as biopellet. Biopellet is a solid fuel in the form of rods with a length of about 10-20 mm. The calorific value of burning cassava peel on average is 3741.71 Cal/g or equivalent to 15715.19 J/g. The calorific value of cassava peel when compared with several biopellet raw materials that have been studied previously such as jatropha dregs – household industry (17550 J/g); dregs distance – traction industry (1624 J/g); Acacia firewood (17270 J/g) showed that cassava peel has the potential to be developed for further processing into biopellets (Rusdianto et al., 2014). Alternative energy sources, biogas and biopellet, have the potential to be applied in the agroindustry. Biogas can be obtained from waste released from the tofu industry, cattle fattening industry, and organic waste from other industries.

A CIRCULAR ECONOMY OF RENEWABLE ENERGY BASED ON AGRICULTURAL WASTE

The industrial revolution caused the use of industrial energy and transportation to be concentrated in developed countries. The industrial revolution led to global growth and rapid resource extraction, thus leading to high consumer demand. Industries in developed countries get their material resources from developing countries around the world. However, developed countries have the availability of capital resources and energy resources so that they can carry out extensive production systems with minimal labor. With these resources, developed countries can apply advanced technology to the production process. During production, process externalities such as waste and pollution that have the potential to degrade environmental quality have been neglected.

For more than a decade, the industry has been dominated by a one-way model of production and consumption. The one-way model means processing raw materials into products, selling them, using them, and then throwing them away. We know this model as "take – make – dispose" which developed during the industrial revolution as a linear economy model. The linear economic model only prioritizes production without thinking about how the goods produced will end (Kolesnik and Merkulina, 2021). Whether the resulting goods eventually become waste that destroys the soil or produces emissions into the air from the combustion products, is not the main concern of the linear economic model. Thus, the linear economy model is not compatible with the sustainability principle.

The principle of sustainability has three pillars, namely economic, environmental and social growth. The linear economy encourages excessive production volume by accelerating the product life cycle. Although high production volumes will accelerate economic growth, high production volumes require high use of natural resources (water, gas, and other resources) and materials (plastic, glass, metal). Due to the high volume of production, the production process waste and final product waste also increase, threatening higher environmental damage. Thus, the production strategy of the linear economic model no longer follows the requirements of environmental sustainability. Therefore, the circular economy or closed-loop economy model was developed.

A circular economy (CE) is a framework that refers to a sustainable economic system through the reduction and recirculation of natural resources. According to (Kopnina, 2017), the circular economy is a restorative and regenerative industrial design, which aims to keep products, components, and materials at the highest utility and value at all times. CE focuses on measuring the circularity of products and services as a basis for designing business policies and strategies with a priority on sustainability. CE practice is reviewed based on four dimensions, production, and consumption, waste management, use of secondary raw materials, innovation, and competitiveness. Thus, CE will create a closed production cycle with 3Rs (reuse, repair, remanufacturing) resource use, redefining producer-consumer into a "service–flow" rather than "sell–use" model and quantifying the value of natural resources.

The circular economy model is rooted in industrial ecology. The main idea in industrial ecology is to redesign industrial societies into specific ecosystems within the biosphere. Thus, the circular economy relies on a comprehensive system that is integrated with the industrial system and the components that make up the ecosystem. The circular economy is built by understanding how industrial systems work, how material and energy flows are managed, and how they interact with the biosphere. The advantages of implementing the circular economy model are 1). minimized pollution, climate emission, waste, and use of raw materials; 2). preservation of natural systems; 3). increased competitiveness; 4). social benefits.

Since the dawn of civilization, fossil resources have been explored to meet human needs because they are limited. Apart from causing extinction, the use of fossil fuels has led to a trade-off between economic growth and environmental degradation, especially in developing countries. An understanding of the process of providing fossil fuels and their use for the industry shows that fossil fuels cause environmental damage and climate change. This is according to the linear economy model because it follows the "take – make – dispose" pattern. Therefore, efforts to explore (Bagherian and Mehranzamir, 2020; Li et al., 2020), produce (Srivastava et al., 2021), promote Ebadian et al., 2020), and use renewable energy sources as an alternative energy replacement for fossil fuels continue (Nogueira et al., 2020).

The use of fossil fuels for transportation and industry causes a rapid increase in greenhouse gas (GHG) emissions compared to the period before the industrial revolution. To reduce dependence on fossil fuels, the use of renewable energy such as biofuels is seen as more promising to inhibit climate change. Biofuels are more environmentally friendly because they produce fewer greenhouse gas emissions than fossil fuels. However, there are several challenges to the commercialization of biofuels, meeting food versus energy needs, economic viability, and product quality.

The principle of the circular economy is that reusing the same materials to produce products will maintain the energy in the materials and products. This will ultimately reduce GHG emissions. Renewable energy sourced from agroindustrial waste is a circular economy practice (Kopnina, 2017). If renewable energy is produced from special crops (eg transgenic corn, transgenic sugarcane, transgenic soybeans) to produce biofuels, then this is a linear economy model. Renewable energy produced from biofuel crops causes competition to fulfill food needs, feed needs, and energy needs (fuel). In addition, planting biofuel crops has been proven to cause deforestation (Hecht, 2014), causing loss of biodiversity, causing flooding in the wet season, and causing drought in the dry season (Nogueira et al., 2020). In the end, the supply of fuel from biofuel crops threatens sustainability.

In addition to geothermal and wind, biomass is a potential source of renewable energy in Indonesia. Indonesia's biomass production potential reaches 146.7 million tons per year. The potential energy generated from geothermal is 17.97 GW, from wind is 60.64 GW, and energy potential from biomass is 31.69 GW. Biomass energy is produced from agricultural production and may come from the reuse process of agroindustry by-products. This model is following the circular economy model because the by-products or waste from industry are used continuously as raw material for renewable energy so that no part is left for further processing. For example, a circular (circular) system for processing sugar cane into sugar produces waste in the form of bagasse, molasses, and filter cake. The by-products (waste) from the industry are managed as raw materials for the ethanol, biogas, or briquette biofuel industry. Ethanol and biogas are used as fuel in industry and transportation. This innovation lowers GHG emissions compared to a linear process. Thus, recycling offers circulation in the economy instead of just generating waste.

SOLUTIONS AND RECOMMENDATIONS

Problems related to the amount of agricultural waste and the potential inherent in the waste and the high energy demand can be solved in various ways. The 3E approach, namely Economic-Environment-Energy, provides promising solutions to complex problems. The 3E approach through waste-to-energy (WTE) strategies has been developed and shows optimal results in several countries (Urive-Toril et al., 2019). Renewable energy is one of the economic drivers, especially in countries that shifted the full use of clean energy (Magazzino et al., 2021)

The 3E approach can provide different strategies depending on objectives, conditions, and technology readiness. For example, the optimum technology strategy for solid waste treatment (agricultural waste, municipal waste, etc) to generate energy in Malaysia (Tan et al., 2015) and China (Liang et al., 2022) is incineration and anaerobic digestion, while suitable technology for electricity generation in Thailand is incineration (Martsri et al., 2021).

FUTURE RESEARCH DIRECTIONS

Each region has different problem conditions and technological capabilities in handling agricultural waste. The role of the government through policies and regulations will have a major influence on the utilization and advancement of agricultural waste treatment technology. The focus of future research will be mostly on three main interrelated aspects, namely economy, environment, and energy. Optimization of existing technology for solid waste treatment in producing energy that has an economic impact will continue to be the main trend of future research. Environmental problems caused by agricultural waste can be solved using conversion technology to generate renewable energy. Shifting from fossil energy to clean energy is an inevitable future challenge for all countries.

CONCLUSION

Biomass from agricultural waste is a potential resource for generating energy. This conversion or transformation (waste-to-energy) has a positive effect on the economical sector. These three aspects (economic-environment-energy) take an important role in future research with technology integration. Optimizing existing technology is also more feasible as a strategy for the application of waste-to-energy technology.

ACKNOWLEDGMENT

The authors thank Diponegoro University for financial support through the Postdoctoral WCU Program 2021.

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KEY TERMS AND DEFINITIONS

Biochemical Process: This is based on breaking down the cellulosic part of the organic fraction of the waste stream.

Biohydrogen: The biological production of hydrogen via dark- and photo-fermentation.

Dark Fermentation: The anaerobic microbial conversion of organic matter to VFAs, H_2 and CO_2.

Hot compressed water: The region of condensed phase of water between the temperature range from 100 °C (boiling point of water) to 374 °C (critical point of water).

Molasses: By-product generated from the process of obtaining refined white sugar from sugar canes as well as from papermaking industries.

Photo fermentation: An organic substrate fermentative conversion, with light energy, by photosynthetic bacteria.

Thermochemical Process: The use of heat to promote chemical transformations of biomass into energy and chemical products.

Chapter 10
Development of Silica Thin Film as a Self-Cleaning Surface on Various Materials

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ABSTRACT

Materials with superhydrophobic surfaces have received great attention fom scientists recently. One of the materials that have this property is silica thin film. Silica thin film has been widely studied due to its high hydrophobicity and ability to be applied in various materials. Superhydrophobic silica thin film has a water contact angle of more than 150; consequently, it is suitable for applications as an anti-fogging, anti-reflective and self-cleaning material which is in great demand by the industry to develop. The development of superhydrophobic materials with self-cleaning capabilities has several advantages, such as reducing maintenance costs, increasing durability, preventing snow or ice adhesion, and protecting materials from the effects of environmental pollution. Superhydrophobic silica thin films have been developed in various materials that are on glass surfaces, wood surfaces, stainless-steel, and cotton fabric coatings. This chapter focuses on discussing the latest developments of superhydrophobic thin film silica applied on various materials.

DOI: 10.4018/978-1-6684-5629-3.ch010

INTRODUCTION

Materials with superhydrophobic surfaces have received much interest from scientists in the past few decades. The design of these materials is biologically inspired by natural adaptations or derivatives that have been observed on heterogenous types of surfaces, such as butterfly wings, lotus leaves, rice leaves, mosquito eyes, red rose petals, cricket wings, spider silk, fish scales, and considerably more. The surface exhibits superhydrophobic properties by nature which is water-resistant. Accordingly, its presence provides new insights into the artificial surface fabrication of superhydrophobic materials.

A superhydrophobic surface is a material surface once dropped with water, forms a relatively perfect globule, and will lightly flow in only a few-tilt. This surface can be obtained by coating the material with a silica-thin film.

Recent reviews of the design and fabrication of surfaces with particular limitations such as superhydrophobicity are available (Feng and Jiang, 2006). Surface roughness should be minimized to reduce light scattering so that light transparency can be achieved. Therefore, the long-scale formation of the surface micro/nanostructure and the appropriate chemical composition becomes very important in the preparation of silica thin films that exhibit superhydrophobic properties (Lin et al., 2011). Based on this, various coating methods have been proposed and studied to improve the surface preparation of superhydrophobic silica thin films through the construction of suitable surface geometric structures.

Recently, there have been numerous studies on silica thin film (Chang et al., 2015; Wu et al., 2014; Gurav et al., 2015; Purnomo et al., 2018) due to its high hydrophobicity as well as its versatile applicability. Superhydrophobic silica thin film has a water contact angle greater than 150^{o} (Sethi and Manik, 2018) and a low shear angle. Furthermore, superhydrophobic silica thin film has anti-fogging, anti-reflective, and self-cleaning capabilities that are in growing demand in the industrial sector to be advanced. Self-Cleaning is a prominent feature of several superhydrophobic surface applications and functions. The development of superhydrophobic materials due to their self-cleaning has plenty of advantages when implemented, such as minimizing maintenance costs, expanding durability, preventing snow or ice adhesion, and protecting the environment from pollution.

Superhydrophobic silica thin film has been utilized for material coatings in various scopes, such as glass to forestall condensation (Eshaghi & Mojab, 2014), wood to prevent rotting (Wang et al., 2011), mild steel to prevent corrosion (Zhang et al., 2020), for self-cleaning shoes and water-resistant cotton fabric (Latthe et al., 2019).

This article emphasizes the study of the latest progression regarding the manufacture of superhydrophobic silica thin film layers and the application of silica thin films on various materials such as coatings.

THE PREPARATION OF SILICA THIN FILM

Thin film is defined as a layer of material and has a thickness typically ranges from nanometers (nm) to micrometers (μm) (Fayomi et al., 2019). The fundamental formula for fabricating thin films consists of organic, inorganic, metal, or metal-organic mixtures that may have the properties of conductors, semiconductors, or insulators. The fabricating characteristics materials of thin films are low surface energy and roughness. Fluorocarbons, silicon, and some organic and inorganic materials are included in the low surface energy materials (Song and Rojas, 2013). Therefore, this discussion will thoroughly focus on the preparation of silica thin films.

There are several silica thin film-coating methods; sol-gel dip coating (Dhere, 2015; Elma and Setyawan, 2018; Brancatelli et al., 2011; Xu et al., 2017), spray coating (Polizos et al., 2018), electrodeposition (Wu et al., 2014; Zhao et al., 2020) and also physical and chemical vapor deposition (Abegunde et al., 2019; Zhang et al., 2017). In dip-coating, the substrate is pulled vertically from the coating bath at a constant rate (Brinker et al., 1992). Furthermore, Xu accomplished generating superhydrophobic silica thin film as a glass coating on anti-reflective solar cells via the sol-gel dip coating method (Zhang et al., 2017). The precursors were tetraethoxysilane (TEOS) and trimethyl ethoxy silane (TMES). The microscope slide was immersed in the sol solution for 5 seconds and then was pulled out. TMES is a hydrophobic reagent often used as a co-precursor with TEOS to synthesize collosol. Hydrophobic property is correlated to the three methyl groups of TMES molecule. Meanwhile, a base catalyst will induce a condensation reaction far higher than the hydrolysis reaction leading to the formation of spherical silica particles with an abundance of hydroxyl groups on the surface.

During the hydrolysis and condensation process of TEOS, silica nanoparticles with residual OH single bonds overflowing on the surface are gradually generated. The interaction between the -OH surface group on the silica and the $-CH_3$ on the side chain of the TMES molecule significantly modified the properties of the hybrid sol during the sol-gel process. After all, the surface of the silica particles will be covered by the $-CH_3$. The results exhibit the maximum transmittance reached 97.1% and 98.8% and the water contact angle of 152°. This study provided an effective strategy for fabricating superhydrophobic antireflective coatings, low manufacturing costs, superior antireflective performance, favorable self-cleaning, and feasible and extensive fabrication methods.

Wu et al. also fabricated a superhydrophobic silica film via the electrodeposition method as a mild steel coating to prevent corrosion (Wu et al., 2014). TEOS and dodecyltriethoxysilane (DTMS) as precursors. The hybrid silica sol-gel film was deposited onto the mild steel substrate from the precursor solution by utilizing the cathodic potential and deposition time. The intensity of the cathodic potential and deposition time affect the thickness (hardness) and contact angle of the film as presented in Table 1.

Table 1. Effect of potential and deposition time on contact angle and thickness of the thin film

Potential (V)	Contact Angle (°)	Thickness (μm)	Time (s)	Contact Angle (V)	Thickness (μm)
-1.0	127	1.45	100	149	1.5
-1.2	155	3.65	200	151	2.0
-1.5	160	4.40	300	155	3.75

The negative potentials or longer electrodeposition time will generate a thicker film and larger water contact angle. Electrodeposited thin hybrid silica films can maintain superhydrophobic properties (^{3}150°) within 48 hours of initial immersion. The results exhibited that the superhydrophobic film accommodates an effective barrier layer for the mild steel interface and increases the corrosion resistance of mild steel in NaCl solution. Thus, the superhydrophobic SiO_2/DTMS hybrid film can be used as corrosion protection for mild steel which competently prevents the corrosive media from penetrating the substrate.

SILICA THIN FILM IN VARIOUS MATERIALS

Utilization of the hydrophobicity of thin films has been implemented and is capable of fabricating a self-cleaning material thus it is effectively applied in either household or industry. The following points present several applications of thin film on various materials.

Glass Materials

The application of thin films as glass coatings has expanded recently. All things considered the uses of glass in daily and in the industry, such as high-rise building glass, car glass, window glass, etc. Mostly, the glass is still hydrophilic, in case that rains, it needs to be wiped manually so the glass remains transparent. It is inefficient.

The thin layers of glass material can be found in anti-reflective and anti-fogging coatings on glasses and car glass. An anti-reflective coating is an optical coating that is applied to the surface of lenses and other optical elements to minimize the reflection of light. The primary benefit is the elimination of the reflection itself so that when eyeglass lenses are coated with an anti-reflective coating, the wearer's eyes can be more visible to others. Contrastively, the thin layer on the glass material as antifogging induces a uniform layer film on the surface of the anti-fog glass because dew or water is unable to form detached droplets, so the surface has hydrophilic properties.

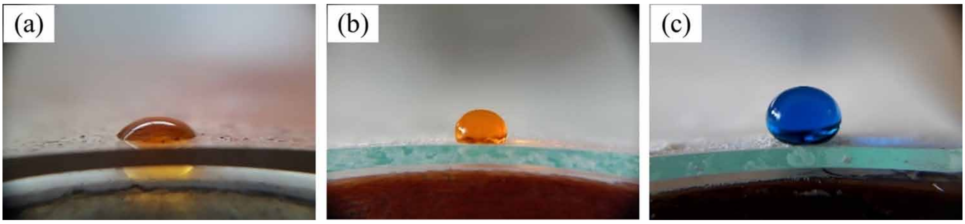
Research on silica thin film as anti-reflective and anti-fogging on glass materials was accomplished by Eshaghi & Mojab via layer-by-layer assembly method using polyacrylic acid/poly diallyl dimethylammonium chloride (PAA/PDDA) (Eshaghi and Mojab, 2014) and also Aghaei & Eshaghi via the sol-gel dip-coating method with polyacrylic acid and tetraethylorthosilicate (PAA/TEOS) precursors (Aghaei and Eshaghi, 2017). The results indicated that the transmittance spectrum of the silica nanoporous thin film intensified the transparency of the glass substrate from 91.8% to 97% (Eshaghi and Mojab, 2014) and 91.3 to 95.9 (Aghaei and Eshaghi, 2017) at 550 nm respectively. In addition, a thin layer of silica nanopores reduced the water contact angle of the glass surface from 67° to 3° for Eshaghi & Mojab while in Aghaei & Eshaghi's research from 51° to 2°.

The glass without coating became blurred or obscured, however, the glass that is coated with silica-thin film nanopores significantly inhibits fogging formation by close instantly scattering the condensed water droplets to form a dilute water layer, thus it keeps the surface clear interminably. Therefore, the silica nanoporous thin films exhibit high transparency and super hydrophilicity which exceedingly boost the antireflective and antifogging functions of the thin films.

Thin silica films for coating glass materials were successfully synthesized using TEOS and DMDMS precursors via the sol-gel method. The two precursors were varied with a certain ratio and then dissolved in ammonia to obtain a sol-gel solution. The thin film coating on the glass was fabricated via a dip-coating process and the glass was immersed with a withdrawal rate of 10 cm/min^{-1} and a residence time of 2 minutes. The results exhibited that the largest contact angle (128^{o}) was obtained using TEOS and DMDMS at a ratio of 1:1 with a calcination temperature of 300^{o}C. The hydrophobicity of the thin film was driven due to the presence of a methyl group from DMDMS as a co-precursor. DMDMS is hydrophobic while TEOS is hydrophilic, accordingly the proportion of the molar ratio affects the factor of the coated material. Surface roughness can be reduced in terms of the DMDMS content being quite high due to additional silane that fills the gaps between particles so that the coating is uniformly distributed and increases hydrophobicity.

Thin silica films were also successfully synthesized via the sol-gel dip coating method with TEOS and TMCS precursors. As illustrated in Figure 1, that the glass without thin film has a very low contact angle, while the glass coated with a thin film of silica displays a larger contact angle. The contact angle becomes higher in 5-time coating (Yayuk and Mernay, 2021).

Figure 1. Waterdroplets on the surface of glass, (a) without coating, (b) coated with a thin silica film twice, (c) coated with a thin silica film four times.



Mild-Steel Materials

Steel is widely used as a fundamental material in various industries. In general, steel is sensitive when in contact with air humidity which possibly inflicts a financial loss. Several researchers carried out the fabrication of superhydrophobic coatings as anti-corrosion protection on steel(Wu et al., 2014; Zhang et al., 2020; Zhang et al., 2016; Huang et al., 2019).

Zhang fabricated superhydrophobic silica thin film via electrodeposition method for corrosion protection of mild steel (Zhang et al., 2016). Tetraethoxysilane (TEOS) as a source of silica and dodecyltrimethoxysilane (DTMS) as precursors. Electrodeposition was conducted on an electrochemical circuit in a classic three-electrode compartment, which the Pt plate as the counter and the commercial electrode Ag/AgCl as the reference electrode. As a result, the superhydrophobic thin film qualified to shield the mild steel effectively when immersed in sodium chloride solution which was identified by measuring the contact angle and dissolution test of iron in saline. Based on the SEM images, the surface of uncoated steel indicated a smooth and compact morphology, while the surface of mild steel was coated via electrodeposition with thin film in a little while (10 seconds) and covered by a thin layer of silica particles. The electrodeposition film (E-SiO_2) modified by DTMS provided a low contact angle value of ~ 113°. At the longer electrodeposition process, the contact angle of the coated mild steel surface increased by 37%. Quantitative measurements exhibited that the silica film continued to rise on the steel substrate by prolonging the electrodeposition time. The superhydrophobic surface fabricated by this method exhibits high mechanical resistance to abrasion and good repairability to heat-crushing treatment.

Recently, Huang fabricated a cardanol-based superhydrophobic polybenzoxazine coating for corrosion resistance on mild steel (Huang et al., 2019). SiO_2 nanoparticles with a diameter of 20 nm were used. Cardanol-based polybenzoxazine and amino-modified silica nanoparticles were combined to develop a superhydrophobic (PC-a/SiO_2) coating on mild steel as an anti-corrosion coating. Polybenzoxazines have both intramolecular and intermolecular hydrogen bonds. The amino groups of SiO_2-NH_2 can also form intermolecular hydrogen bonds with phenol groups in polybenzoxazine. Therefore, the amino groups of SiO_2-NH_2 can react with benzoxazine during the fumigation process. The results indicated that a water contact of PC-a /SiO_2 was 162.8° and maintained superhydrophobic properties even after heat treatment at 250°C for an hour or immersion in 3.5% wt. NaCl solution for ten days.

Wood Materials

Wood materials are still commonly used in society, such as household furniture (tables, chairs, cupboards, etc.), house frames, and in the industry. However, it is easily rotten when frequently exposed to the dampness in the air, therefore it might be harmful and risky. As a consequence, a thin film coating is necessary to generate hydrophobic properties on the wood surface.

Begin with Wang made a superhydrophobic wood surface with a thin layer of silica via a sol-gel process (Wang et al., 2011). The precursors were fluorination reagents 1H, 1H, 2H, 2H-perfluoroalkyltriethoxysilanes (POTS) as a superhydrophobic surface modifier and TEOS as a silica source. As illustrated in the superhydrophobic surface formation scheme Wang et al. (2011), silica nanoparticles were deposited on the wood surface and modified surface with POTS reagents which generated a superhydrophobic surface. The comparison of the wettability of the three samples can be seen in Table 2.

Table 2. The water contact angle of three samples with and without treatment

Sample	Contact angle
Sample 1 (without coating)	59 °
Sample 2 (coated with silica nanoparticles)	0 °
Sample 3 (POTS modified)	123 °

Precipitation of silica nanoparticles treated by fluorination indicates high superhydrophobicity. This process turned the wood surface from hydrophilic to superhydrophobic with a water contact angle of about 164°.

In addition, Wang coated the surface of Cunninghamia wood with a nano-coating of silica particles and bonded it with long chain alkyl silane (Wang et al., 2013). The method was a sol-gel dip-coating process with TEOS precursors, ethanol, ammonium, and hexadecyltrimethoxysilane (HDTMS). As detailed in the superhydrophobic surface formation scheme, the initial stage of surface coating with silica nanoparticles was constantly hydrophilic due to the abundance of hydroxyl groups on its surface derived from TEOS. Therefore, the stage of hydrolyzed HDTMS saturating provided hydrophobicity to the wood surface since HDTMS has a long alkyl chain which enhances hydrophobicity. This circumstance was indicated by the water contact angle of about 141° on the longitudinal surface and 150° on the transverse surface. The results exhibited that the silica nanoparticles were deposited uniformly on the wood surface.

Fabrication of superhydrophobic wood surfaces which mechanically resistant using polydimethylsiloxane and silica nanoparticles was also undertaken (Chang et al., 2015). The materials used were TEOS as a precursor, HDTMS as a source of silica, polydimethylsiloxane (PDMS Sylgard 184), and samples of Chinese fir wood (*Cunninghamia lanceolata*). PDMS-coated on wood exhibited high water resistance with a contact angle of about 140°. When silica particles are injected into the PDMS film, the water-resistance properties are significantly enhanced. By increasing the mass fraction of silica-PDMS from 0 to 4, the previous contact angle of about 140° was enhanced to 152°. Subsequently, it moderately dropped and constantly remained at around 150°. As the ratio of silica particles to PDMS increases, the shear angle of the coated wood decreases drastically to 10° and water globules can slide off the surface smoothly.

The latest, Purnomo coated the surface of various materials (Purnomo et al., 2018). There are bamboo, zinc, and glass via spray coating method with trimethylchlorosilane (TMCS) and geothermal silica as a source of silica. In addition, the solvents for silica polymers were n-hexane, isooctane, and xylene. The results indicated that the silica thin film coating on all materials provided the same contact angle of about 180° as the TMCS concentration used was 5.5% (w/v). A high concentration of TMCS tends to generate a superhydrophobic film due to the transposition of silanol groups on the silica surface with alkyl groups. The effect of isooctane solvent can significantly induce hydrophobicity much more than the other two solvents. Decisively, superhydrophobic qualified to absorb water on the bamboo surface with a contact angle of about 70° (hydrophilic properties) into a water-resistant material with a contact angle of 180° (superhydrophobic properties).

Paper Material

Paper is a material globally used as a notebook, book, newspaper, or material for handicrafts. Paper, composed of cellulose, is easily crumbled due to liquids and humidity. Consequently, several researchers have developed a technique of coating silica nanoparticles on paper to boost the quality of the paper's properties.

In any of them, Yildirim succeeded in making the paper surface superhydrophobic via spin-coating with methyltrimethoxysilane (MTMS) as a precursor, dimethyl sulfoxide (DMSO) solvent, and an acid-base catalyst (Yildirim et al., 2011). As reported in the MTMS coating scheme, the DMSO solvent formed a homogeneous gel on the substrate, contrastively, the methanol solvent formed a heterogenous gel. The gel was rinsed with methanol as a solvent substitution via the colloidal suspension deposition method. Afterward, the colloid gel suspension yield was stable for several months and generated a hydrophobic film on paper with the formula 7 mL DMSO. Generally, uncoated paper has a hydrophilic surface and absorbs water promptly. To remedy the defect, the nanoporous film-coated paper exhibits superhydrophobicity with a contact angle of about 143°. Paper coated with SiO_2 has superhydrophobic properties because SiO_2 has the lowest number of residual hydroxyl groups, so it is rapidly substituted by hydrocarbon groups.

Fabric Materials

Developing surface properties of the material using silica thin film has become a lively attraction for industries, particularly in the textile industry. Garments that are washed routinely encourage the fabric to lose its luster and tend to shorten the life cycle. Thus, the coating of hydrophobic silica nanoparticles on the fabric is generated to maintain and upgrade the fabric surface so keeps durable.

Xu modified superhydrophobic cotton fabric by combining MTMS silica nanoparticles as a source of silica and HDTMS with base catalyst and surfactant (Xu et al., 2011). The preparation of silica hydrosols by the sol-gel method involving the hydrolysis and condensation of MTMS in an aqueous solution is further described in the scheme of the sol-gel process reported by Xu. Silica nanoparticle coating was manufactured by immersing the cotton fabric in a SiO_2. The cotton fabric was immersed successively in a hydrolyzed HDTMS alcohol solution. So the Si–OCH_3 in the HDTMS molecule was hydrolyzed to form alkyl silanol. The following dehydration reactions occur between the alkylsilane and the hydroxyl groups on the surface of the SiO_2 leading to the bonding of HDTMS into fibers with a coarse surface. Cotton fabric coated with SiO_2 with modified HDTMS has a high water contact angle (WCA) value reaching 151.9° attributed to excellent superhydrophobicity.

Shoe Materials

Indoor and outdoor activities are notable factors that encourage dust and dirt to stick to the shoes. As mentioned before, the daily wash generally can shorten the life cycle of shoes. So, superhydrophobic coatings are the best alternative to be applied as self-cleaning shoes.

Dong completely fabricated silica nanoparticles to form superhydrophobic surfaces with PDMS precursors that were applied to shoe soles (Dong et al., 2015).

Preparation samples were three types of structure: smooth, nano, and micro. The spray-coating method was used for the shoe soles. Three types of solutions were sprayed on the soles to generate a hydrophobic layer with a thickness of hundreds of micrometers. The result of the contact angle measurements obtained is presented in Table 3.

Table 3. The water contact angle of three different surface structures of products

Types of structure	Water contact angle	Hydrophobicity
Smooth	116.7° ±2.2°	Hydrophobic
Nano	154.3° ±3.1°	Superhydrophobic
Micro	170.8° ±3.8°	Superhydrophobic

In the hydrodynamic scheme of the surface flow of the shoe sole, Dong et al. (2015) reported that the superhydrophobic shoes were significantly qualified to suppress the overflow of muddy water and provide anti-splash performance. The shoes were verified by a 10 km walk test on muddy trails. In the long run, the edge of the hydrophobic soles was filled with dirt. Unlike the superhydrophobic shoes, the surface was able to eliminate the dirt so that it remained clean. This study provides an effective strategy for silica nanoparticles as a surface superwettability through chemical surface modification and surface morphology of micro/nanostructures. In particular, splash-proof shoes with superhydrophobic sole edges are fledging interest and opportunities in the shoe materials industry.

SOLUTION AND RECOMMENDATIONS

For the basic material for making a superhydrophobic surface layer, the authors suggest using materials that are abundant in nature, non-toxic, environmentally friendly, and have low prices. For example, utilizing geothermal waste which has a high silica content. Meanwhile, the method used to make a superhydrophobic surface layer, the authors suggest using a practical, efficient, and fast method so that it can be developed on an industrial scale.

FUTURE RESEARCH DIRECTION

Many approaches have been carried out for the fabrication of artificial superhydrophobic surfaces by adopting the central idea of micro/nanostructure and surface chemical composition. Superhydrophobic surfaces exhibit some outstanding properties such as anti-fogging, anti-reflective and self-cleaning. This capability has great potential for industrial applications. In recent years, several studies have been developed on methods to produce superhydrophobic surfaces, but most of these studies are limited to laboratory scale and have not been used in commercial products. To develop superhydrophobic surfaces on an industrial scale, research must be carried out by combining new theoretical models with newly developed techniques to determine the relationship between composition, structure, and other properties to obtain durable superhydrophobic surfaces. In addition, the availability and price of raw materials must also be taken into account. So that it is efficient and environmentally friendly when developed on a commercial or industrial scale.

CONCLUSION

Thin film is defined as a layer of material and has a thickness typically ranges from nanometers to micrometers that can be synthesized from silica-containing materials such as tetraethylorthosilicate (TEOS), trimethyl ethoxy silane (TMES), dodecyltriethoxysilane (DTMS), poly(dimethylsiloxane) (PDMS), and dimethoxy dimethyl silane (DMDMS). Moreover, thin silica films have excellent hydrophobic properties so that they are qualified and extensively applied as surface coatings in various materials such as glass, wood, mild steel, paper, cloth, and shoes for specific purposes for each material. Several parameters are examined, such as water contact angle and surface roughness, to determine the surface hydrophobicity of a material.

ACKNOWLEDGMENT

The authors are grateful to Diponegoro University for the financial support of this work through World Class University (WCU) program 2021.

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KEY TERMS AND DEFINITIONS

Anti-fogging: The physical property of material surface to prevent the water condensation into fog-like small droplets.

Anti-reflective: The physical property of material surface to reduce reflection.

Corrosion: A natural process transforming a refined metal into a more chemically stable form normally into its oxide.

Electrodeposition: Deposition of particles on the conducting surfaces using electrochemical principle.

Hydrophobic: Material surfaces having this property tend to avoid or repel water.

Hydrophobicity: Physical property of materials showing a tendency to prefer a nonaqueous over an aqueous environment.

Morphology: The study of shape, size, texture of materials.

Nanoparticles: Particles with the size in the range of 1 to 100 nanometres.

Precursor: Raw material used to produce another or a new material.

Self-cleaning surface: Materials having this property have ability to remove any dirt or wreckage and even virus or bacteria from their surfaces in several of ways.

Sol-gel method: Method applied to generate a new material by chemical transformation of a system from "sol" to "gel" phase.

Superhydrophobic: A measure of hydrophobicity with water contact angle > 150°.

Wettability: A measure describing the ability of fluid to spread on a solid surface.

Chapter 11
Utilization of Vegetable and Fruit Waste as Raw Material of Bioethanol

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ABSTRACT

Most of the fruit and vegetable production ends up as agricultural waste. The waste is generated not only from fruits and vegetable residues that cannot be consumed directly, such as seeds, peels, and stems, but also from the result of inefficient post-harvest processing, in addition to the perishable nature of fruits and vegetables. Those wastes undoubtedly become a problem to the environment because it contributes to gas emissions production. Meanwhile, those wastes contain lignocellulose, starch, or sugar, which can be processed into bioethanol. As is known, bioethanol is an alternative in dealing with the problem of dwindling fossil energy. So, this chapter will overview various fruits and vegetable waste potential as raw materials for bioethanol production and the processing steps such as hydrolysis, fermentation, distillation, and dehydration. Besides, it will suggest future research about bioethanol production from fruits and vegetable wastes.

DOI: 10.4018/978-1-6684-5629-3.ch011

INTRODUCTION

Vegetables and fruits are two horticultural plants needed by the human body. Along with the growth in population density, which tends to increase, the production of vegetables and fruits also increases. The number of vegetables and fruit produced is not entirely consumed by humans. There are parts of vegetables and fruits that are not edible, such as skins, seeds, stems, and roots, depending on the type of vegetables and fruits. The nature of fruits and vegetables, which are susceptible to spoilage, also increases the amount of waste produced from fruits and vegetables. On the annual report prediction of carbon footprint or the number of greenhouse gases (GHG), it was estimated that food waste could produce 3.3 Gigaton of CO_2 emission, where 26% of that value was contributed by vegetable & fruit waste (FAO, 2013). Substantively, the waste contains sugar, starch, and lignocellulose which can be converted into energy sources. On the other hand, energy demand increases while fossil energy reserves decrease. So, alternative energy sources are needed to overcome the problem. One alternative energy source that can be developed is bioethanol. Mixing fossil fuels with bioethanol can increase combustion efficiency, reduce carbon monoxide emissions released into the environment, and prevent overexciting fossil energy. Bioethanol plays an essential role in developing the use of renewable energy to overcome existing environmental problems. Bioethanol can be produced from biomass raw material.

Thus, this chapter will review the potential of vegetable and fruit waste in meeting the needs of bioethanol raw materials and the stages of the process carried out to produce the expected product quality.

BIOETHANOL DEMAND

Bioethanol is a type of ethanol produced through a fermentation process. This clear and colorless liquid is widely used in the cosmetics, pharmaceutical, perfume, food beverage industries, and transportation industries. Because it has a high-octane rating (Yukesh Kannah et al., 2020) and low lead, sulfur, and carbon monoxide (Sudiyani et al., 2019), bioethanol is increasingly used as a fuel. It has been named one of the alternative energies in meeting the demand for world energy, which increased yearly. The latest data on (U.S. Energy Information Administration, 2022) reported that from 2015 until 2019, the energy consumption grew from 567.329 to 601.04 quad Btu, where the average annual energy requirement was 584.4934 quad Btu.Of the total energy consumption, fossil energy still dominates. At the same time, based on projection data, it is said that around 2060, the world's fossil energy reserves will be exhausted (Saleem, 2022).

Therefore, currently, alternative energy sources such as bioethanol are being maximized. This utilization will undoubtedly encourage an increase in the consumption of ethanol fuel grade in the world market. This phenomenon has been confirmed in data by (U.S. Energy Information Administration, 2022), which showed a proportional increase in fuel ethanol consumption every year. Fortunately, this figure can still be met by the amount of existing fuel ethanol production. In value, the world fuel ethanol production increased from 2.189 to 2.448 quad Btu, while the consumption accrued from 2.212 to 2.422 quad Btu. In addition, the average annual fuel ethanol production was 2.300 quad Btu, while the consumption was 2.274 quad Btu. Therefore, it confirms that the opportunity to use bioethanol as fuel still has a large gap.

Bioethanol as a vehicle fuel has been applied by mixing it with gasoline. This blending fuel is known as "E." For example, if the mixture contains 5% bioethanol and 95% gasoline, the resulting mixture is called E5. The number following the letter represents the percentage of bioethanol used in the mixture. This mixed fuel has been widely used in Brazil, the US, and Europe, where the E5-E25 can be used directly without any engine modifications to the vehicle. Meanwhile, mixing higher ethanol content, namely E85 to E100, has also been carried out for flex-fuel vehicles (Hossain et al., 2021; Siciliano et al., 2021).

However, the application of bioethanol as a fuel in some countries is still constrained. One of them in Indonesia, gasoline blending bioethanol, has been applied, namely E5. However, due to the inconsistent supply of bioethanol fuel grades and the significant difference between the price of gasoline and bioethanol, the use of E5 has been stopped since 2010 (Sudiyani et al., 2019; Wright & Rahmanulloh, 2017). In the end, Nusantara bioethanol producers who are still operating choose to export because the export price is higher, making it more profitable. Even so, the government has begun to seek to return to the use of bioethanol in this Archipelago. This is related to the government's commitment to developing renewable energy as contained in Government Regulation No.79 of 2014 concerning National Energy Policy and Presidential Regulation No.22 of 2017 concerning the General National Energy Plan (RUEN), which targets the use of EBT up to 31% of the demand for renewable energy. national energy (Setyono & Kiono, 2021). The government's effort is to carry out the procurement of bioethanol type Biofuel by mixing it with RON 92 fuel oil in East Java (Energi, 2020), which is stated in the Strategic Plan of the Directorate General of Renewable Energy and Energy Conservation.

BIOETHANOL RESOURCES

Based on the development of the raw materials used, bioethanol has reached four generations. The first generation (G1) is produced from food crops containing sugar and starch (Haji Esmaeili, Sobhani, et al., 2020), such as sweet potato (Abdullah et al., 2015), corn, sugarcane, sugar beet (Sydney et al., 2019). The second-generation (G2) is produced from biomass containing lignocellulose, namely agricultural waste and woody materials (Haji Esmaeili, Szmerekovsky, et al., 2020), such as palm trunks (Kusmiyati et al., 2018), oil palm empty fruit branches (Sari et al., 2017), pineapple peel waste (Wandono et al., 2020). The third generation (G3) is produced from algae such as *Sargassum muticum* (del Río et al., 2019) and *Palmaria palmata* (Mutripah et al., 2014). The fourth generation (G4) is produced from genetically modified biomass such as sorghum phenotype (Deshavath et al., 2018) and transgenic rice straw (Ai et al., 2021). The biomass used in all these generations is biomass that contains carbohydrate chains, be it in the form of sugar, starch, or lignocellulose.

According to the data provided by Organisation for Economic Cooperation and Development (OECD, 2021), over the last five years, bioethanol was produced mainly utilizing maize as a raw material for an annual production value of 63220 million liters or about 90% of total production. Other following resources were wheat, sugar beet, sugar cane, and other resources such as sorghum, tuber, etc. These resources, of course, compete with the food needs. Where still become one of the issues for human life.

Currently, biomass waste is again attracting the attention of researchers in meeting the raw materials for making biofuels. In addition to being a solution for the environment, its availability is relatively abundant. It does not compete with food, which is a reason for the world to optimize its utilization further. On this occasion, the source of biomass that will be reviewed is vegetable and fruit waste. The production of these two horticultural crops each year has increased along with the increase in the human population. For example, in Indonesia alone, based on statistical data production of vegetables and fruits period 2016 to 2020 (BPS Indonesia, 2021), almost all commodities experienced a production increase each year, where the total production reached tens of millions of tons per year. The vegetables such as onion, chinese cabbage, capsicum anmum, capsicum frutescens, and tomato have an annual average production value of 1563227, 636994, 1187439, 1257471, and 985634 tons, respectively, or in another way, it was remarked as having enhancement about 5.97, 2.65, 5.04, 13.59 and 5.31%. Fruit production also ran into increment. For example, tangerine, mango, jackfruit, pineapple, and banana have an annual average increase of 6.58, 12.69, 6.15, 15.56 and 4.06%, respectively.

Table 1. Composition of several fruits and vegetables waste as bioethanol resources

No	Fruits & Vegetables Waste	Components	Bioethanol Obtained	References
1	Durian Peel	Hemicellulose: 13.09% Cellulose: 60.45%	Concentration: 8.5%	(Ginting et al., 2018)
2	Orange Peel	Hemicellulose: 6.1% Cellulose: 13.61% Sugar: 38%	Purity: 99.22%	(Fini & Fattahi, 2021)
3	Mulberry	Hemicellulose: 4.22% Cellulose: 9.68% Sugar: 75.30%	Purity: 83.56%	
4	Grapes	Hemicellulose: 7% Cellulose: 17.87% Sugar: 79.2%	Purity: 93.17%	
5	Avocado Seed	Starch: 21.3%	Concentration: 32.65%	(Rizwan et al., 2018)
6	Pineapple Peel	Hemicellulose: 74.96% Cellulose: 21.98% Sugar: 13.65%	Concentration: 36%	(Nulhakim et al., 2019)
7	Jackfruit Peel	Cellulose: 27.75% Starch: 4.12% Sugar: 19.75%	*	(Sundarraj & Ranganathan, 2017)
8	Mango Seed	Hemicellulose: 20.6% Cellulose: 55%	*	(Henrique et al., 2013)
9	Apple Pomace	Sugar: 10.36%	Purity: 99.5%	(Hernández et al., 2021)
10	Banana Peel	Hemicellulose: 6-8% Cellulose: 60-65%	*	(Novianti & Setyowati, 2016)
11	Suweg	Starch: 78.24%	Concentration: 13.2 g/L	(Hargono et al., 2019)
12	Potato	Hemicellulose: 0.045% Cellulose: 0.55% Sugar: 17.88%	Purity: 90.02%	(Fini & Fattahi, 2021)
13	Iles-Iles	Hemicellulose: 43.3% Cellulose: 8.54% Starch: 71.25%	Concentration: 13.13% Yield: 64.42	(Kusmiyati et al., 2016)
14	Cruciferous Vegetable Residue	Sugar:30%	Yield: 85.7%	(Song et al., 2017)
15	Carrot Pulp	Hemicellulose: 4%wt Cellulose: 16.8%wt Sugar: 27.6%wt	Concentration:40.63 g/L	
*No available data in the related reference				

The amount of production of vegetables and fruits that are abundant produces a comparable waste. It is said that the waste generated from vegetables and fruits is the number one contributor to the amount of food waste production, which is 42% (Ganesh et al., 2022). (Esparza et al., 2020) said that the solid waste produced by fruits is approximately 7.5%-23% of its wet weight and about 3%-11% for vegetables. The waste can be in the form of seeds, stems, roots, skins, or pulp leftover from the processing of the fruit and vegetable food industry, as well as vegetables and fruit that have rotted during distribution from upstream to downstream. The waste produced from these fruits and vegetables can contain lignocellulose, starch and sugar, which are the converted component in manufacturing bioethanol from biomass, depending on the type of fruit or vegetable waste. Table 1 provides component data on several types of fruit and vegetable waste. These data confirm the potential of fruit and vegetable waste to be used as raw material for bioethanol production. Although in the end, the process carried out in the conversion of these components will determine the amount and quality of the bioethanol produced. At least based on the previous research, it appears that there was an opportunity to obtain bioethanol with relatively high purity.

BIOETHANOL PROCESSING

Processing of biomass into bioethanol can be done through several stages, namely pretreatment, hydrolysis, fermentation, and purification stages. **Pretreatment** is an early stage that focuses on getting more substrate for hydrolysis. The pretreatment stage can be done physically, namely by heating, microwave radiation, chemically, by giving a strong acid or base, and biologically with the help of enzymes or bacteria. **Hydrolysis** is a chemical decomposition process in which water separates chemical bonds from a substance. The process of breaking down starch molecules into simpler molecules such as dextrin, isomaltose, maltose, and glucose is known as hydrolysis of starch. Because the hydrolysis process can be sluggish, a catalyst is required to accelerate the reactivity of water. Some catalysts used for hydrolysis are enzymes, concentrated acid, dilute acid, and other catalysts. (Rayana et al., 2014) cited the advantage of using the enzyme catalyst in hydrolysis, such as more accurate, more controllable and cheaper refining cost. However, (Darmokoesoemo et al., 2016) stated that using an enzyme catalyst requires a high cost and the rate of reaction still tends to slow due to enzyme activation. On the other side, hydrolysis using the dilute acid catalyst had advantages, like only needing a small quantity of acid and a short residence period. Nevertheless, the process necessitated a high temperature resulting in a decreased sugar output (Herliati et al., 2018). Meanwhile, that study mentioned that using the concentrated acid catalyst in the hydrolysis process may be done at low temperatures, and the sugar yield was high. However, the significant amount of concentrated acid catalyst could evoke corrosion of equipment, particularly iron tools. Besides, the process required a long reaction time, ranging from two to six hours.

Fermentation is a biocatalyst process in which microorganisms and enzymes turn carbs into simple sugars and sugars into alcohol or acids (Hossain et al., 2017). Bacteria, fungi, and yeasts are examples of microorganisms that aid in fermentation. The alcohol generated during the fermentation process is 8-10% (Maharani et al., 2021). The fermentation process can be performed in two ways: spontaneous and non-spontaneous. Spontaneous fermentation is an easy and affordable process with a high economic value. However, it takes a long time to ferment due to growing slowly, being difficult to control, and can cause contamination from unwanted microbes (Jayus et al., 2019). In contrast, (Hidayanto, 2017) stated that non-spontaneous fermentation demand a short fermentation period, and the process conditions could be regulated. Nevertheless, it also has a disadvantage: the process can be costly.

The last stage is the purification stage. The purification stage can be carried out by the distillation process. **Distillation** is a purifying method involving heating liquid substances and condensing the evaporated liquid with a condenser. The basic principle of distillation is the difference in boiling points of liquid substances in a liquid mixture, with the lowest boiling point substance (compound) evaporating first, then condensing and dripping as a pure substance when cooled (distillate) (Nadliroh & Fauzi, 2021). There are many types of process distillation such as conventional distillation (simple distillation), multivel distillation (fractional), vacuum distillation (low pressure distillation), and azeotropic distillation. (Mustiadi et al., 2020) mentioned that conventional distillation was more straightforward and uncomplicated to conduct than other distillations. However, this process only works well on components with a wide range of boiling points. On the other hand, multi-stage distillation (fractional distillation) can be applied to the mixture with a slight difference in boiling point. Besides, the evaporation and condensation times are shorter, and the temperature is more adjustable during the process. Nevertheless, this distillation also has disadvantages, like requiring intensive energy (Ping et al., 2022) and being incapable of separating azeotropic liquid solutions. Vacuum distillation is highly recommended for separating unstable compounds, which can decompose before achieving the boiling point during the heating process. Because it requires a low temperature, it becomes more energy-saving than conventional distillation (Li et al., 2022). However, vacuum distillation can not be performed for solvents with a low boiling temperature for condensers employing cold water because the volatile components cannot be condensed by water (Mustiadi et al., 2020).

After reaching the azeotrope point, purifying ethanol from the water will experience a problematic separation. It requires a particular separating method to break the chain formed. The distillation method which can be applied in such conditions is azeotropic distillation. Azeotropic distillation introduces additional components or entrainer in the separating process. This process requires much energy and needs integration for economical processes (Kunnakorn et al., 2013). Another method in purification stage is distillation-adsorption, utilizing porous media to obtaining large amounts of ethanol (Yuliana et al., 2015). The process of attaching molecules in specific fluids, both liquid and gaseous fluids, to the pore surface of the solid that functions as the adsorbent are known as **dehydration/adsorption**. This phenomenon indicates that this process involves contacting a solution or gas with an adsorbent material, which is a solid material, such that the solution or gas is absorbed near the surface of the solid pore, and the solution's composition changes. The adsorbed substance is known as the adsorbent, and the adsorbent is known as the adsorbate (Amrullah et al., 2021).

FUTURE RESEARCH DIRECTIONS

(Herdini et al., 2020) stated that the proper method of carbohydrate synthesis to produce bioethanol levels of petai peel (*Parkia speciosa* Hassk) was acid hydrolysis. The effect of the presence of a monosaccharide-positive hydrolysate solution resulting from acidic hydrolysis through the fermentation process affected the number of bioethanol products. Long-time hydrolysis correlated with bioethanol levels produced from petai peel. The results showed that an acid concentration of 2.0%, a temperature of 70 °C, a hydrolysis time of 120 minutes, and *Saccharomyces cerevisiae* inculcated for five days produced the highest bioethanol levels of 3.0%. The carbohydrate composition of petai was nearly identical to that of barley seeds, which have a carbohydrate content of 63.2% (Febriyanti & Suparti, 2019). According to (Putra, I Wayan Arief Pradana Kartika & Panggabean, 2017) research, bioethanol might be produced from barley seeds using an enzymatic hydrolysis process and a fermentation process including *Saccharomyces cerevisiae* bacteria fed with *Spirulina sp*. The hydrolysis process was carried out at a 4-5 pH, followed by liquefaction with the α-amylase enzyme and saccharification with the glucoamylase enzyme. The fermentation process was carried out for 5, 7, and 9 days at 36^{o}C, with *Spirulina sp*., added in 0.5%, 1.0%, and 1.5%, respectively, with a weight ratio of *Spirulina sp.* per volume of the fermentation process. The cultured bioethanol was distilled for 3 hours at 78°C to separate the bioethanol and get high amounts of bioethanol. According to gas chromatography examination, the highest bioethanol purity of barley seeds was 93.096%, with the addition of *Spirulina sp.* as much as 1.0% with a fermentation duration of 7 days. (Susmanto et al., 2020) evaluated the optimal substrate efficiency, bioethanol content, fermentation period, and kind of nutrition in producing bioethanol from durian seeds. The procedure of washing, stripping, drying, and lowering the size of durian seeds was the starting point for the research. The hydrolysis procedure was then carried out with 750 mL of 0.3 mL H_2SO_4 acid catalyst, followed by *Saccharomyces cerevisiae* fermentation at pH 4. The fermentation process was carried out for 24, 40, 72, 96, 120, 144, and 168 hours, with 3% and 4% urea and NPK added. After that, the fermented product is refined by distillation. Comparing the addition of nutrients in urea to the addition of nutrients in NPK, urea resulted in more significant amounts of bioethanol. The bioethanol concentration produced in the 3% urea sample tended to decline after the optimal condition was attained after 120 hours of fermentation time. Meanwhile, the 4% NPK sample had the greatest bioethanol concentration at 144 hours of fermentation time, and after that, the bioethanol level started to decline. The highest bioethanol content was 57.1429%, with the addition of 3% urea. In this experiment, the maximum substrate efficiency was 99.24%. (Agustina et al., 2021) used wasted fruit and vegetable peel waste as raw material for generating bioethanol. A hydrolysis reaction utilizing an H_2SO_4 acid catalyst with concentrations of 0.5%, 1%, and 5% was the first stage of the bioethanol manufacturing process. The fermentation method used 1 gram of *Saccharomyces cerevisiae* yeast dissolved in 100 mL of distilled water as the following step. The fermentation process was delayed for nine days to get ethanol and water. The fermentation products are next purified for 12 hours using a distillation procedure. Bioethanol was produced from organic waste generated from fruit and vegetable peels with varied catalyst concentrations. The inclusion of a 1% H_2SO_4 catalyst resulted in ethanol with a high content of 25% and a density of 0.9151 grams per liter.

The previous study indicates that each stage of the process influences the manufacture of bioethanol from vegetable and fruit waste, starting from the type of catalyst used in the hydrolysis process, providing additional nutrients during the fermentation process and the purification process carried out. However, the raw materials used in these studies are homogenous or from only one type of vegetable or fruit waste. In actual condition, the vegetable and fruit waste has been mixed or can come from two or three types of fruit and vegetable waste. As the previous parameters affect, the variation of the waste used will affect the bioethanol product produced. In addition, in its application to overcome the existence of vegetable and fruit waste in reality, this step becomes one of the insights that need to be considered. (Song et al., 2017) have researched the manufacture of bioethanol with raw materials of a mixture of cruciferous vegetable waste consisting of broccoli, beets, cabbage, Chinese cabbage, and kohlrabi. The results reported by the authors indicate that the yield of ethanol obtained is quite large, which is around 85.7%. However, the data reported by researchers regarding the difference in raw materials for mixed waste and homogeneous waste is still limited to the enzyme hydrolysis stage. Besides, bioethanol production from those various resources was studied at a laboratory scale, while the industrial scale was still limited. It is essential to scale up bioethanol production to an industrial scale to implement the process. Because commonly, when operation conditions at the laboratory are adopted for more significant production, the biggest challenge is to control the quality while obtaining the quantity desired. It needs an optimization process. Therefore, it is highly recommended to study the optimization process of bioethanol production on an industrial scale.

CONCLUSION

Vegetable and fruit waste has the potential to be used as raw materials for bioethanol production. In terms of availability, the number is increasing every year as the increase in the human population. Meanwhile, hemicellulose, cellulose, and sugar are in relatively high amounts from the constituent components in several types of vegetable and fruit waste, such as suweg and pineapple peel. Indeed, the process stages become a challenge in converting the waste into bioethanol. However, from previous research carried out, it is not impossible to obtain bioethanol with high purity from these raw materials. As a recommendation, for further research, it is necessary to conduct research on the manufacture of bioethanol from a mixture of fruit and vegetable waste.

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KEY TERMS AND DEFINITIONS

Adsorption: The process of absorbing a fluid in an absorbent substance and forming a thin layer on its surface.

Biomass: This is all organic compounds derived from algae, agriculture, and organic waste.

Distillation: This is the process of separating a mixture of liquida based on the difference in its boiling point.

General National Energy Plan: This is a government policy related to energy planning management related to the implementation and implementation of energy policies of all related sectors in order to achieve predetermined targets.

Greenhouse gasses: This is a gas that absorb and emit radiant energy within the limits of thermal infrared thus causing the greenhouse effect.

Section 3

Adaptation and Mitigation Strategies for Developing Countries

Chapter 12
iTCLab Temperature Monitoring and Control System Based on PID and Internet of Things (IoT)

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ABSTRACT

The rapid increase in applications that combine modern concepts and innovations, due to the development of the internet of things (IoT) and cloud computing around the world, make all areas of life continue to move towards an advanced and intelligent society. This innovation continues to enter almost all fields, ranging from simple to complex innovations. In this chapter, IoT is used as a means for tuning PID parameters, when the error does not converge to zero. The experimental results show that the PID parameter tuning process can be done through IoT. And the results are quite encouraging, as an alternative way of tuning PID parameters.

DOI: 10.4018/978-1-6684-5629-3.ch012

INTRODUCTION

Internet of things (IoT) is a developing region in which billions of keen objects are associated with one another utilizing the web to share information and assets (Rahmat, Moeljani, Widjajani, Sudiyarto, & Harianto, 2021). IoT innovation permits objects around us to be associated with the internet network. Where each object associated with the internet can be accessed anytime and anyplace. For illustration, able to remotely turn on and off machines at domestic (lights, TVs, stoves, radiators, etc.) as long as the equipment is associated with the IoT cloud and an online association is accessible. In general, the IoT architecture consists of an Application Layer, Middleware Layer, Network Layer, and Physical Layer (Rahmat et al., 2021, and Ravidas, Lekidis, Paci, & Zannone, 2019). The basic system of the IoT consists of 3 components, namely hardware or physical (things), internet connection, and cloud data center as a place to store or run the application (Rahmat et al., 2021). Some of the research on IoT and its application can be read in the following papers: Internet of things based attendance system design and development in a smart classroom (Eridani, Widianto, Windasari, Bawono, & Gunarto, 2021), Simplified automatic VAR/Power factor compensator using fuzzy logic based on internet of things (Luqman, Lestari, & Setiawan, 2019), Development of a smart parking system based on internet of things using object-oriented analysis and design method (Maulana, Adhy, Bahtiar, & Waspada, 2020), Smart Greetthings: Smart Greenhouse Based on Internet of Things for Environmental Engineering (Sofwan et al., 2020), Development of Controller for Internet of Things Based Anti Pollution Smart Toll Gate System (Syafei, Afiq, Wahyudi, & Hidayatno, 2020), LoRa Gateway as Internet of Things (IoT) Infrastructure Components on Undip Vocational School (Tadeus, Yuniarto, & Mangkusasmito, 2020), and lastly Door and light control prototype using Intel Galileo based Internet of Things (Windarto & Eridani, 2017).

In this paper, IoT is used as an alternative tuning of the proportional integral and derivative (PID) parameters of the internet-based temperature control lab (iTCLab) temperature control system. iTCLab is a temperature control kit for feedback control applications with an ESP32 Microcontroller, LED, two heaters, and two temperature sensors. The heater power output is adjusted to maintain the desired temperature set-point. Thermal energy from the heater is transferred by conduction, convection, and radiation to the temperature sensor. Heat is also transferred from the device to the environment.

This iTCLab kit is inspired by BYU (Brigham Young University) TCLab Products (BYU, 2018), one of the private campuses in Provo, Utah United States. This iTCLab kit is a miniature control system in a pocket that can be used as a practical IoT learning package, IoT programming, and IoT-based control system practice. This kit can also be used to learn system dynamics and control systems, Arduino and Python programming, Machine Learning programming, and others. One of the control system strategies that can be applied to this iTCLab Kit is PID control.

The most famous control system in the industry is the PID. PID combines three proportional, integral, and derivative control actions. Each of these control actions has certain advantages, where the proportional control action has the advantage of a very fast rise time, the integral control action has the advantage of reducing errors, and the derivative control action has the advantage of reducing errors or reducing overshoot. The purpose of combining these three control actions is to produce output with fast research time and small errors. Several studies on the application of PID control systems can be read in the following papers: PID controller tuning by differential evolution algorithm on EDM servo control system (Andromeda, Yahya, Samion, Baharom, & Hashim, 2013), Design of Adaptive PID Controller for Fuel Utilization in Solid Oxide Fuel Cell (Darjat, Sulistyo, Triwiyatno, & Julian, 2018), Design and simulation of PID controller for lower limb exoskeleton robot (Munadi, Nasir, Ariyanto, Iskandar, & Setiawan, 2018), Design of Gain-Scheduled Fuzzy PID Controller for AFR Control System of SI-Based Motorcycle Engine Model (Panjaitan, Kurniahadi, Triwiyatno, & Setiawan, 2020), and Development of hovercraft prototype with stability control system using PID controller (Riyadi, Rahmando, & Triwiyatno, 2017).

The PID controller in its work automatically adjusts the control output based on the difference between the set-point (SP) and the measured process variable (PV), as the control error e(t). The controller output value u(t) is transferred as a system input. Each relationship used is as shown in Equations (1) and (2) (BYU, 2018).

$$e(t) = SP - PV \tag{1}$$

$$u(t) = u_{bias} + K_c e(t) + \frac{K_c}{\tau_I}\int_0^t e(t)\,dt - K_c \tau_D \frac{d(PV)}{dt} \tag{2}$$

$$u(t) = u_{bias} + K_c e(t) + \frac{K_c}{\tau_I}\sum_{i=1}^{n_t} e_i(t)\Delta t - K_c \tau_D \frac{PV_{n_t} - PV_{n_t - 1}}{\Delta t} \tag{3}$$

Equation (2) when expressed in digital form as shown in Equation (3) (BYU, 2018).

From Equation (3) it can be seen that three parameters determine the success of the control process, namely gain Kc, integral time constant I (τ_I), and derivative time constant D (τ_D). The process of searching or setting or tuning to obtain the best Kc,

τ_I, and τ_D values is generally called the tuning process. In this paper, a remote tuning process method is proposed using an internet connection via the MQTT protocol.

PID controller setup generally involves controlling four variables:

- Rise time: the amount of time it takes for the initial output of the system to rise past 90% of its desired value.
- Overshoot: the number by which the initial response exceeds the set-point value.
- Resolving time: the amount of time it takes for the system to converge to the set-point value.
- Steady-state error: the measured difference between the system output and the set-point value.

The purpose of the PID controller is to take the input value and maintain it at a certain set point over time. However, if the values for the three PID parameter controller loops are selected incorrectly, the system will become unstable through one of the numbers of failure modes. Usually, it involves output deviant with or without oscillation and is limited by the physical characteristics of the control mechanism, including actuator disconnection, sensor and encoder burnout, etc.

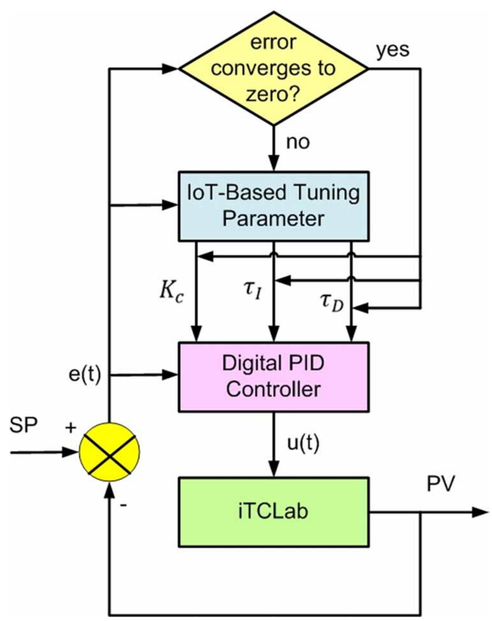
BACKGROUND

A control system can be said to be perfect if it can perform disturbance rejection (capable of returning the process that has been affected by disturbances back to a stable state) or also able to overcome the tracking set-point (the controller can produce a stable state even though we change the set point value). One of the tasks of the controller component is to reduce the error signal, namely the difference between the value of the set-point (SP) and the measured process variable (PV). This is consistent with the objective of the control system to get the measured process variable (PV) equal to the value of the set-point (SP). The faster the system reaction follows the set-point and the smaller the error that occurs, the better the performance of the applied control system. If the difference between the set-point value and the value of the measured process variable is relatively large, a good controller should be able to observe this difference to immediately produce appropriate control actions to affect the plant. Thus, the system rapidly changes the plant output until the difference between the set-point (SP) and the measured process variable (PV) is as small as possible. This is where the PID parameter tuning plays an important role to produce the best control performance. So far, the parameter tuning process is only carried out in places where the control process is carried out. This paper proposes a remote PID parameter tuning process using Internet of Things (IoT) technology. Thus, this study provides an alternative solution to the PID parameter tuning process, to produce the best control system performance.

METHODOLOGY

As explained above, the basic Internet of Things (IoT) system consists of 3 things, namely hardware or physical (objects), an internet connection, and a cloud data center as a place to store or run applications. This paper proposes a PID parameter tuning technique through IoT. The plant used for testing is the internet-Based Temperature Control Lab (iTCLab) kit. Cloud IoT as the MQTT Broker we use is hivemq.com. The port and protocol information from the broker will be used as the setting of the microcontroller program on the iTCLab system. The illustration of the PID parameter tuning system architecture in the iTCLab Temperature Control System is shown in Figure 1. While the temperature control method via IoT uses PID on the iTCLab Temperature Control System as shown in the figure 1. From this control method, the authors intended to use general PID parameter tuning using the Ziegler-Nichols method or a trial using arbitrary parameter values. When the

Figure 1.



output of the iTCLab system does not immediately enter the expected set-point or the error does not converge to zero, then another tuning alternative is needed. In this study, remote tuning is proposed using IoT technology via an internet connection.

The three PID parameters are played by being given intuitively the values that are expected to produce the best control performance, which can be given directly in the parameter settings via a cellphone using the IoT MQTT Panel. If the output error decreases or the output approaches the set-point the parameter values are retained. The advantage of tuning parameters through IoT is they can be controlled and monitored remotely. The same technique can be applied to general control systems using PID controllers for solving other cases. This technique, apart from being an alternative solution for remote control and monitoring, also presents its challenges for further development.

SOLUTIONS AND RECOMMENDATIONS

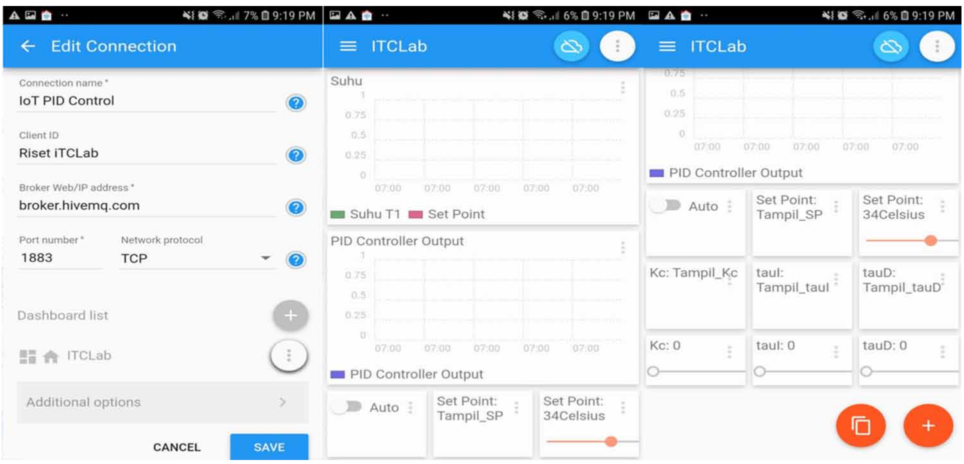
The kit used for testing in this experiment is the internet-based temperature control lab (iTCLab) kit. The iTCLab is a printed circuit board (PCB) shield that connects to an ESP32 microcontroller. The iTCLab shield has two transistors as heaters and two LM35 temperature sensors. The process exhibits second-order dynamics and the two adjacent heaters create a compact multivariate control system. The ESP32 microcontroller includes a 10-bit analog to digital converter (ADC) to measure the voltage of the temperature sensors in 1024 (2^{10}) discrete analog levels and Pulse Width Modulation (PWM) with 256 (2^{8}) levels to change the output to the heaters and LED.

The transistor heaters are TIP120 NPN bipolar junction transistors (BJTs) in a TO-220 package. These transistors are commonly used in audio, power, and switching applications but not commonly as heaters. The TIP120 can act as both the switch and the heater. The two temperature sensors on the iTCLab are standard LM35 with an output voltage (mV) that is linearly proportional to temperature (+ 10-mV/°C Scale Factor) and no requirement for calibration. Typical sensor accuracy is 0.5°C Ensured Accuracy (at 25°C).

As a safety and equipment protection precaution, the ESP32 microcontrollers come preprogrammed to shut off the heaters if the temperature rises above 60°C. The heaters are powered by a 12V 2A power supply for a maximum power output of 24W. A USB cable connects the ESP32 to a computer for serial data communication. One TIP120 heater and one LM35 sensor are connected and with a thermal heat sink attached to the TIP120 transistor. The two heater units are placed in proximity to each other to transfer heat by convection and thermal radiation.

Furthermore, the program that must be embedded in the ESP32 microcontroller on the iTCLab system is adjusted to the settings provided by the MQTT broker or IoT Cloud. The MQTT broker used in this experiment is using the Public HiveMQ MQTT broker, hivemq.com. HiveMQ has a dashboard so we can see the amount of traffic on this broker. HiveMQ also maintains a list of MQTT client libraries that can be used to connect to HiveMQ. To be able to access this broker, we use broker settings: broker.hivemq.com, TCP port: 1883, or web socket port: 8000. An example of its use on the IoT MQTT panel is shown in figure 2 as well as the program used for tuning the PID parameters on this iTCLab Kit which is shown in the following coding https://io-t.net/itclab/files/09-IoT_PID_Control.ino.

Figure 2. IoT MQTT panel



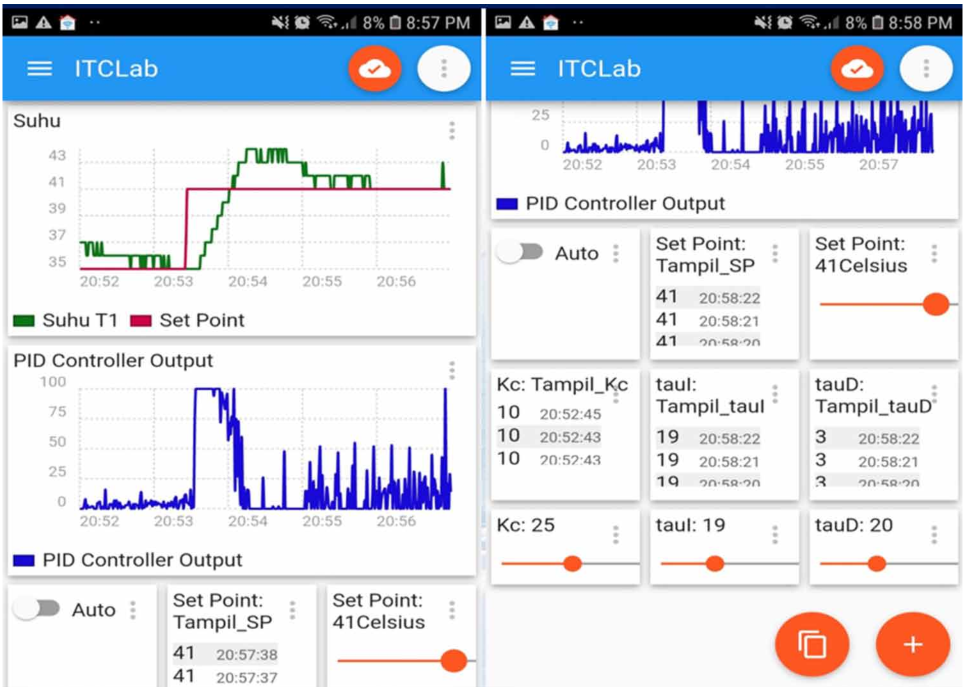
Some important code snippets include:

```
//Initial Setting
#include <WiFi.h>
#include <PubSubClient.h>
#include <Arduino.h>
const char* ssid = “wifi”; // Enter your WiFi name
const char* password =  “Password”; // Enter WiFi password
#define mqttServer “broker.hivemq.com”
#define mqttPort 1883
WiFiServer server(80);
WiFiClient espClient;
```

```
PubSubClient client(espClient);
// PID Controller
float pid(float sp, float Kc, float tauI, float tauD, float pv,
float pv_last, float& ierr, float dt) {
  float KP = Kc;
  float KI = Kc / tauI;
  float KD = Kc*tauD;
  // upper and lower bounds on heater level
  float ophi = 100;
  float oplo = 0;
  // calculate the error
  float error = sp - pv;
  // calculate the integral error
  ierr = ierr + KI * error * dt;
  // calculate the measurement derivative
  float dpv = (pv - pv_last) / dt;
  // calculate the PID output
  float P = KP * error; //proportional contribution
  float I = ierr; //integral contribution
  float D = -KD * dpv; //derivative contribution
  float op = P + I + D;
  // implement anti-reset windup
  if ((op < oplo) || (op > ophi)) {
    I = I - KI * error * dt;
    // clip output
    op = max(oplo, min(ophi, op));
  }
  ierr = I;
  Serial.println("sp="+String(sp) + " pv=" + String(pv) + "
dt=" + String(dt) + " op=" + String(op) + " P=" + String(P) + "
I=" + String(I) + " D=" + String(D));
  return op;
}
```

Finally, the results of controlling using a PID controller, and tuning PID parameters remotely using IoT are shown in figure 3. From the control results displayed on the cellphone using the IoT MQTT Panel, it can be seen that the temperature output was overshoot, but then convincingly went to the set-point.

Figure 3.



CONCLUSION

It has been tested in an internet-Based Temperature Control Lab kit (iTCLab). IoT is used as a means of setting parameters for a Proportional Integral Derivative (PID) controller when the error does not converge to zero. The proposed method can be used as an alternative to manually tuning PID parameters remotely by utilizing IoT technology. First, a program is created that must be embedded in the iTCLab Kit. Then the settings are made on the cellphone using the IoT MQTT Panel. The experimental results show that the PID parameter tuning process can be done through IoT. And the results are quite encouraging, as an alternative way of setting PID parameters.

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KEY TERMS AND DEFINITIONS

iTCLab: This stands for internet-Based Temperature Control Lab. ITCLab is a temperature control kit for feedback control applications with an ESP32 Microcontroller, LED, two heaters and two temperature sensors.

IoT: This stands for Internet of Things. IoT is a developing region in which billions of keen objects are associated with one another utilizing the web to share information and assets.

PID: This stands for Proportional, Integral, and Derivative. PID Controller is the most famous control system in the industry. PID combines three proportional, integral and derivative control actions.

PID tuning parameter: This is how to choose the best parameter values: proportional gain, integral time constant, and derivative time constant in order to achieve optimal tuning, and produce optimal controller performance.

MQTT broker: This is an intermediary entity that enables MQTT clients to communicate. Specifically, an MQTT broker receives messages published by clients, filters the messages by topic, and distributes them to subscribers.

IoT MQTT Panel: This is a mobile application used to manage and visualize IoT projects, based on the MQTT protocol.

Chapter 13
The Mediating Role of Innovation in Financial Literacy and Financial Performance: An Implementation in SMEs

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ABSTRACT

The purpose of this study was to determine the relationship between financial literacy, innovation capability, and financial performance; and to determine the effect of mediators of innovation capability on the relationship between financial literacy and financial performance with implementation in small and medium enterprises (SMEs). To test the hypothesis in the research model, a field study was conducted using a survey method with a total of 189 owners and managers, out of 189 SMEs operating in the manufacturing sector of tempe chips and dinoyo ceramics. The data collected from 189 owners and managers were analyzed using correlation and regression analysis with the SEM Structural Equation Model. The analysis was carried out using SPSS and AMOS software. As a result of this study, it is evident that innovation capability has a partial mediator effect on the dimensions of market orientation and export performance. This empirical finding contributes to the achievement of the competitive advantage of SMEs through increasing market-based innovation capabilities.

DOI: 10.4018/978-1-6684-5629-3.ch013

INTRODUCTION

Theories in the field of resource-based strategic management that focus on the internal dynamics of organizations suggest that competitive advantage and higher average returns to resources and innovation capabilities can reach the forefront of business. This can create their future strategy which is accepted as the basic management philosophy (Lailah & Soehari, 2020). Changes in the business world occur constantly and very quickly. This process of change is formed due to certain dynamic concepts such as globalization, relentless competition, shorter product life cycles, speed of technological innovation, and loss of market boundaries. SMEs must be able to produce products and services that have higher quality standards than the market. This factor forces SMEs to think and act with a broader perspective; customer oriented but still aiming to increase profits. The financial performance of SMEs is a measure of the success rate of SMEs in achieving their business which describes the sales, capital, the number of employees, market share, and profits that continue to increase. The COVID-19 pandemic has resulted in the financial performance of SMEs dropping drastically, this can be seen from the declining sales volume because business actors cannot work optimally with restrictions on their operational space, which has an impact on profit decline. Another factor that causes the financial performance of SMEs to decline in Malang is the decline in financial literacy and innovation. Financial literacy is the knowledge, behavior, and attitudes of a person in managing their finances (OJK Regulation No.76/POJK.07/2016). If financial knowledge is low and does not have clear financial goals, it will have an impact on the decline in the financial performance of SMEs.

Financial knowledge in understanding the basic concepts, benefits, and financial management supported by good financial behavior and attitudes will improve the financial performance of SMEs which includes increasing sales volume and profits (this is in line with the research of (Amri & Iramani, 2018); (Hilmawati & Kusumaningtias, 2021); (Susilo et al., 2022). Changes in external environmental conditions and increasing customer expectations require SMEs to develop innovations for sustainable business.

This situation occurs in Indonesia due to intense competition and the general dominance of SMEs in the economy. SMEs must develop organizational capabilities that enable their business continuity in the long term. Today's highly competitive business environment and innovation capabilities within this organization are critical to achieving a sustainable competitive advantage. However, intense competition and rapidly changing market structures in the context of consumer demand and expectations make this innovation capability important to develop that contributes to the financial performance of SMEs based on market dynamics (Ciampi et al., 2021). At this point, financial literacy offers an effective perspective to increase the effectiveness and efficiency of this innovation capability (Aljanabi, 2018); (Wulandari F., Djastuti I., Nuryakin., 2017). SMEs are trying to develop innovation capabilities based on market expectations to gain a competitive advantage. Considering the results of the literature study, it can be said that the innovation capabilities needed by this company can be realized with a market-oriented management approach (Ferreras-Méndez et al., 2021). The innovation capability can produce creative products with a customer-oriented competitive advantage that can increase sales volume and profit, thus having an impact on increasing the financial performance of SMEs (this is according to a study conducted by (Iqbal & Yuliandari, 2019); (Lailah & Soehari, 2020); (Nurwandi, 2011). However, several research results show that innovation does not affect the financial performance of SMEs (Susilo et al., 2022). The Research Gap arises because there are still discrepancies from the results of previous studies which makes this research still interesting to study.

The results of research that prove the influence of financial literacy on the financial performance of SMEs are as follows: (Amri & Iramani, 2018); (Tuffour et al., 2020). However, several research results show financial literacy has no significant effect on the financial performance of SMEs, namely: (Eresia-Eke & Raath, 2013). The existence of a research gap makes research gaps still open for further investigation regarding the influence of financial literacy and innovation capability on the financial performance of MSMEs (Susanty A., Sirait N.M., Bakhtiar A., 2018). This is done by analyzing the innovation capability variable that can mediate the effect of financial literacy on the financial performance of MSMEs. The theory that can explain how a person performs an action or behavior is the Theory of Planned Behavior which is appropriate to describe any action/behavior that requires planning(S., B., F., 2018). He researched aspects of behavioral theory supported by empirical evidence which revealed that 3 factors influence a person’s behavior change, namely attitudes, subjective norms, and behavioral control. The emergence of financial behavior is the result of the high desire of an MSME actor to fulfill his business needs according to the level of income he earns (Eniola & Entebang, 2015).

While the novelty of this research is the mediating role of innovation capability on financial literacy and financial performance of SMEs.

BACKGROUND

SME Financial Performance

Financial performance is the achievement of financial achievements shown (Big Indonesian Dictionary, 2001). Financial performance is the process carried out and the results achieved by an organization in providing services or products to customers. In this study, the financial performance of SMEs is measured by the number of assets, sales volume (turnover), and profits obtained by SMEs over a certain period. The measurement of SME assets (wealth/resources) is measured using units of money and the ordering system is based on how fast it is growing which is converted into cash units (Destiana & Jubaedah, 2016). Beneficial directly or indirectly, productive in nature and included in the company's operations, and can reduce cash disbursements. Assets have potential future benefits in the form of productive things that can generate cash or cash equivalents (Susilo et al., 2022). Another benefit of assets is that they produce goods and services, can be exchanged for other assets, and pay off liabilities (debts). Sales turnover is identical to sales volume. Sales turnover will increase if accompanied by effective sales activities. The word turnover means the amount, while sales mean the activity of selling goods to make a profit or income. Sales turnover is the total number of sales of goods or services within a certain period, which is calculated based on the amount of money earned. Net income is the excess of total revenue over total expenses. Also known as net income.

Financial Literacy

The definition of financial literacy is financial knowledge, skills, attitudes, and behavior as well as beliefs in financial institutions, products, and services. The most important element of literacy is financial literacy. Financial literacy includes knowledge, skills, and beliefs, which influence attitudes and behavior to improve the quality of decision-making and financial management to achieve prosperity (POJK, 2016). People who have a high level of financial literacy have the potential to provide higher production values. Financial literacy needs to be applied more broadly to create a society that has innovations with higher competitiveness to achieve financial prosperity. Many countries place financial literacy as one of the priorities (Tuffour et al., 2020). Most countries use financial literacy as a combination of sound financial awareness, knowledge, skills, attitudes, and behavior.

Innovation Capability

Innovation is the application of new organizational methods in new products, services, and processes or significantly modified by new marketing methods or business practices in the workplace organization and external relations (Hilmersson & Hilmersson, 2021). Innovation capability can be defined as improving the management of existing technologies and the skills and knowledge required for the creation of new products (Colovic, 2021). In an environment dominated by high-tech applications with rapid variations, it is very important for SMEs to develop innovation capabilities, because dynamic competitive advantages can be achieved (Latifi et al., 2021). Innovation capability has an important meaning for superior innovation performance because of the short product life cycle in the market and high new product introduction rate (Nair et al., 2013); (Huang & Wang, 2011). It is very difficult to imitate organizations that have high innovation capability in the market because the costs of imitating and transferring the knowledge on which innovation is based are very high due to the difficulty of imitating the verbal content of Research and Development (R&D) activities. This characteristic of R&D capability contributes to gaining a competitive advantage because of its nature that triggers the success of innovation (Anzola-Román et al., 2018). The innovation capability of an SME/entrepreneur is the process of turning opportunities into ideas or ideas that can be used to gain profit by constantly looking for new patterns. An SME actor who has high innovation capability can collaborate on creative ideas and imagination systematically to increase success in entrepreneurship. Through this innovation capability, SMEs can take advantage of all the opportunities that exist to find gaps in any problems that arise. In addition, the innovation capability of an SME actor must be able to find the easiest, fastest, and best way to solve a problem with the main indicators being effectiveness and efficiency (Lailah & Soehari, 2020).

Based on the explanation above, the research model can be made as follows:

Figure 1. Research Model

While the hypothesis is as follows:

H1: Financial literacy has a significant positive effect on the financial performance of SMEs.

H2: Financial literacy has a significant positive effect on innovation capability.

H3: Innovation capability has a significant positive effect on the financial performance of SMEs.

H4: Financial literacy has a significant positive effect on the financial performance of SMEs through innovation capability.

Method, Data, and Analysis

This study was designed to investigate the mediating effect of innovation capability between financial literacy and financial performance in SMEs in Malang City. There are several reasons for choosing Malang City SMEs as the implementation area of this research. First, Malang City SMEs have a more flexible structure compared to large companies and SMEs are easy to adapt to changes that occur in the external environment. SMEs are also closer to the market so the development of innovation capabilities is more applicable to SMEs. Second, SMEs can be seen as one of the main drivers of the economy in Malang City because SMEs compete in the gap between the needs of large companies and customers. SMEs act as a bridge between the two factors that drive the economy. The object of population is small and medium enterprises (SMEs) in the city of Malang. In this study, the sampling technique used a probability sampling technique, which was carried out using a simple random sampling technique. This study uses a questionnaire that includes introductory statements, demographic information, and steps. The data needed for the research has been collected through face-to-face questionnaire techniques and self-administration with the owners of various SMEs in the Malang city area. A database consisted of 189 questionnaires which were collected among 189 SMEs. Research data were collected from SMEs through a questionnaire. The questionnaire consists of an introductory statement, demographic information, and measures. The

Table 1. Descriptive statistics

Gender			*Education*		
	Frequency	**Valid %**		**Frequency**	**Valid %**
Female	79	42	Undergraduate	55	29
Male	110	58	Graduate (S1/D4)	106	56
			Master / PhD	28	15
Total	189	100	Total	189	100
Firm Size			***Status***		
	Frequency	**Valid %**		**Frequency**	**Valid %**
3--10	29	16	Owner / Shareholder	17	9
11--50	46	25	Top Level Manager	34	18
51-250	83	44	Middle / Bottom Level	138	73
250-500	31	15			
Total	189	100	Total	189	100

Table 2. Factor analysis

Items	Factor Loadings					
	EFA			CFA		
	1	2	3	Std.Est.	t Value	P
We understand financial records and reports	0,882			0,591		
We carry out records in an orderly manner and analyze Financial Statements	0,734			0,772	11,801	***
We understand the purpose and process of credit and are able to pay it off	0,712			0,791	11,819	***
We have savings in bank for business operations and we understand productive investment	0,781			0,775	17,45	***
All of our managers understand how everyone in our company can contribute to creating customer value		0,847		0,828	16,778	***
We stimulate an infomal information exchange between the different functions of the firm.		0,727		0,779	15,837	***
All of our business functions (e.g. marketing/sales, manufacturing, R&D, Finance/accounting, etc) are integrated in serving the needs of our target markets		0,558		0,679	13,848	***
Our company frequently tries out new ideas		0,778		0,662	15,113	***
Our company seeks out new ways to do things		0,729		0,631	15,027	***
Our company is creative in its methods of operation		0,861		0,772	14,412	***
Innovation in our company is perceived as too risky and is resisted		0,846		0,823	15,057	***
Our new product introduction has increased over the last 5 years		0,863		0,829	15,182	***
Our sales and revenue are increasing every year			0,916	0,913	29,391	***
Our gross profit and net profit are increasing every year			0,912	0,927	33,362	***
Increase in our current assets and fixed assets every year			0,878	0,838	26,158	***
Increasing the number of our workers every year			0,903	0,831	25,653	***
Labor cost efficiency every year			0,897	0,842	26,339	***
Explained Total Variance: 67,8%; 1. Financial Literacy, 2. Innovation Capability, 3. SME financial performance						
x^2/df = 2,465 GFI = 0,904 TLI = 0,941 CFI = 0,949 RMSEA = 0,056						

data needed for the research have been collected through face-to-face questionnaire techniques and self-administration with SME owners of various sizes of manufacturing companies in the Malang City area, which is the center of SMEs in Malang City. A database consisted of 189 questionnaires which were collected from 189 SMEs. Table 1 shows that most of the data come from Middle/Lower Managers with 73%. The education level is Bachelor (S1) and 29% are non-graduate. If we look at the company size data, it can be seen that 44% of the data comes from SMEs which have 51-250 employees. SMEs that have 250-500 employees are only 15% in this study. The descriptive statistical values are shown in Table 1.

For data evaluation using SPSS and AMOS computer programs. Exploratory and confirmatory factor analysis, correlation analysis, reliability test, mean of variables, and regression analysis with structural equation model (SEM) were used to analyze the relationship between variables of the research model. The frequency of demographic variables was analyzed, then the mean and standard deviation were calculated. The results are presented in table 2.

The construction of this study was developed using a measurement scale taken from previous studies and all were measured using a five-point Likert scale ranging from (1) strongly agree to (5) strongly disagree. Financial literacy (basic knowledge of financial management; credit management skills and beliefs, attitudes, and behavior to manage savings and investments) was measured using a 4-item scale adapted from Wahyono & Hutahayan (2021). Innovation ability is measured by an 8-item scale adapted from a different scale developed by Zehir et al., (2015). Furthermore, the SME financial performance question was adapted from a different scale developed by Ho et al., (2018), and measured on a 5-item scale.

Factor Analysis and Reliability

The scales were submitted to exploratory factor analysis. The best fit of the data was obtained with a principal component analysis by a Promax rotation. There are four items for financial literacy, eight items for innovation capability, and five items for SME financial performance. The factor loadings of financial literacy, innovation capability, and SME financial performance are seen in Table 2. Three factors captured all of the variances with 67,8%. To confirm exploratory factor analysis, we conducted confirmatory factor analysis. These are the fit indices used in our research to examine whether the model is fitted; x^2/df (=<3), GFI (=>0,90), TLI (=>0,90), CFI (=>0,90), RMSEA (<0,08).

Descriptives, Correlations, and Reliabilities of the Measures

As shown in Table 3, all variables are significantly and positively correlated with each other. For exploratory research, a Chronbach α greater than 0.70 is generally considered reliable. Chronbach α statistics for the study are 0.86, 0.87, and 0.77 for each of the three factors respectively. The average variance extracted (AVE), whose values should be greater than 0.50 assesses convergent validity. As seen in Table 3, the AVE value of all variables exceeds 0.50.

Table 3. Descriptives, correlations, and AVE Alpha Reliabilities of the Measures

		μ	**δ**	**AVE**	**α**	**1**	**2**	**3**
1	Financial Literacy	3,71	0,617	0,56	0,86	1		
2	Innovation Capability	3,12	0,556	0,53	0,87	0,561**	1	
3	Financial Performance	2,67	0,487	0,52	0,77	0,573**	0,412**	1

*p<0,05; **p<0,01; ***p<0,001

Regression Analysis

To test the hypotheses, we performed multiple regression analyses with SEM. Table 4 shows the results of the regression analysis. The result of regression analysis in Model 1 shows that there is a significant effect on financial literacy (β=0,207, p=0,002). There is a significant effect of financial literacy on SME financial performance. As a result of these findings, H1, dimensions of financial literacy have a positive effect on SME financial performance, is supported. Model 2 indicates that there is a significant effect of financial literacy (β=0,132, p=0,031) on innovation capability. Thus H2, dimensions of financial literacy have a positive effect on innovation capability, is supported. In Model 3, there is a significant effect of innovation capability (β=0,483, p=0,000) on SME financial performance and so H3, innovation capability has a positive effect on SME financial performance, is supported.

To investigate the mediator effect of innovation capability on the relationship between financial literacy and SME financial performance, Model 4 was designed. According to the results, innovation capability is a partial mediator variable in this relationship. We see that the effects of financial literacy on SME financial performance shown in Model 1 are changing in Model 4. Therefore H4, dimensions of financial literacy have a positive effect on SME financial performance through innovation capability, is partially supported.

Table 4. Regression analysis

	Model 2			Model 1		
	B	T	p	B	t	p
Financial Literacy	0,132*	1,992	0,031	0,207**	2,876	0,002
	DV: Innovation Capability			DV: SME financial performance		
	x^2/ df=2,652	GFI=0,919,	TLI=0,937	x^2/df=2,597	GFI=0,923	TLI=0,952
	CFI=0,946	RMSEA=0,058		CFI=0,961	RMSEA=0,057	
	Model 3					
	B	t	p			
Innovation Capability	0,483***	9,126	0,000			
	DV: SME financial performance					
	x^2/ df=3,561	GFI=0,952	TLI=0,961			
	CFI=0,973	RMSEA=0,073				
Model 4						
	B	t	p	B	t	P
Financial Literacy	0,132*	1,983	0,046	0,162**	2,333	0,01
Innovation Capability				0,338***	5,428	0,000
	DV: Innovation Capability			DV: SME financial performance		
x2/df=2,466 GFI=0,903 TLI=0,942 CFI=0,948 RMSEA=0,057						

*p<0,05; **p<0,01; ***p<0,001

SOLUTIONS AND RECOMMENDATIONS

This chapter was conducted using a theoretical framework that was developed based on previous studies. The main objective of this study is to determine the role of the mediator of innovation ability in the relationship between financial literacy and the financial performance of SMEs. This is important because the findings of this study can lead SMEs to find solutions to take advantage of growth opportunities in a competitive business environment. The results of hypothesis testing suggest the following information:

Knowledge, skills, beliefs, attitudes, and financial behavior which are dimensions of financial literacy have a positive impact on the financial performance of SMEs. This situation not only shows the financial performance of SMEs but also has to consider their competitors in developing their business strategies. The importance of alignment and cooperation of business functions must be emphasized. The cause of the ineffectiveness of customer-oriented financial literacy on the financial performance of SMEs can occur because of the dominant relationship between the other two dimensions. This situation can also open up space for further research.

It was found that all dimensions of financial literacy had a positive impact on innovation ability. These findings support the idea of SMEs to determine strategies based on a profit-oriented approach that will contribute to the long-term sustainability of their business (Prabawani & Hidayat, 2017). Focus on meeting stated or hidden customer needs and wants. It was also found that innovation capability has a positive effect on the financial performance of SMEs. For this reason, entrepreneurs are successful in implementing innovation-oriented creative ideas.

This study has several limitations. The main limitation of this study is that it only takes into account the financial performance of SMEs as an indicator of the performance of SME companies, which could potentially limit making generalizations. Another limitation is making the analysis only on SMEs operating in the Malang City Region. Although the Malang City Region covers most SMEs in East Java it is appropriate to make generalizations, it could be useful for future research to make this analysis also on large-scale, global, and multinational companies. Information on financial performance indicators is only measured by subjective opinion. For further research, it is suggested that objective performance indicators such as analyzing the company's balance sheet.

FUTURE RESEARCH DIRECTIONS

As mentioned earlier, the variables used in this analysis are not commonly shared in the literature. For this reason, this chapter aims to address this gap as much as possible and also thinks that this analysis can also be applied to other SMEs operating in different regions of the world. Moreover, it provides strong evidence for future work to gain further insight into financial literacy, innovation capability, and financial performance of SMEs. For further research, the analysis can also be expanded by considering the variables of entrepreneurial orientation, financial inclusion, financial digitization, and other capabilities.

CONCLUSION

One of the most important results of this chapter is the ability of innovation to have a partial mediator role in the financial literacy and financial performance of SMEs. These findings require SMEs to develop market-oriented innovation capabilities to achieve a competitive advantage. The development of new products and services taking into account the needs of customers and the possible actions of competitors will bring growth in the domestic market and overseas market.

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Chapter 14
Coastal Protection and Rehabilitation Technology as Climate Mitigation and Adaptation Strategies

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ABSTRACT

The north coast of Java Indonesia is an area threatened by erosion due to rising sea levels triggered by climate change. Sayung District, Demak, which experienced severe erosion impacts. Restoring lost sediment is an effective way to stop erosion processes and restore a stable coastline. In this chapter, the strategies of coastal protection carried out are presented with the ultimate goal of restoring the natural defense of the coast, namely, mangroves. The first step is to build a coastal protective building to reduce waves and create calm waters. It will accelerate the sedimentation process so that new sludge-substrate land will be formed that is suitable for mangrove ecosystem growth. This coastal erosion mitigation activity is an effort to increase the resilience of coastal areas from physical aspects that cause deterioration or reduction of coastal functions. The concept of building together with nature has a very high technical, socioeconomic, and environmental feasibility because it is a coastal engineering approach as one of the solutions to the problem of sustainable erosion.

DOI: 10.4018/978-1-6684-5629-3.ch014

INTRODUCTION

The growth of the population, the extensive economic developments, industrial expansion, and enormous human activity, all produced greenhouse gas emission that leads to global warming and climate change. Climate change poses many threats to the balance of the environment as well as human life. Many places around the world have experienced changes in rainfall season that caused more floods, droughts as well as severe heat waves. The oceans are warming and the ice is melting, causing the rising of sea level. These unbalanced environmental conditions and ecosystem damage present challenges to our society and our environment especially threatening food security. Food security is the most visible and immediate problem that arises after the occurrence of natural disasters/damage. This will affect all aspects of food security starting from the aspects of food availability, distribution, consumption, and safety. Increasing human awareness of the environment is indispensable to minimizing the negative impact of some human activities on the environment. One of the efforts that can be done by the community in reducing environmental damage is to apply the concept of being environmentally friendly.

Coastal areas have many problems related to the environment, especially water dynamics. Existing problems occur due to many dynamic physical processes, including 'tidal' floods, land subsidence, a rise in sea level, and erosion sedimentation. These processes play an important role in coastline changes that occur in coastal areas (Marfai et al., 2006).

The North Coast of Java is an area threatened by erosion disasters due to rising sea levels triggered by climate change. Sea level rise also causes changes in ocean currents in coastal areas and destroys mangrove ecosystems (Sugianto et al., 2018). The North Coast of Java wave is a type of wave that is generated by the wind. The propagation of waves to shallow waters will reduce speed but produce greater energy and wave height, which can cause eroding of bottom sediments, causing a reduction in the land. Demak Regency, Central Java, Demak Regency is located in the central Java Province, Indonesia with an area of 1,149.07 km^2, which consists of a land area of $\pm$ 879.43 km^2 and a sea area of $\pm$ 252.34 km^2 (Hawati et al., 2017). Demak Regency is an area with high erosion and coastline reduction problems. The erosion that occurred in the Sayung District area occurred from 1991 until now with the eroded area reaching 2,073.7 hectares (Ismanto et al., 2017). If left unchecked, this condition will be very detrimental to the coastal community of Demak due to the loss of residential land and to carry out activities.

Based on data from the Indonesian Ministry of Maritime Affairs and Fisheries, almost 80% of the mangrove forests in the northern coastal area of Java have been damaged and have disrupted coastal security. In 2014, nearly 750 km of 1,690 km of coastline were eroded, and 130 km2 of mangrove habitat was lost. This condition affects the lives of 30 million people in Java. Annually, economic losses are estimated at USD 2.2 billion caused by urbanization, industry, conversion of ponds, and land subsidence (Pramita et al., 2021). Thus, a solution is needed to restore the environmental conditions of the coastal area of Demak and reduce the negative impact of erosion by applying environmentally friendly and sustainable methods.

Coastal and Marine Damage Due to Erosion

Coastal erosion occurs because the coast has experienced a reduction or loss of sediment, where the sediment that is collected is greater than that deposited (Triatmodjo, 1999). Coastal erosion causes coastline changes that can damage urban settlements and infrastructure. Coastal erosion occurs naturally by wave activities or due to human activities such as logging mangrove forests, construction of ports or other coastal buildings, expansion of pond areas towards the sea without considering the coastal border area, taking coastal corals, and so on (Triatmodjo, 1999). Coastal erosion has affected the social and economic lives of local communities, which can threaten cultural heritage and hinder the development of coastal tourism (Sagoe-Addy & Appeaning Addo, 2013). A large number of homes have been lost due to coastal erosion in the past and continued in some areas along the coast (Boateng, 2012).

The coast can experience erosion and accretion that occurs naturally. However, coastal erosion exacerbated by human activities such as converting coastal ecosystems such as mangrove forests into settlements and accretion is a major problem in coastal areas. This land conversion is based solely on economic objectives without thinking about the consequences caused (Akbar et al., 2017).

Timbulsloko Village is a village located on the coast of Sayung District, Demak Regency which experienced severe erosion impacts, causing people to suffer and lose their homes and livelihoods. Many residents have lost land, rice fields, and ponds due to the worsening influence of coastal erosion. Many residents are homeless, especially those in the front row. Even facilities and places of worship were also affected. Many residents have elevated their residences as a form of adaptation efforts. Erosion that occurs in Timbulsloko is normal, this is due to the type of muddy beach typology and has a gentle slope (Sugianto et al., 2022). However, this condition was exacerbated by the conversion of agricultural land and mangroves in the coastal area of Timbulsloko from a sedimentation area to land of fishponds that occurred since 1980, which eliminated an area of about 4,248.85 ha per year (Sugianto et al., 2022).

Meanwhile, in 2013, the village lost about 400 – 1300 meters of its coastal area The process of coastal erosion also occurred due to an imbalance in sediment supply to and from the coast. This phenomenon is triggered by changes in natural balance such as the disruption of mangrove forests. The problem of erosion and coastline changes that occur in the Demak region reaches an average of 100 meters per year (Sugianto et al., 2018). This is also exacerbated by the impact of climate change which is characterized by an average sea level rise of 7.9 mm/year (Sugianto et al., 2022). The high value of sea level rise also plays a major role in the process of permanent inundation which can eliminate most of the land in Timbulsloko Village, because it turns into part of the ocean.

Erosion Disaster Mitigation Efforts

Erosion problems have recently tended to increase in various regions. Several ways can be done to protect the beach, namely by (1) strengthening or protecting the beach to be able to withstand wave attacks; (2) changing the rate of sediment transport along the coast; (3) reducing the energy of the waves that reach the shore; (4) reclamation by increasing the sediment supply to the coast or by other means. There are two main approaches to overcoming coastal erosion, namely the hard approach and the soft approach (Sugianto et al., 2020). Hard approach handling is in the form of breakwaters, groins, coastal walls, jetties, and revetments. A breakwater is a marine structure used to protect the coastal area from wave disturbances. Breakwaters are also commonly used to protect the coast from being hit by waves to reduce the impact of coastal erosion, but in reality, hard structures such as embankments and breakwaters block the transport of sediment to the coast and increase the influence of waves due to reflection (Ismanto et al., 2017). The reflected waves have greater energy, allowing sediment to be carried back to the sea and causing the accretion process to be hampered. As for erosion confectionery, a soft approach can be done by planting coastal plants such as mangroves as a natural coastal protector. Mangrove rehabilitation and restoration is the most effective way that can be applied by the community and is environmentally friendly (Suripin et al., 2017).

Mangrove Ecosystems as Coastal Protection

Some experts define mangroves from different points of view however it refers to the same thing. According to Hutchings and Saenger (1987), mangroves are typical littoral plant formations and grow on protected beaches in the tropics and subtropics. According to Tomlinson (1986), the word mangrove has the meaning of a tropical plant and its community that grows in intertidal areas. The intertidal area is the area under the influence of tides along the coastline. Meanwhile, according to Soerianegara (1986), mangrove forests are forests that mainly grow on alluvial mud soils in coastal areas and river estuaries that are influenced by tides, and consist of types of trees *Avicennia, Sonneratia, Rhizophora, Bruguiera, Ceriops, Lumnitzera, Excoecaria, Xylocarpus, Aegiceras, Scyphyphora and Nypa.*

Mangroves are a specific ecosystem because they are only found on relatively small choppy beaches or even in areas protected from waves that are affected by water and mud inputs from land. A mangrove ecosystem is a system consisting of organisms (animals and plants) that interact with environmental factors in a mangrove habitat. Mangrove ecosystems have habitat characteristics in the form of muddy substrates, are influenced by tides and seawater inundation, and can live in conditions of low and high salinity. Mangrove ecosystems are dynamic because mangrove ecosystems can continue to grow and develop along with the development of their natural growing places. The mangrove ecosystem is also a habitat for animals and biota, both on land and in water. Other functions of mangrove forests are as a buffer for coastal abrasion, buffering tidal waves and tsunamis, absorbing waste, preventing seawater intrusion, and providing food needs for the surrounding population. Mangrove forests are the main ecosystem that supports the life of coastal communities.

As one part of the coastal area whose role is very important, the existence of mangrove forests has many functions and benefits. As a physical function, mangrove forests can act as a *green belt* that protects coastal areas from erosion due to waves and tsunamis, keeps coastlines stable, buffers against seawater seepage (intrusion), and treats waste. Mangroves also act as filters to reduce the detrimental effects of environmental changes. Mangrove forest areas also help humans in getting clean water and fresh air. Mangrove forests absorb all kinds of harmful metals and make water quality cleaner. The economic function of mangrove forests is as a source of building materials, fuel, agricultural purposes, fisheries, and sources of industrial raw materials. Trees and mangrove wood that have dried and decayed can be used as firewood. Indirectly, it will reduce the need for gas or fuel. Meanwhile, its biological function is as a hatchery for shrimp, fish, shellfish, and other types of fish, a nesting place for birds and a source of nutfah plasma. Mangrove forest areas have helped maintain the availability of fish resources in the sea that will not run out. These resources can be utilized by fishermen as a source of livelihood.

Indonesia is a country that is fortunate to have mangrove plants with very high diversity and has the largest area in the world. This condition is possible due to several factors, including related geographical position, geological history, and archipelago typology, as well as typical oceanographic characteristics owned by Indonesia. Several types of mangroves are often found in Indonesia, namely, Avicennia, Bruguiera, Rhizophora, and Sonneratia (Kusmana, 2014).

Mangrove ecosystems can grow well in areas that have a combination of sand, mud, and clay substrates that are rich in organic matter. In general, the characteristics of mangrove substrates are wet, contain salt, and have little oxygen. Some types of mangrove species have adaptations to environmental salinity. If hyper salinity occurs in the mangrove ecosystem environment, the mangrove will adapt by removing excess salt levels through the salt glands or by aborting leaves accumulated by salt. The temperature in the mangrove ecosystem is influenced by the intensity of sunlight. The temperature tolerance threshold for mangrove ecosystems is following the Quality Standards in Kepmen LH No. 51 of 2004 which states that the ideal seawater temperature for mangroves is 28°C – 32°C. Tidal fluctuations are also very important in preventing conditions of hypersalinity in soils in areas with high evaporation rates. Tidal also plays a role in the spread of mangrove seedlings and propagules (mangrove fruits that have germinated). Mangroves will live optimally in areas that are protected from strong currents, such as in coastal areas and deltas where water flows contain a lot of mud (Hossain & Nuruddin, 2016).

SOLUTIONS AND RECOMMENDATIONS

The erosion process that occurs in the waters of Timbulsloko will cause huge losses to the surrounding community if it continues to be allowed. Restoring lost sediment is an effective way to stop erosion processes and restore a stable coastline. The various stages of coastal protection carried out are with the ultimate goal of restoring the natural defense of the coast, namely mangroves. The importance of mangrove ecosystems for coastal areas and the threats faced by mangrove ecosystems today, encourage the rehabilitation and conservation of mangrove ecosystems. Another impact of damage to the mangrove ecosystem in Timbulsloko Village is the rise of seawater in the village streets at high tide (Suripin et al., 2017). Coastal protection strategies are mainly based on infrastructure-based solutions usually expensive for their construction, require high maintenance costs, and provide only limited protection against extreme and unforeseen events (Yuwono, and Kodoatie, 2004). Therefore, innovative coastal defense solutions are needed that combine natural conditions and infrastructure (Winterwerp et al., 2014).

The first step for this solution is to build an eco-friendly coastal protection structure to dampen waves without reflecting them and create calm waters. This integrated approach uses an environmentally friendly local resource-based coastal security structure. In principle, this structure is used to stop erosion by building a coastal belt in the form of a wooden/bamboo lattice filled with small permeable bundles of twigs or logs (Suripin et al., 2017). In addition to being environmentally friendly, bamboo is used as the main material for building structures because of its economic value and easy availability. These plants grow in almost all parts of Indonesia and are used as building construction materials.

The advantage of this structure is that it can withstand sediment carried by currents and waves from the high seas to the mainland and minimizes the strength of erosion (Suripin et al., 2017). This structure is also able to create calm water conditions by adapting the mangrove root system so that a mud substrate will be formed which can be used for the restoration and rehabilitation of mangroves as a natural green belt for coastal protection. Things that need to be considered in the construction of this structure are site selection, contractor options, material selection, construction, inspection/monitoring, maintenance, and when to involve local stakeholders/community. This method will create very favorable conditions for beach rehabilitation, as well as allow the coastal ecology to recover naturally.

Mangrove ecosystems act as coastal protectors from erosion. The root structure of mangroves can withstand sediments that will also indirectly protect the coast from erosion. If the mangrove ecosystem is disturbed, the coast will lose its natural protection. Therefore, rehabilitation activities for mangrove conservation are very important to be carried out as an effort to protect coastal areas. Based on these problems, technology to rehabilitate damage to beaches and mangrove ecosystems as an effort to mitigate disasters in coastal areas is very necessary. It is expected the coastline can be restored, and the mangrove ecosystem can become a coastal greenbelt that supports efforts to achieve sustainable development goals by applying the concept of joint development of nature. The concept of building together with nature has a very high technical, socioeconomic, and environmental feasibility because it is a coastal engineering approach as one of the solutions to sustainable erosion problems (Vriend et al., 2015).

Living more familiar with the ecosystem can also help in the success of rehabilitation activities. Living more familiar with this ecosystem means that local communities whose locations are closest to the rehabilitation site should have a high awareness of the importance of the existence of ecosystems and their benefits (Suripin et al., 2017). All the efforts that have been made are Climate Mitigation and Adaptation Strategies that occur in the North Coast region, especially on the coast of Demak.

FUTURE RESEARCH DIRECTIONS

The biggest challenge in the mangrove planting program is when the mangroves are still at a young age because they are prone to damage due to strong waves and currents. One way to overcome the problem of damage to young mangroves is to create a temporary protection structure that can protect mangrove seedlings from wave attacks (Yuanita et al., 2019). So it is necessary to do further research to create a safe planting media structure for mangrove vegetation so that it is protected from waves and currents.

CONCLUSION

The implementation of mangrove rehabilitation technology has had a positive impact on the environment and the surrounding community. Slowly the coastal area of Timbulsloko Village, Demak Regency began to return to its previous condition. Erosion is a natural process that cannot be stopped, but the existence of mangrove ecosystems as natural protectors of the coast has been able to reduce damage caused by erosion. Mangrove ecosystems can absorb the energy of the large waves that form on the high seas. Furthermore, the mangroves can withstand the erosion generated by the waves.

ACKNOWLEDGMENT

Extend gratitude to Oceanography Department Universitas Diponegoro, Laboratorium Ocean Modelling and Climate Change-UPT Integrated Laboratory, Universitas Diponegoro, LPPM Universitas Diponegoro, Center for Coastal Rehabilitation and Disaster Mitigation Studies (CoREM-PKMBRP) - Center of Excellence Science and Technology (PUI), and Ministry of Education and Culture Republic of Indonesia for funding our research with grant number 257-104/ UN7.6.1/PP/2021.

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KEY TERMS AND DEFINITIONS

Breakwater: A permanent structure constructed at a coastal area to protect against tides, currents, waves, and storm surges.

Climate Change: A significant change in climate, air temperature and rainfall. This is caused by the increase in the temperature of the earth as a result of the increase in the concentration of greenhouse gases in the earth's atmosphere.

Coastal Protection: Measures aimed at protecting the coast against coastline retreat, thus protecting settlements, infrastructure, the coast and the hinterland from erosion.

Disaster Mitigation: A series of efforts to reduce disaster risk, both through physical development as well as awareness and capacity building to face disaster threats.

Environmentally Friendly: A program that aims not to damage the surrounding environment.

Erosion: The action of surface processes that removes soil, rock, or dissolved material from one location on the Earth's crust, and then transports it to another location where it is deposited.

Ocean Current: The movement of seawater masses from one place to another.

Sediment: The main material forming the morphology (topography and bathymetry) of the coast.

Sedimentation: The process of deposition of solids from suspension, solution, or liquid form. Sedimentation forms deposits in the form of sediments that form the earth's surface.

Tidal: A fluctuation in sea level as a function of time due to the attraction of objects in the sky, especially the sun and moon, to seawater masses on earth.

Wave: An up and down movement of sea water that occurs due to several factors, such as wind, gravity of the sun and moon, volcanic eruptions or earthquakes at sea, and moving ships.

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Index

F

G

H

I

K

L

M

N

O

P

Q

R

S

T

W

Z