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Designing an Eco-Industrial Park Blueprint for a Kerupuk MSME Cluster to Support Circular Green Culinary Tourism Value Chains in Bogor, Indonesia

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ABSTRACT

Traditional kerupuk production is closely tied to Indonesia's culinary identity and can support local gastronomic tourism, yet many small producers still lose materials and energy through everyday inefficiencies and are unmanaged by products. This study explores how an eco-industrial park approach can be adapted for a kerupuk micro and small enterprise case in Bogor Regency to strengthen circular practices and contribute to a greener culinary tourism value chain. Using a course-based case study design, we conducted an EIP quick scan guided by the International Framework for Eco Industrial Parks, then mapped the main production steps from mixing and steaming to drying, frying, and packaging. A simplified inventory of material, water, and energy flows was compiled to pinpoint the most visible waste streams, especially wastewater, organic residues, and used cooking oil. From this baseline, potential industrial symbiosis options were proposed and screened qualitatively using practicality for small-scale operations, expected environmental benefit, and ease of implementation with local partners. The resulting blueprint prioritizes feasible circular actions such as separating starch-based residues for composting or animal feed, introducing shared wastewater treatment with non-potable reuse where appropriate, organizing the collection of used cooking oil for conversion into biodiesel or soap, and improving energy performance in frying through cleaner fuel options and better equipment practices. The study offers a practical starting point for cleaner production, collaboration, and simple monitoring within a kerupuk cluster that aims to support sustainable culinary tourism.

Keywords: *Eco-Industrial Park, Industrial Symbiosis, Circular Economy, MSMEs, Kerupuk, Green Tourism Value Chain*

1. INTRODUCTION

Industrial estate development is an effort to promote environmentally oriented industrial growth while providing convenience and attractiveness for investment through approaches based on efficiency, spatial planning, and environmental management. As such, it contributes to driving economic improvement, high growth, and competitiveness. Industrial estate development also provides location certainty in accordance with the Regional Spatial Plan (RTRW) and facilitates the integration of industrial infrastructure planning and development, including basic infrastructure, supporting infrastructure, and auxiliary facilities within the industrial estate.

The declining environmental quality has compelled companies and global industrial organizations to manage and improve their operations in order to comply with international trade regulations, which increasingly position environmental protection as a prerequisite for industrial products to be globally accepted (Panyathanakun et al., 2013). The rapid advancement of science and technology, along with increasing demands from communities and surrounding environments regarding environmental protection, has driven the emergence of environmentally oriented industrial estate concepts, namely the Eco-Industrial Park (EIP). According to Chertow (1998), the EIP concept emphasizes the physical exchange of raw materials, energy, water, and by-products as a critical consideration. The development of EIP also focuses on fostering synergistic industrial clusters among its members.

The importance of sustainable culinary tourism is closely related to the potential environmental impacts generated by culinary activities, particularly in the kerupuk industry. This sustainability concept includes the use of local raw materials, waste management, and

the implementation of environmentally friendly operational practices. Therefore, sustainable culinary practices in the kerupuk industry are essential not only to ensure economic benefits but also to generate positive impacts for society and the environment.

The kerupuk industry is distributed across various regions in Indonesia and utilizes raw materials such as different types of flour and fishery products. However, nearly 50% of kerupuk enterprises are classified as household-scale and small industries. This industry generally does not generate significant environmental pollution, particularly for flour-based kerupuk production. Nevertheless, the application of EIP in this sector remains important, even though the environmental impacts are relatively minimal.

The observation of EIP implementation in this context focuses more on a zero-waste concept rather than an end-of-pipe approach. Although the waste generated is not hazardous, there are inefficiencies in resource utilization. Therefore, this study aims to identify and analyze the potential for EIP implementation in the kerupuk industry.

The objectives of EIP implementation in the kerupuk industry include the following:

1. EIP promotes the efficient use of raw materials, water, and energy, thereby reducing waste and production costs in the kerupuk industry.
2. Waste generated from the kerupuk industry, such as residual flour, washing water, and used oil, can be managed through environmentally friendly approaches. For example, organic waste can be utilized as fertilizer or biomass fuel.
3. By adopting cleaner technologies and environmentally friendly production patterns, EIP helps reduce greenhouse gas emissions, air pollution, and wastewater that may contaminate the surrounding environment.
4. Within the EIP framework, kerupuk industries can collaborate with other industries, for instance by utilizing their waste as raw materials for other sectors, thereby creating mutually beneficial industrial symbiosis.
5. EIP encourages greener production practices, enabling kerupuk products to be marketed as environmentally friendly products. This increases market competitiveness, particularly among environmentally conscious consumers.
6. EIP supports the development of more sustainable business models by reducing dependence on non-renewable resources and optimizing operational performance.

2. LITERATURE REVIEW

An Eco-Industrial Park (EIP) is defined as an industrial area development concept that aims to integrate industrial activities with environmental sustainability. Its primary objectives are to reduce negative environmental impacts, promote resource efficiency, and create a balanced relationship between economic, environmental, and social aspects. Within an EIP, companies collaborate to utilize resources efficiently, minimize waste, and reduce environmental impacts. This concept encourages collaboration among industries, government, and communities to establish a more sustainable industrial system.

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The objective of implementing an Eco-Industrial Park (EIP) in the kerupuk industry is to create a more environmentally friendly and sustainable production process. The adoption of cleaner production practices also improves production efficiency, reduces operational costs, and enhances the quality of kerupuk products.

The kerupuk industry is part of the snack food sector that is rapidly developing in Indonesia, ranging from household-scale and micro, small, and medium enterprises (MSMEs) to large-scale industries. Kerupuk products are characterized by their light and crispy texture and are typically made from starch or flour with added seasonings, and are generally fried in oil.

1. Production Process
   a. Raw Material Mixing

      The initial stage of production involves mixing the main raw materials, such as flour, starch (e.g., tapioca flour), seasonings, and water in specific proportions to achieve a homogeneous dough. In this process, mixing machines are commonly used at the industrial scale, while household-scale or MSMEs still rely on manual labor. Key factors in this stage include determining the appropriate material composition to maintain quality consistency, as well as optimal mixing time to prevent lump formation or uneven dough texture.

   b. Steaming or Boiling of Dough

      After the materials are mixed, the dough is transferred into a steamer or boiled at a certain temperature to form the basic structure of kerupuk. This process aims to reduce excess moisture, strengthen starch bonding, and facilitate molding. At a larger scale, autoclaves or steam cookers are used for efficiency, while MSMEs typically use manual steamers. Inadequate control of temperature and steaming time may result in overly hard or overly soft dough, thereby affecting the final product quality.

   c. Molding and Cutting

      The dough that has undergone the steaming process is first cooled before being fed into a molding machine. It is then shaped according to the desired kerupuk design, such as circular, rectangular, or elongated forms. After molding, the dough is cut into specific sizes using cutting machines or manual tools. Precision in this

stage is essential to ensure uniform shapes and to minimize residual dough that may become waste.

d. Drying

The drying process is carried out to reduce the moisture content of raw kerupuk so that it can be stored longer and produces a crispy texture when fried. Traditionally, drying is performed by sun-drying; however, this method depends heavily on weather conditions. Alternatively, drying using ovens or dehumidifiers provides faster and more consistent results. The selection of drying methods affects energy costs, production time, and final product quality.

e. Frying

Dried raw kerupuk is then fried in hot oil at temperatures of 180–200°C. This process aims to develop a crispy texture and a golden color. Frying is conducted using large pans, deep fryers, or automated frying machines at the industrial scale. This stage requires strict temperature control, as low temperatures may result in oily products, while excessively high temperatures may cause burning. In addition, repeated use of cooking oil without filtration can produce carbon residues that affect product quality and generate waste oil that requires proper management.

f. Packaging

Cooked and cooled kerupuk is packaged for distribution. Packaging is carried out using airtight plastic to prevent moisture ingress that may damage the product. At a larger scale, automated packaging machines are utilized to improve efficiency and consistency. This stage also serves to provide labeling information, such as production date, expiration date, and nutritional content, in order to comply with food safety standards.

3. METHOD

The method employed is a quick scanning approach covering all stages of the industrial process. The procedure includes the following steps:

1. Understanding the basic concepts by reviewing the definition and principles of the Eco-Industrial Park (EIP).
2. Data collection is conducted using a literature review approach.
3. Formulating a plan and strategy for EIP implementation.

4. FINDINGS AND DISCUSSION

Kerupuk has become a popular complementary food among consumers; therefore, this industry continues to grow to meet both domestic and export market demand. However, despite its potential, the kerupuk industry faces challenges related to production efficiency and waste management.

The main challenges include the efficient use of raw materials, high energy consumption, and the management of generated waste. The frying process, which constitutes a critical stage in production, requires a significant amount of energy and often involves repeated use of cooking oil, thereby generating waste oil that needs to be managed. In addition, the use of flour or starch-based raw materials often produces residual materials during mixing and molding processes. The generated waste also includes wastewater from equipment washing, gaseous emissions from fuel combustion, and solid waste such as residual flour and raw materials.

Nevertheless, the kerupuk industry has considerable potential to implement cleaner production concepts in order to improve efficiency while reducing environmental impacts. Cleaner production can be achieved through raw material savings by optimizing the mixing process, utilizing renewable energy sources such as biomass or biogas, and implementing integrated waste management practices. Wastewater can be treated through simple wastewater treatment systems, while organic solid waste can be utilized as animal feed or compost material. Furthermore, used cooking oil can be converted into biodiesel as an alternative energy source.

Through a sustainable approach, the kerupuk industry can contribute to reducing environmental impacts while enhancing competitiveness. By implementing the Eco-Industrial Park (EIP) concept, kerupuk industries can utilize each other's waste within an industrial symbiosis framework, in which waste from one production process becomes input for another. Strategic location, energy efficiency, integrated waste management, and environmentally friendly infrastructure design are key factors in developing a more sustainable kerupuk industry in the future.

Waste Management (liquid, solid and gas)

a. Liquid Waste

Liquid waste in the kerupuk industry generally originates from the washing of production equipment, such as pans, mixers, and molds, as well as wastewater from mixing processes and floor cleaning. This waste often contains flour residues, oil, and organic matter that have the potential to increase Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels. If not properly managed, this liquid waste can contaminate the environment, particularly nearby water bodies.

1. Liquid Waste Management:

a. Wastewater Treatment System, liquid waste can be treated using a simple treatment system consisting of several stages, such as:
b. Sedimentation Tank, wastewater is directed into a sedimentation tank to separate coarse solids such as residual flour and dough. The settled solids can be collected and utilized as animal feed or compost material.

c. Anaerobic Biofilter Process, wastewater that has undergone sedimentation is conveyed to an anaerobic biofilter to decompose organic compounds using microorganisms. This process effectively reduces BOD and COD levels.
d. Aeration Process, wastewater is transferred to an aeration tank to supply additional oxygen, thereby supporting aerobic microorganisms that further degrade organic compounds.Final Filtration: Treated wastewater can be filtered using sand or membranes before being discharged into water bodies.
e. Treated wastewater can be reused for non-hygienic purposes, such as irrigation or preliminary washing of equipment, thereby reducing freshwater consumption.

2. Gaseous Waste Management

Gaseous waste is primarily generated from fuel combustion emissions during the frying stage, particularly when fossil fuels such as kerosene, LPG, or firewood are used. These emissions contain air pollutants such as carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), and particulate matter, which may adversely affect air quality and workers' health.

a. Energy source substitution, fossil fuels can be replaced with biomass such as sawdust, rice husk, or coconut shells, which are more environmentally friendly. In addition, combustion residues can be utilized as organic fertilizer.
b. Methane gas from biogas, organic waste (such as residual raw materials and liquid waste) can be fermented in a biodigester to produce methane gas, which is used as an alternative fuel for frying processes.
c. Emission control technologies, frying stoves can be equipped with emission control devices, such as scrubbers or particulate filters, to remove pollutants before being released into the air. This system effectively reduces carbon emissions and air pollution.
d. Ventilation and air circulation systems, ventilation systems and exhaust fans are installed in production areas to maintain air circulation and protect workers from direct exposure to combustion emissions.

3. Solid Waste

Solid waste in the kerupuk industry includes residual raw materials such as discarded flour or dough from the mixing process, leftover pieces from molding, and combustion residues when biomass fuels are used. In addition, used cooking oil that can no longer be reused constitutes a significant waste stream in this industry.

a. Utilization of raw material residues, uncontaminated flour and dough residues can be collected and utilized as animal feed, particularly for poultry and organic residues, such as spoiled dough or flour residues, can be processed into compost through aerobic composting.
b. Utilization of biomass residues, combustion residues from biomass, such as rice husk ash or sawdust ash, can be utilized as components in organic fertilizers or construction materials (e.g., bricks).
c. Management of used cooking oil, used cooking oil is collected in designated containers to prevent environmental contamination. Waste oil can be processed into biodiesel through transesterification, thereby producing an environmentally friendly alternative fuel. Industries can establish partnerships with third parties to manage used cooking oil in a centralized manner.
d. Liquid soap production, in addition to biodiesel, waste oil can also be converted into liquid soap through the addition of chemicals such as caustic soda (NaOH).

4. Site Selection, Design, Concept, Development, and Infrastructure

a. Site Selection
A strategic location is selected, preferably close to raw material sources (flour, starch), renewable energy sources (biomass, methane gas), and distribution networks. Environmental impacts are considered, particularly with respect to water resources and nearby residential areas.
b. Design
The design adopts a circular economy concept with a focus on industrial symbiosis, in which waste from one industry serves as input for another. The layout is developed to minimize inter-unit transportation and to maximize energy efficiency.
c. Concept
The concept emphasizes the use of renewable energy (e.g., biogas derived from industrial organic waste or solar panels). It includes an integrated waste management system for liquid, solid, and gaseous waste, as well as the implementation of energy-efficient technologies such as efficient boilers or modern ovens.
d. Development
Development activities include establishing shared facilities, such as centralized waste treatment plants, product quality laboratories, and storage warehouses. It also involves providing education and training for small-scale industry actors on cleaner production practices and waste management.
e. Infrastructure
The infrastructure consists of integrated waste treatment facilities (centralized WWTP), efficient transportation systems for raw material and product distribution, and the provision of clean water and low-carbon energy. In addition, environmental monitoring systems are implemented to assess water quality, air quality, and solid waste management.

5. CONCLUSIONS

The kerupuk production process involves several stages, including raw material mixing, steaming, drying, and frying. During these processes, liquid waste (e.g., washing water), solid waste (e.g., residual flour or

dough), and oil residues emerge as major issues. If not properly managed, these wastes can contaminate the environment and reduce production efficiency. This study indicates that waste management in the kerupuk industry can still be improved through the Eco-Industrial Park (EIP) approach. Liquid waste can be treated using a simple wastewater treatment system (WWTP) for reuse in cleaning processes. Solid waste, such as residual flour or raw material residues, can be utilized as biomass fuel or organic fertilizer, while oil residues can be converted into alternative energy through bioenergy processes. Overall, this study also highlights that the implementation of an Eco-Industrial Park is not only important for supporting environmental sustainability but also has significant potential to enhance the competitiveness and economic sustainability of the kerupuk industry. Therefore, support from the government, stakeholders, and industrial communities is required to effectively implement this concept.

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