JASSU
Journal of Agrosociology and Sustainability
JASSU 2(2): 130-151
ISSN 3025-1362

Institute for Advanced Science, Social and Sustainable Future
MORALITY BEFORE KNOWLEDGE

ZeaPackage: The potential of corn husk (Zea mays L.) for biodegradable paper bags as a strategy for waste reduction and implementation of circular economy concept

Fahmi Azrial[1,*], Febrian Afrida[1], Olivia Jindani Al-Mupidah[1], Rosya Diyaul Aulya[1]
[1] *Department of Biology, Faculty of Science and Technology, Raden Intan Islamic State University of Lampung, Bandar Lampung City, Lampung 35131, Indonesia.*
*Correspondence: fahmiazrial77@gmail.com

Received Date: December 22, 2024 Revised Date: January 26, 2025 Accepted Date: January 30, 2025

ABSTRACT

Background: Plastic waste has become a global issue, including in Indonesia, where its growing impact has prompted the need for sustainable alternatives. Corn husk, an abundant agricultural waste in Indonesia, presents a potential raw material for producing biodegradable paper bags, aligning with circular economy principles and addressing the increasing demand for eco-friendly packaging. **Method**: This study uses a comprehensive literature review, drawing from scientific journals, textbooks, and official publications. Data analysis is conducted through descriptive and comparative techniques, including SWOT analysis, to assess the viability of corn husk-based biodegradable paper bags as an alternative to plastic. **Findings**: The study reveals that ZeaPackage, a biodegradable paper bag made from corn husks, is a promising alternative to plastic bags. Corn husks' high cellulose content and abundance make them ideal for large-scale production, offering an eco-friendly solution while supporting circular economy goals. **Conclusion**: ZeaPackage has significant potential as an environmentally sustainable alternative to plastic bags. By leveraging the abundant supply of corn husks, it contributes to waste reduction and aligns with circular economy principles, though challenges in implementation remain. **Novelty/Originality of this article**: This study highlights the innovative use of corn husk as a raw material for biodegradable packaging, offering a practical solution to plastic waste while adding value to agricultural by-products in Indonesia.

KEYWORDS: biodegradable; circular economy; corn husk; paper bag; waste.

1. Introduction

Indonesia is the second-largest contributor to plastic waste in the world after China. This indicates that the plastic waste problem in Indonesia has reached an alarming stage. Data from the Ministry of Environment and Forestry/*Kementerian Lingkungan Hidup dan Kehutanan* (KLHK) reveals that plastic generated from 100 stores or members of the Indonesian Retail Merchants Association/*Asosiasi Pengusaha Ritel Indonesia* (APRINDO) reaches 10.95 million pieces of plastic bag waste in one year. However, Indonesia possesses a unique opportunity to address this challenge through its abundant agricultural resources. This amount equals an area of 65.7 hectares of plastic bags or about 600 times the size of a football field. This condition is further worsened by the low level of plastic recycling and lack of public awareness regarding environmentally friendly waste management. As a result, plastic waste not only pollutes land but also damages marine ecosystems, where

Cite This Article:
Azrial, F., Afrida, F., Al-Mupidah, O. J., & Aulya, R. D. (2025). ZeaPackage: The potential of corn husk (Zea mays L.) for biodegradable paper bags as a strategy for waste reduction and implementation of circular economy concept. *Journal of Agrosociology and Sustainability, 2*(2), 130-151. https://doi.org/10.61511/jassu.v2i2.2025.1630

Copyright: © 2025 by the authors. This article is distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

Indonesia is known as one of the countries with the largest marine biodiversity in the world. If not addressed immediately, this issue can cause serious impacts on the environment, human health, and economic sustainability (Kumar et al., 2021).

This news is certainly distressing as Indonesia contributes to environmental damage ranking second on Earth. This shows how critical the situation is, where the impact of environmental damage is felt not only by humans but also by flora, fauna, and the ecosystem as a whole. This news simultaneously warns the Indonesian nation to try to change their mindset and lifestyle to be environmentally conscious or go green. A mindset that is only oriented towards consumption and exploitation of natural resources must be replaced with awareness of environmental sustainability (Daigle & Vasseur, 2019).

The plastic waste problem has become an increasingly urgent global issue to address. According to the United Nations Environment Programme (UNEP) report, about 8 million tons of plastic end up in the oceans each year, causing damage to marine ecosystems and threats to biodiversity (Oberoi & Garg, 2021). According to the Indonesian Consumers Foundation (YLKI), the use of single-use conventional plastic bags reached 9.8 billion pairs per year (Paul et al., 2023). The urgency to find environmentally friendly alternatives is increasing along with public awareness of the negative impacts of plastic.

Paper bags fall into the kraft paper category which, in its use, must maintain strength even in wet conditions, so the paper used requires high wet strength value, or has a tensile resistance yield above 10% when wet. This paper is also known as wet resistant paper. The principle of making wet resistant paper for paper bags is to provide wet resistant resin in the production process (Barbosa et al., 2021). Wet strength agents can increase resistance to wetness without reducing paper absorption of liquids, and at the same time make the paper not easily torn. Additionally, wet strength agents can also help the water removal process in paper, make paper products dry faster and increase paper strength when dry (Ntifafa et al., 2024).

Wet strength properties have two meanings. One is the initial wet strength intended to provide sufficient wet sheet resistance while the paper sheet is being processed in the paper machine. The other meaning is the strength of paper when rewetted, which is the strength of fully finished paper that is rewetted with water. For use as a paper bag, the wet strength referred to is the second one (Francolini et al., 2023). Paper bags as biodegradable containers/packaging are not widely known in Indonesia, so no paper manufacturers have tried to develop this product. This is because current packaging made from plastic (plastic bags) is considered stronger, more practical, and cheaper. However, from an environmental perspective, it becomes problematic because it cannot decompose within decades.

In this context, corn husk (*Zea mays* L.) emerges as a promising alternative raw material. Indonesia, as the third-largest corn producer in Southeast Asia, produces about 30 million tons of corn per year with estimated corn husk waste reaching 38.4% of total production (Indonesian Ministry of Agriculture, 2020). Corn husk has characteristics and composition that make it a potential material for making biodegradable paper bags. According to research by Ratna et al. (2022), corn husk consists of 15% lignin, 35% hemicellulose, and 40% cellulose. This high cellulose composition makes corn husk a good fiber source for papermaking. Corn husk fiber has an average length of 1.5 mm and diameter of 20 µm, providing good tensile strength to the final product. Bhardwaj et al (2023) states that corn husk has high water absorption capacity and good biodegradability, with natural degradation time of about 60-90 days.

Corn husk is agricultural waste that has great potential for utilization. According to Jin et al. (2021), global corn production generates about 230-250 million tons of corn husks per year, most of which are still not optimally utilized. Corn husk contains about 38-40% cellulose, 28% hemicellulose, and 7-13% lignin, making it a potential raw material for various applications including paper making and biodegradable products (Novia et al., 2022). Sari & Suteja (2020) shows that corn husk has good mechanical properties with tensile strength reaching 126.57 MPa making it suitable for use as packaging material. Corn husk utilization can not only reduce agricultural waste but also provide economic added value for farmers and related industries, thus aligning with circular economy principles (Bloise, 2020).

Previous research has demonstrated the versatility of corn husk in creating environmentally friendly products, from biodegradable packaging materials to sustainable textiles. While these studies have established the technical feasibility of corn husk utilization, there remains a significant gap in understanding how to effectively scale these innovations for commercial retail applications, particularly in the Indonesian context. Patil & Athalye (2023) explored the use of corn husk as a natural fiber source for textile and composite applications by demonstrating good tensile strength and biodegradability. In the context of papermaking, Castrillón et al. (2021) successfully produced good quality paper from a mixture of corn husk pulp and waste paper, showing the potential of corn husk as an alternative raw material in the paper industry. Optimizing the fiber extraction process from corn husk to improve the quality of the resulting pulp. In the realm of biodegradable packaging, Aygün et al. (2022) developed biodegradable film from corn husk starch reinforced with cellulose nanocrystals, resulting in materials with enhanced mechanical and barrier properties. This review aims to bridge these knowledge gaps by analyzing the potential for integrating corn husk-based products into Indonesia's retail packaging system while considering the practical, economic, and regulatory challenges unique to the country's context.

2. Methods

2.1 Type of paper

This study was conducted through a literature review with a qualitative descriptive-analytical approach. The literature study method was used to analyze and synthesize various scientific information sources related to the potential of corn husks as biodegradable packaging. A qualitative approach was applied to gain an in-depth understanding of the technical, environmental, and socio-economic aspects of biodegradable packaging development, as well as to explore existing challenges and opportunities in its implementation. With this approach, this study aims to provide more comprehensive insights into the sustainability and efficiency of using corn husks as an environmentally friendly alternative in the packaging industry.

2.2 Data and information sources

Data collection in this study utilized two types of information sources. Primary sources include scientific journal articles published in accredited national journals and reputable international journals, scientific conference proceedings, research reports, and related reference books that provide an in-depth understanding of the discussed topics. Secondary sources include statistical data or policy documents and related regulations from authorized government institutions, which are used to support analysis and provide relevant context in this study. Both types of information sources are expected to provide a complete and valid picture of corn husks' potential as biodegradable packaging material and the implications of its development in various sectors.

2.3 Data collection techniques

Data collection techniques in this paper were conducted through comprehensive literature studies from various reliable sources. These sources include scientific journals, textbooks, research reports, and official publications from relevant institutions. The focus of data collection emphasized aspects such as corn husk (*Zea mays* L.) characteristics, environmentally friendly paper-making techniques, circular economy concepts, and waste reduction strategies. The collected information includes both quantitative and qualitative data relevant to the development of bio-paperbag from corn husk as a biodegradable packaging alternative. Additionally, analysis of case studies and best practices related to similar product implementation in various countries was also conducted. This data collection process aims to build a strong theoretical foundation and provide comprehensive insights regarding the potential use of corn husks as raw material for environmentally friendly paper bag production.

2.4 Data processing techniques

Data processing techniques in this paper were conducted through descriptive and comparative analysis of information collected from various literature sources. Qualitative data was organized and categorized based on main themes such as corn husk characteristics, biodegradable paper bag production processes, environmental impacts, and circular economy implementation. Meanwhile, quantitative data, such as plastic usage statistics and production efficiency, was processed using descriptive statistical methods to provide a clear picture of bio-paperbag from corn husk's potential and development challenges. SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis was also applied to evaluate this product's feasibility and sustainability in the context of waste reduction and circular economy. Furthermore, synthesis techniques were used to integrate findings from various sources, compare bio-paperbag from corn husk with other alternatives, and draw comprehensive conclusions regarding its implementation potential as an environmentally friendly solution.

2.5 Data analysis

Data analysis in this study was conducted descriptively qualitatively, focusing on a comprehensive literature review from various reliable sources. The analysis process included collecting secondary data from scientific journals, technical reports, and official publications related to biodegradable packaging development, agricultural waste utilization, and circular economy implementation. The collected data was then categorized based on relevance to the main research aspects, namely corn husk characteristics, biodegradable paper production processes, environmental impacts, and economic potential. Subsequently, information synthesis was performed to identify patterns, trends, and gaps in current knowledge. Comparative analysis was also applied to compare bio-paperbag from corn husk with other packaging alternatives, using parameters such as biodegradability, material strength, and cost efficiency. The results of this analysis were used to formulate strong arguments regarding bio-paperbag from corn husk's potential in reducing waste and supporting the circular economy.

2.6 Drawing conclusions

Conclusions in this study were drawn through a synthesis and interpretation approach from various analyzed literature sources. This process involved critical evaluation of key findings by integrating information from various aspects studied, such as corn husks' potential as raw material, feasible production processes, positive environmental impacts, and promising economic prospects. Conclusions were formulated by considering bio-paperbag from corn husk's alignment with waste reduction objectives and circular economy principles. Additionally, identification of practical and theoretical implications of bio-paperbag from corn husk implementation was conducted, along with recommendations for further research and related policy development. The validity of conclusions was strengthened through data triangulation from various sources and different perspectives.

3. Results and Discussion

3.1 The potential of corn husks as raw material for bio-paperbag from corn husk

3.1.1 Physical and chemical characteristics of corn husks

Corn husks, or often called corn klobot, are the outer part that covers corn kernels. These corn husks are also a modified form of leaves that function to wrap corn cobs. Morphologically, corn husks have a rough surface and are dark green, sometimes found in light green. In one corn cob, the average number of corn husks reaches 12-15 sheets (Fikri & Yuniwati, 2022). The formulation of paper bag materials needs to be done to produce packaging with desired characteristics and suitable as a plastic substitute, such as the composition of raw materials and additives. This becomes a factor in producing quality paper bags, both in terms of strength, elasticity, tensile strength, and biodegradability (Sandak et al., 2019). The physical and chemical characteristics of corn husks show potential as raw material for paper bag production.

Corn husks have physical and chemical characteristics that make them highly potential as raw material for biodegradable paper bags. Physically, corn husks have a long and strong fiber structure with an average fiber length of 1.32 mm and diameter of 20.96 µm (Ubene, 2023). The chemical composition of corn husks is dominated by cellulose (38-42%), hemicellulose (28-32%), and lignin (7-13%), which provide good strength and flexibility for packaging applications (Setiawan et al., 2024). This high cellulose content enables the formation of strong hydrogen bonds between fibers, resulting in materials with adequate tear resistance and tensile strength for packaging functions. Additionally, corn husks have relatively low water absorption capacity compared to other natural fibers. This characteristic is advantageous in making paper bags that are resistant to moisture. The biodegradable properties of corn husks are also enhanced by the presence of cellulase enzymes that can break down cellulose structures, accelerating the natural decomposition process (Zuorro et al., 2019). This combination of physical and chemical characteristics makes corn husks a promising raw material for developing bio-paperbag from corn husk as an environmentally friendly packaging alternative.

3.1.2 Availability and sustainability of raw materials

The availability and sustainability of corn husks as raw material for bio-paperbag from corn husk is a crucial aspect in ensuring long-term production viability. This is also important in supporting the government to address dependence on plastic use by replacing it with natural fiber materials such as corn husks. Specifically, corn as a food crop commodity plays an important role in the economy and food security, due to its benefits in animal feed and fishery raw materials at 60% (Grote et al., 2021). Local food can meet food security aspects. From the production side, local food grows scattered and abundant throughout Indonesia, which can guarantee its availability, with a short distribution system also making local food systems more easily accessible. Local food has good quality and implements agroecology to ensure sustainability (Partini & Sari, 2022).

Corn is one of the main food crops in the world with global production reaching 1.16 billion tons in 2020 (Food and Agriculture Organization, 2021). Of this total production, corn husks contribute about 7-10% of the total weight of the corn plant (Ratna et al., 2022). In Indonesia alone, corn production reached 15.2 million tons in 2024 (Badan Pusat Statistik, 2024), generating significant potential availability of corn husks. The sustainability of this raw material is supported by corn's nature as an annual crop that can be harvested 2-3 times a year in tropical regions (García-Lara & Serna-Saldivar, 2019). Moreover, the use of corn husks for bio-paperbag from corn husk does not compete with food use, thus minimizing potential conflicts with food security. The use of corn husks, which are generally considered agricultural waste, also aligns with circular economy principles, where 'waste' from one process becomes a 'resource' for another process (Velenturf & Purnell, 2021).

3.1.3 Comparison with alternative raw materials

In developing biodegradable packaging, corn husks used as raw material for bio-paperbag from corn husk offer several advantages compared to other alternative materials. Corn husks, which are agricultural waste, have abundant availability and can be processed sustainably without threatening main food supplies. Additionally, this material contains strong natural fibers, making it suitable for use as strong yet environmentally friendly packaging material. Compared to conventional plastic, corn husks decompose faster in nature, reducing negative environmental impacts, particularly soil and water pollution from plastic waste. Corn husks have a much shorter growth cycle of 3-4 months compared to 10-20 years for trees, making them a more quickly renewable source (Zheng et al., 2022). Furthermore, the cellulose content of corn husks (38-42%) is relatively comparable to cotton fiber (85-90%) and hemp (68-76%) but with lower production costs (Kambli et al., 2021). The cellulose content in corn husks enables them to be made into paper, especially art paper (Fornari et al., 2022). Compared to starch-based biodegradable plastics like PLA (Polylactic Acid), bio-paperbag from corn husk has advantages in terms of faster biodegradability and does not compete with food sources. Meanwhile, compared to other natural fiber alternatives such as coconut husks or banana stems, corn husks have more abundant and consistent availability throughout the year in many countries (Jiao et al., 2022). The tensile strength and tear resistance of corn husk-based materials are better, due to their high cellulose content, compared to natural fiber raw materials from coconut pulp (Prasetia et al., 2022).

3.2 Bio-paperbag production process

The process of making paper bags from corn husks consists of several interconnected steps to produce a quality product (Figure 1). The first stage is collecting corn husks as the main material. The collected corn husks must be cleaned of dirt, dust, and corn kernel residue to avoid affecting the final product quality. After that, the corn husks are cut into pieces of about 5 cm. This cutting aims to facilitate the grinding process to produce uniform fine fibers. Next, the cut corn husks are dried to reduce moisture content. This drying process can be done naturally under sunlight or using mechanical dryers. After the corn husks are dry, the next step is grinding. In this stage, corn husks are ground into fine fibers. Grinding is very important because the quality of the resulting fibers affects the paper's tensile strength, particularly related to cellulose composition and adhesive homogeneity. More bonded fibers produce paper with better tensile strength. This grinding aims to produce paper with a smooth texture (Nairfana et al., 2023).

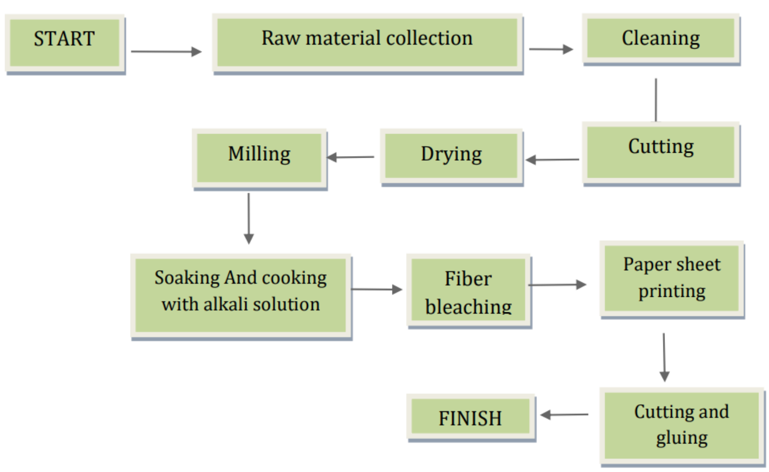

Fig. 1. ZeaPackage creation flow

After grinding, the fibers are soaked and cooked in an alkaline solution. This process functions to remove lignin and hemicellulose contained in the fibers, resulting in more flexible and easily moldable fibers. The cooked fibers are then weighed and mixed with additional materials according to the predetermined formulation. This mixture aims to achieve optimal cellulose content (Wowa & Yuniwati, 2021).

The next stage is fiber bleaching using environmentally friendly chemicals to increase paper brightness. The bleached fibers are then molded into paper sheets using a papermaking machine. After drying, the paper sheets are cut according to patterns and bonded to form paper bags. As a final touch, the paper bags can be decorated or printed with specific designs as needed to add aesthetic value and product appeal (Kaur et al., 2024). The pre-prototype of the ZeaPackage, which represents an early-stage model of the developed paper bag, is illustrated in Figure 2. This prototype provides a visual representation of the initial design and structural formation before full-scale production.

Fig. 2. ZeaPackage pra-prototype

3.3 Environmental impact analysis of bio-paperbag from corn husk

3.3.1 Biodegradability and decomposition time

Bio-paperbag from corn husk, as a corn husk-based product, shows high biodegradability potential. Biodegradability refers to the property of a material that allows it to naturally decompose in the environment with the help of microorganisms, such as fungi, bacteria, and algae. This process involves breaking down material components into simpler compounds, such as carbon dioxide, water, and biomass. Biodegradable materials usually come from natural sources, such as plants or animals, making them more environmentally friendly compared to synthetic materials that are difficult to decompose. Thus, they do not pollute the environment in the long term by leaving harmful residues. In this context, comparing different types of raw materials based on their biodegradability is important to determine the best use of each type of raw material. In determining raw material priorities, several factors can be used as references, namely biodegradable raw materials containing starch, amylose, and amylopectin (Aritonang et al., 2024). Raw materials with faster biodegradation rates are suitable for single-use products, while raw materials with slower biodegradation rates can be used for products requiring long-term durability. Additionally, knowledge about the biodegradability of raw materials used to make products can help industries and consumers make wise decisions regarding product selection and use. Industries can develop specific products based on biodegradability levels according to needs, while consumers can choose and buy more environmentally friendly products based on available information (Alam et al., 2024).

Literature review shows that cellulose-based materials from agricultural waste, such as corn husks, can naturally decompose within 2-5 months, depending on environmental conditions (Prasetyo & Nurainy, 2024). The biodegradation process in bio-paperbag from corn husk occurs through soil microorganism activity that breaks down cellulose structures into simple compounds, such as glucose, carbon dioxide, and water. Microorganisms like bacteria, fungi, and algae play important roles in this process as they produce enzymes capable of effectively breaking down cellulose. The decomposition rate of this material is influenced by various factors, such as temperature, humidity, and microbial activity levels in the soil. Warm temperatures and sufficient moisture will increase microbial activity, thus accelerating decomposition. With these properties, bio-paperbag from corn husk becomes an environmentally friendly solution that helps reduce non-biodegradable waste accumulation.

Compared to conventional plastic bags that can take up to 1000 years to decompose, bio-paperbag from corn husk offers a much more environmentally friendly solution (Hossain & Tuha, 2020). For biodegradability, corn husks decompose within 1-2 months under optimal conditions, faster than bamboo fibers (4-6 months) but comparable to banana fibers (1-2 months). Additionally, bio-paperbag from corn husk decomposition products can function as organic fertilizer that provides nutrients to the soil and supports plant growth.

3.3.2 Carbon footprint reduction compared to conventional plastics

Bio-paperbag from corn husk offers great potential in reducing carbon footprint compared to conventional plastic bags. Conventional plastics, such as polypropylene (PP) and polyethylene (PE), are known to have inert and durable properties, making them difficult to degrade naturally. Consequently, these plastics take a very long time to decompose in the environment, even up to hundreds of years. Moreover, their degradation process is less efficient and often leaves microplastic residues that contaminate soil and water (Asriza et al., 2023).

Conversely, bio-paperbag from corn husk utilizes corn husks as the main raw material, which is a byproduct of agricultural activities. Using this material not only supports agricultural waste management but also optimizes existing resources. By avoiding new raw material extraction, corn husk use directly reduces carbon emissions typically associated with petroleum-based plastic production processes. Based on life cycle assessment studies, natural fiber-based bags like bio-paperbag from corn husk can reduce greenhouse gas emissions by up to 40% compared to conventional plastic bags (Bishop et al., 2021).

Furthermore, bio-paperbag from corn husk's production process is designed to be simpler and requires less energy compared to synthetic plastic production. This energy efficiency directly contributes to reducing carbon emissions generated during manufacturing. Bio-paperbag from corn husk's biodegradability is also an important advantage, as this material can naturally decompose by soil microorganisms without leaving harmful residues. This reduces methane emissions that often arise from conventional plastic waste piles in landfills, which are significant sources of greenhouse gases (Wangyao et al., 2021).

Another advantage of ZeaPackage is its ability to absorb carbon dioxide during corn plant growth. Thus, corn husks used in its production serve as temporary carbon storage, providing additional benefits in climate change mitigation efforts. Overall, bio-paperbag from corn husk not only helps reduce the environmental impact of conventional plastics but also becomes a concrete step in supporting sustainability and environmental conservation (Lamba et al., 2022).

3.3.3 Potential reduction of agricultural and plastic waste

Agricultural waste has not been utilized by communities despite its potential to become economically valuable products, including corn husk waste which is usually only used as raw material for handicrafts. However, utilization efforts are not yet optimal because only some waste is absorbed (Darmayanti et al., 2020). Therefore, appropriate processing technology is needed to increase the added value of this waste and provide economic benefits for farmers and communities. Through agricultural waste utilization, it not only reduces plastic waste but also helps address waste problems generated by agricultural activities themselves (Mihai et al., 2021).

Bio-paperbag from corn husk offers an innovative solution to address two environmental problems simultaneously: agricultural waste and plastic waste. Using corn husks as the main raw material for bio-paperbag from corn husk significantly reduces agricultural waste that is usually burned or discarded, a practice that contributes to air pollution and greenhouse gas emissions (Adegbeye et al., 2020). According to FAO, global corn production reached 1.1 billion tons in 2019, with an estimate that about 20% of the total plant weight is corn husks (Ibrahim et al., 2019). Converting this waste into value-added products like bio-paperbag from corn husk not only reduces agricultural waste volume but also creates additional income sources for farmers. Meanwhile, as a biodegradable alternative to conventional plastic bags, bio-paperbag from corn husk has the potential to substantially reduce plastic waste accumulation. Considering that about 5 trillion plastic bags are used globally each year (Suleman et al., 2022), replacing some of this number with bio-paperbag from corn husk can have a significant impact in reducing plastic waste that pollutes the environment and threatens ecosystems.

3.4 Bio-paperbag from corn husk in the context of circular economy

3.4.1 Circular economy principles applied

The principles of circular economy include designing products that generate no waste (design out waste), maximizing the use of renewable and recyclable resources, and systems thinking (Franco, 2019). Circular economy refers to the concept of creating a restorative industrial system, and this concept is expected to provide greater competitive advantages in the future by creating high value from managed resources compared to the linear economic model (take-make-dispose) (Jayawati et al., 2020). Additionally, it can minimize environmental impact by designing more efficient and sustainable production and consumption processes. Sustainable product innovation is not a choice but an urgent necessity; products that apply renewable, recycled, or reusable sustainability principles not only create new value but also support reducing non-renewable resources (Irwin et al., 2024).

Bio-paperbag from corn husk implements several key circular economy principles that demonstrate its potential as a sustainable solution in the packaging industry. First, this product applies regenerative design principles by utilizing corn husks that are usually discarded as the main raw material (Stathatou et al., 2023). This creates value from what was previously considered waste, aligning with the "waste to resource" concept in circular economy. Second, bio-paperbag from corn husk supports material efficiency principles through the use of renewable and biodegradable materials to reduce dependence on non-renewable resources like petroleum used in conventional plastic production (Singh et al., 2022). Bio-paperbag from corn husk also drives system innovation by creating new opportunities in agricultural and packaging industry value chains, supporting the transition towards more circular and sustainable business models.

3.4.2 Value chain and product lifecycle

Bio-paperbag from corn husk demonstrates circular economy implementation through its sustainable value chain and product lifecycle. Starting from the raw material procurement stage, bio-paperbag from corn husk utilizes corn husks, which are agricultural by-products, to create added value from what was previously considered waste, proving capable of improving the economy for farmers and communities while reducing direct environmental impact (Mainardis et al., 2022). Bio-paperbag from corn husk 's production process is designed to minimize waste and optimize resource use in accordance with material efficiency principles in circular economy; corn husks are considered abundant waste that hasn't been well managed, making their utilization as raw material for bio-paperbag from corn husk production an appropriate solution (Velenturf & Purnell, 2021).

During the usage phase, bio-paperbag from corn husk supports the concept of product life extension through potential reuse before eventual decomposition, as paper produced from corn husk raw materials has relatively long durability and strength. At the end of its life, bio-paperbag from corn husk's biodegradability allows the product to return to the biological cycle as soil nutrients to avoid waste accumulation and support natural system regeneration, as bio-paperbag from corn husk contains natural fibers that easily degrade in soil and can improve soil quality (Daria et al., 2020). The bio-paperbag from corn husk business model has the potential to build new partnerships between corn farmers, packaging producers, and end consumers, which can encourage cross-sector collaboration, a key element in circular economy (Arista, 2024). This implementation also offers opportunities in creating more dynamic and adaptive business models, prioritizing sustainability that not only benefits the economy in the long term but also builds consumer loyalty aware of the environmental impact of what they use. This becomes an opportunity not just because of its innovation but commitment towards a better future (Tang et al., 2019).

3.4.3 Recycling and reuse potential of bio-paperbag from corn husk

Bio-paperbag from corn husk has significant potential in supporting circular economy concept implementation through its recycling and reuse capabilities. As a cellulose-based product, bio-paperbag from corn husk can be integrated into existing paper recycling systems that enable reprocessing into new paper products, producing quality paper combinations that can be used according to needs (Sahal et al., 2020). However, unlike conventional paper, bio-paperbag from corn husk's biodegradable properties open wider utilization opportunities and products designed for durability, considering its lifecycle from beginning to end, thus reducing the need for continuous production and ultimately reducing waste (S. Zhang et al., 2022). After use, bio-paperbag from corn husk can be composted, providing nutrients for soil and supporting sustainable agriculture, thus providing additional benefits for farmers (Tahat et al., 2020). Used bio-paperbag from corn husk can be processed into bioethanol through fermentation, providing added energy value in the circular economy chain (Devi et al., 2022). Residues from the bioconversion process can be utilized as organic fertilizer, creating a closed nutrient cycle (Chavan et al., 2022). This cascading use approach aligns with circular economy principles, where material value is maintained as long as possible in the economic system. Bio-paperbag from corn husk's multipurpose potential not only reduces waste but also creates new value streams, drives innovation in resource utilization, and contributes to the transition towards a more sustainable economic system.

3.5 Economic and market aspects of bio-paperbag from corn husk

3.5.1 Production cost and selling price analysis

The analysis of bio-paperbag from corn husk's production costs and selling price is crucial in determining the product's economic viability and market competitiveness. bio-paperbag from corn husk's production costs are influenced by several key factors, including raw material costs, processing costs, and production scale. Corn husks as the main raw material have a cost advantage given their status as agricultural by-products often considered waste (Donner et al., 2021). Research by Bajpai (2021) shows that production costs of plant fiber-based paper, including corn husks, can be 5-15% lower than conventional paper depending on process efficiency and production scale. However, initial investment in specific processing technology can increase production costs in the early stages. In terms of selling price, bio-paperbag from corn husk can potentially be positioned as a premium eco-friendly product given the growing trend of environmentally conscious consumers. Market studies by Hao et al (2019) show that consumers are willing to pay 10-25% more for environmentally friendly packaging products. Considering competitive production costs and premium price potential, bio-paperbag from corn husk has promising economic prospects. However, appropriate pricing strategies need to consider demand elasticity and competition in the growing biodegradable packaging market (Confente et al., 2020).

3.5.2 Economic impact on corn farmers and local industries

Bio-paperbag from corn husk implementation has the potential to create positive economic impacts for corn farmers and local industries. Utilizing corn husks previously considered agricultural waste can create additional revenue streams for farmers, increasing the total economic value of corn production. Research by Ayoo & Bonti-Ankomah (2019) shows that utilizing agricultural by-products can increase farmer income by 15-20%. Additionally, bio-paperbag from corn husk development can drive local processing industry growth, create new jobs, and stimulate regional economies. A case study by Toplicean & Datcu (2024) on agricultural waste-based bioeconomy shows the potential creation of 7-9 jobs per 1000 tons of processed raw materials. Integrating bio-paperbag from corn husk into local value chains can strengthen relationships between agricultural and industrial sectors to drive innovation and technology transfer (Sherwood, 2020). However, challenges such as raw material price fluctuations and initial investment needs for processing infrastructure must be addressed to maximize economic benefits. In practice, circular economy principles often require complete overhauls in production processes and supply chains, making many industry players reluctant to take these risks. Policy support such as tax incentives or subsidies for environmentally friendly processing industries can play an important role in accelerating adoption and expanding bio-paperbag from corn husk's positive economic impact (Oberoi & Garg, 2021). Stakeholder collaboration becomes key in building an ecosystem that supports circular economy; without synergy between government, industry, and society, efforts to implement circular economy will struggle to achieve the desired scale for successful transition towards a circular economy.

3.6 SWOT analysis

The SWOT analysis in this topic highlights the main factors influencing the development of biodegradable paper bags from corn husks, including strengths, weaknesses, opportunities, and threats. Corn husks have great potential as raw materials for biodegradable paper bags, with a cellulose content of around 41.23% (Fitriani & Amalia, 2024). Its advantage lies in its abundant availability in Indonesia, with corn production reaching 15.02 million tons per year (BPS, 2024a; 2024b). Utilization of this waste not only reduces environmental pollution but also provides economic added value for farmers.

However, the processing of corn husks into biodegradable paper still faces obstacles, especially in the cellulose extraction technology which requires high costs (Masturi et al., 2021). Consistency of product quality is also a challenge, especially in terms of paper strength and durability, which is still influenced by the high lignin content. In addition, global demand for biodegradable products continues to increase (Moshood et al., 2021), driven by policies such as Presidential Regulation No. 97 of 2017 concerning Plastic Waste Reduction. Collaboration between universities, industry, and government can accelerate product innovation and commercialization, while the widespread distribution of corn production in Indonesia allows for supply chain efficiency and job creation in rural areas.

On the other hand, competition with alternative materials such as bamboo fiber and seaweed is a major challenge. In addition, fluctuations in raw material prices and limitations in industrial-scale production technology can hamper product development. Low consumer awareness of environmentally friendly products is also a significant obstacle (Abdussamad et al., 2024). To provide a clearer picture of these aspects, the results of the SWOT analysis in this study are presented in Table 1.

Table 1. SWOT analysis of corn husk-based biodegradable paper bags

Factors	Internal (Strengths & Weaknesses)	External (Opportunities & Threats)
Positive impact	Strengths 1. High cellulose content (41.23%) makes corn husks suitable for biodegradable paper production. 2. Abundant availability with Indonesia's corn production reaching 15.02 million tons in 2024. 3. Utilization of corn husk waste reduces environmental pollution and adds economic value for farmers.	Opportunities 1. Rising global demand for biodegradable products (Moshood et al., 2021). 2. Government regulations (Presidential Regulation No. 97 of 2017) encourage plastic waste reduction. 3. Collaboration with universities, industry, and government can accelerate innovation. 4. Localized processing reduces costs and creates rural job opportunities.
Negatif impact	Weaknesses 1. High technology and costs required for cellulose extraction (Masturi et al., 2021). 2. Inconsistent paper quality requiring process modifications. 3. High lignin content affects paper production efficiency.	Threats 1. Competition with alternative biodegradable materials (bamboo fiber, seaweed-based paper). 2. Fluctuating raw material prices and limited industrial-scale production technology. 3. Low consumer awareness of eco-friendly products (Abdussamad et al., 2024).

3.7 Challenges of implementation and solutions for corn husk bio-paper bags

The implementation challenges and solutions for corn husk bio-paper bags are crucial aspects in assessing the feasibility and sustainability of this innovation. Furthermore, Table 2 identifies various challenges as well as future strategies and solutions that can be implemented, as summarized from previous research results.

Table 2. Challenges, root causes, impacts, and strategic solutions for corn husk-based biodegradable paper bags

Challenges	Root Causes	Impact	Future Strategies & Solutions
Raw material quality variability (Ratna et al., 2022).	Dynamic interactions between plant genetics, agroecological conditions, cultivation practices, and corn maturation stages.	Varying range of cellulose content.	Developing strict standardization protocols, identifying corn varieties with high cellulose content, geographic mapping of raw material potential.
Production technology constraints (Lingga et al., 2024).	Limited industrial-scale agricultural waste processing infrastructure and low cellulose extraction efficiency .	Reduced competitiveness of biodegradable paper bags due to inefficiencies in production.	Strategic investment in research and development to enhance extraction technologies and technology transfer from research to industry.

Economic and market challenges (Li et al., 2022)	Biodegradable paper bags are still 30-40% more expensive compared to conventional plastic products.	High costs limit market adoption and consumer preference for cheaper alternatives.	Scaling up production to reduce per-unit costs and implementing consumer education campaigns on environmental benefits.
Regulatory complexity (Tarumingkeng, 2024).	Overlapping regulations between ministries create barriers in waste management and sustainable product development.	Slow adoption of green initiatives due to bureaucratic inefficiencies and lack of regulatory harmonization.	Establishing a coordination team for cross-ministerial regulatory harmonization and simplifying permit mechanisms.
Sustainable development strategy (Yanti, 2024)	Lack of synergy between universities, industry, and local governments in driving sustainable innovation.	Ineffective implementation of circular economy principles and slow technological progress.	Implementing innovation cluster models to create ecosystems that facilitate knowledge, resource, and expertise exchange.
Nanomaterial technology innovation (Noor et al., 2020).	Lack of advanced material engineering techniques to enhance paper properties.	Weak mechanical performance and limited durability of biodegradable paper bags.	Molecular modification through nanotechnology to improve tensile strength, degradation rate, and overall performance.
Genetic engineering and corn variety optimization (Hearon et al., 2021).	Inconsistent cellulose content and high lignin levels in natural corn husks .	Limited raw material suitability for biodegradable paper production.	Genetic engineering to increase cellulose content and reduce lignin levels in corn husks.
Integrated circular economic strategy (Jiang et al., 2022).	Fragmented supply chains and lack of structured recycling systems.	Suboptimal utilization of agricultural waste and economic inefficiencies.	Establishing an integrated production network involving farmers, industries, and recycling systems.
Advanced production technologies (N. Zhang et al., 2022).	Traditional extraction methods are inefficient and environmentally harmful.	High production costs and environmental concerns due to inefficient processes.	Implementation of hydrothermal and sonication technologies to reduce costs and improve efficiency.
Global market expansion (Moshood et al., 2021).	Limited international recognition and market penetration for corn husk-based biodegradable products.	Indonesia's potential as a leading producer remains underutilized.	Expanding global market outreach, focusing on the Asia-Pacific region, and leveraging Indonesia's competitive advantages.

Variability in the quality of raw materials is a fundamental challenge in producing biodegradable paper bags from corn husks, which requires a comprehensive and systematic approach. Ratna et al. (2022) revealed a wide range of cellulose content while emphasizing the complexity of the factors that influence it. This variation is caused by the dynamic interaction between plant genetics, agroecological conditions, cultivation practices, and corn maturation stages. To overcome this inconsistency, the researchers proposed a multi-level strategy. First, develop a strict standardization protocol including sampling methods, chemical characterization, and raw material quality assessment. This protocol will include detailed guidelines ranging from variety selection, cultivation techniques, to optimal harvest time and methods. Identifying corn varieties with high cellulose content is the focus of genetic research. Through plant breeding and genetic engineering approaches, scientists are trying to develop superior varieties that consistently produce corn husks with ideal cellulose characteristics. In addition, geographical mapping of potential raw materials will enable a more structured production pattern, ensuring sustainable supply and reducing the risk of supply uncertainty.

Furthermore, the limitations of industrial-scale production technology present significant challenges in converting the potential of corn husks into competitive biodegradable products. Lingga et al. (2024) highlighted that agricultural waste processing infrastructure is still inadequate, with low cellulose extraction efficiency. To change this condition, strategic investment in research and development is needed. The main focus is to develop more efficient, environmentally friendly, and sustainable cellulose extraction technology. This approach not only includes technical aspects but also considers environmental impacts and production sustainability. In addition, technology transfer from research institutions to industry is key to success. Collaboration between universities, research institutions, and the industrial sector can accelerate the innovation process. The government can play a role through research grant incentives and policies that encourage green technology innovation.

The economic dimension is also an important factor in determining the success of biodegradable paper bag implementation. Li et al. (2022) found that production costs remain a significant barrier, with biodegradable paper bags still 30-40% more expensive than conventional plastic products. Cost reduction strategies require a comprehensive approach. Increasing the scale of production is a top priority to achieve cost efficiency. The larger the production volume, the lower the cost per unit, making the product more competitive in the market. In addition, consumer education campaigns play an important role in raising awareness of environmental benefits. Effective communication about the positive impacts of using environmentally friendly products can change consumer perceptions and preferences. Governments and environmental organizations can actively encourage changes in consumption behavior to support the transition to sustainable products.

Regulatory complexity is another obstacle to the development of environmentally friendly products. Tarumingkeng (2024) identified overlapping regulations between ministries as a major challenge in waste management and sustainable product development. Harmonization of cross-ministerial regulations is a strategic step. The formation of a special coordination team involving various stakeholders can accelerate policy synchronization. Simplifying the licensing mechanism for sustainable innovation will encourage more green initiatives, thereby creating a conducive environment for the development of environmentally friendly products.

The implementation of the circular economy concept requires a multidimensional and collaborative approach. Yanti (2024) emphasized the importance of synergy between universities, industry, and local governments in encouraging sustainable innovation. The innovation cluster model has proven to be the most effective, creating an ecosystem that allows the exchange of knowledge, resources, and expertise. This approach not only accelerates innovation but also has a broader positive impact on green economic development. With a comprehensive strategy that addresses technological, economic, regulatory, and collaborative aspects, the potential of biodegradable paper bags from corn husks can be optimized, contributing significantly to reducing plastic pollution and supporting sustainable economic growth.

Looking at future developments, nanotechnology introduces significant breakthroughs in the production of biodegradable paper bags. Noor et al. (2020) showed the transformative potential of nanocellulose, with a 78% increase in paper tensile strength and a 35% reduction in degradation rates. Molecular modification through nanotechnology enables the engineering of materials with superior characteristics. This approach not only improves mechanical performance but also optimizes environmental resistance and product functionality. Nanotechnology opens up the possibility of creating stronger, lighter, and more efficient biodegradable materials.

Genetic engineering and optimization of corn varieties also have great potential. Hearon et al. (2021) presented a revolutionary genetic breakthrough, with the ability to increase the cellulose content in corn husks by up to 55% while significantly reducing lignin levels. The genetic engineering approach allows the creation of corn varieties specifically designed for the production of biodegradable paper bags. Genetic optimization not only promises to improve the quality of raw materials but also opens up opportunities to design more efficient plants in the production of environmentally friendly materials. This strategy can transform the supply chain and production of biodegradable materials.

Integrated circular economy strategies are essential to ensure long-term sustainability. Jiang et al. (2022) proposed a complex and integrated production network model. This concept goes beyond traditional biodegradable paper bag production, creating a sustainable economic ecosystem involving farmers, processing industries, and recycling systems. Projections for this model are very promising, with the potential to create 12,000 new jobs in the agricultural waste processing sector. This holistic approach not only drives technological innovation but also supports sustainable economic development.

Advances in production technology will further strengthen the industry. Zhang et al. (2022) identified hydrothermal and sonication technologies as transformative solutions in production. These methods promise to reduce production costs by 40% while providing the benefits of faster, cleaner, and more environmentally friendly cellulose extraction. Innovation in production technology will accelerate the development of biodegradable paper bags, making the product more competitive and sustainable. This approach marks a significant evolution in agricultural waste processing technology.

Finally, the expansion of the global market presents significant opportunities. Moshood et al. (2021) reported promising market growth projections, with global demand increasing by 22.5% per year. The Asia-Pacific region is the focus of major market development for biodegradable products. Indonesia holds a strategic position to become a leading producer of corn husk-based biodegradable paper bags. Competitive advantages in raw materials and technological innovation put Indonesia on the path to global leadership in the environmentally friendly material industry. The integration of technological innovation, genetic engineering, circular economy strategies, and production technology development will drive the transformation of the biodegradable paper bag industry, creating sustainable solutions that address global environmental challenges.

4. Conclusions

Based on the literature analysis conducted, bio-paperbag from corn husk, a biodegradable paper bag made from corn husks (*Zea mays* L.), demonstrates significant potential as an environmentally friendly alternative to plastic bags. The physical and chemical characteristics of corn husks, particularly their high cellulose content, make them a promising raw material for biodegradable packaging production. The abundant availability of corn husks as an agricultural by-product further supports the sustainability of bio-paperbag production on a large scale. Furthermore, bio-paperbag from corn husk effectively implements the circular economy concept through the utilization of agricultural by-products as the main raw material, reflecting the principles of recycling and resource reuse. Its potential for composting or conversion into other value-added products after use supports a sustainable material cycle that minimizes disposal while maximizing economic value.

For future research directions, several key areas warrant investigation. First, studies should focus on optimizing the manufacturing process to enhance the mechanical properties and durability of corn husk-based packaging while maintaining its biodegradability. Second, comprehensive life cycle assessments should be conducted to quantify the environmental benefits and potential impacts of scaled-up production. Third, research into consumer acceptance and behavior regarding corn husk-based packaging products would provide valuable insights for market development. Additionally, economic feasibility studies examining various production scales and market conditions would help identify optimal business models for commercialization. Finally, investigation into policy frameworks and incentive structures that could support the adoption of bio-paperbag from corn husk in retail environments would contribute to its successful implementation at scale.

Acknowledgement
The authors sincerely thank our colleagues and advisors for their valuable guidance and support. Appreciation is extended to Department of Biology, Faculty of Science and Technology, Raden Intan Islamic State University of Lampung for providing resources. Special thanks to all contributors who assisted in this study.

Author Contribution
Conceptualization, F.Az.; Methodology, F.Af.; Software, F.Af.; Validation, F.Az.; Formal Analysis, F.Az.; Investigation, O.J.A., and R.D.A.; Resources, O.J.A. and R.D.A.; Data Curation, F.Af.; Writing – Original Draft Preparation, O.J.A., and R.D.A.; Writing – Review & Editing, F.Az. and F.Af.; Visualization, F.Az.; Supervision, F.Az.; Project Administration, F.Af.; and Funding Acquisition, O.J.A. and R.D.A.

Funding
This research received no external funding.

Ethical Review Board Statement
Not available.

Informed Consent Statement
Not available.

Data Availability Statement
Not available.

Conflicts of Interest
The authors declare no conflict of interest.

Open Access
©2025. The author(s). This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third-party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit: http://creativecommons.org/licenses/by/4.0/

References
Abdussamad, S., Tamrin, M. M., Rusmulyadi, R., Dunggio, S., & Abdussamad, J. (2024). Pendidikan dan Kesadaran Masyarakat tentang Manfaat Briket dari Limbah Tongkol Jagung: Strategi Pengabdian Masyarakat. *Empiris Jurnal Pengabdian Pada Masyarakat*, *2*(1), 19–31. https://doi.org/10.59713/ejppm.v2i1.1094

Adegbeye, M. J., Reddy, P. R. K., Obaisi, A. I., Elghandour, M., Oyebamiji, K. J., Salem, A. Z. M., Morakinyo-Fasipe, O. T., Cipriano-Salazar, M., & Camacho-Díaz, L. M. (2020). Sustainable agriculture options for production, greenhouse gasses and pollution alleviation, and nutrient recycling in emerging and transitional nations-An overview.

Journal of Cleaner Production, *242*, 118319. https://doi.org/10.1016/j.jclepro.2019.118319

Alam, M., Perdana, R., & Salnus, S. (2024). Perbandingan Sifat Biodegradabilitas Plastik Biodagradable Berbahan Dasar Pati Ampas Sagu dan Selulosa Tongkol Jagung. *Jurnal SAINTEK Patompo*, *2*(1), 50–58. https://ojs.unpatompo.ac.id/index.php/saintek/article/view/362

Arista, N. I. D. (2024). Karakteristik limbah pertanian dan dampaknya: Mengapa pengelolaan ramah lingkungan penting? *Waste Handling and Environmental Monitoring*, *1*(2), 67–76. https://doi.org/10.61511/whem.v1i2.2024.1204

Aritonang, S., Rhomadon, F. I., Subiakto, A. K. H., & Nismarawati, A. K. (2024). Pemanfaatan Limbah Biomassa Sebagai Plastik Biodegradable Yang Diaplikasikan Pada Food Packaging Ransum Tni. *Jurnal Rekayasa Material, Manufaktur Dan Energi*, *7*(2). https://jurnal.umsu.ac.id/index.php/RMME/article/view/18455

Asriza, R. O., Nurhadini, N., Azizah, Q. N., & Narulita, A. (2023). Analisis Sifat Mekanik dan Permukaan pada Degradasi Plastik Konvensional. *Jurnal Riset Fisika Indonesia*, *4*(1), 25–29. https://doi.org/10.33019/jrfi.v4i1.4645

Aygün, A., Özdemir, S., Gülcan, M., Yalçın, M. S., Uçar, M., & Şen, F. (2022). Characterization and antioxidant-antimicrobial activity of silver nanoparticles synthesized using Punica granatum extract. *International Journal of Environmental Science and Technology*, *19*(4), 2781–2788. https://doi.org/10.1007/s13762-021-03246-w

Ayoo, C., & Bonti-Ankomah, S. (2019). Economic Impacts of Value Addition to Agricultural Byproducts. In B. K. Simpson, A. N. A. Aryee, & F. Toldrá (Eds.), *Byproducts from Agriculture and Fisheries* (1st ed., pp. 685–698). Wiley. https://doi.org/10.1002/9781119383956.ch31

Badan Pusat Statistik [BPS]. (2024a). *Produksi Tanaman Perkebunan—Tabel Statistik—Badan Pusat Statistik Indonesia*. https://www.bps.go.id/id/statistics-table/2/MTMyIzI=/produksi-tanaman-perkebunan--ribu-ton-.html

Badan Pusat Statistik [BPS]. (2024b). *Luas Panen, Produksi, dan Produktivitas Jagung Menurut Provinsi—Tabel Statistik*. https://www.bps.go.id/id/statistics-table/2/MjIwNCMy/luas-panen--produksi--dan-produktivitas-jagung-menurut-provinsi.html

Bajpai, P. (2021). *Nonwood plant fibers for pulp and paper*. Elsevier.

Barbosa, E. D., Neto, J. L., Teixeira, D. G., Bezerra, K. S., do Amaral, V. S., Oliveira, J. I., Lima, J. S., Machado, L. D., & Fulco, U. L. (2021). Exploring human porphobilinogen synthase metalloprotein by quantum biochemistry and evolutionary methods. *Metallomics*, *13*(4), mfab017. https://doi.org/10.1093/mtomcs/mfab017

Bhardwaj, A., Sharma, N., Alam, T., Sharma, V., Sahu, J. K., Hamid, H., Bansal, V., & Alam, M. S. (2023). Development and Characterization of Chitosan and Beeswax–Chitosan Coated Biodegradable Corn Husk and Sugarcane Bagasse-Based Cellulose Paper. *Waste and Biomass Valorization*, *14*(5), 1625–1636. https://doi.org/10.1007/s12649-022-01952-1

Bishop, G., Styles, D., & Lens, P. N. (2021). Environmental performance comparison of bioplastics and petrochemical plastics: A review of life cycle assessment (LCA) methodological decisions. *Resources, Conservation and Recycling*, *168*, 105451. https://doi.org/10.1016/j.resconrec.2021.105451

Bloise, C. (2020). Collaboration in a circular economy: Learning from the farmers to reduce food waste. *Journal of Enterprise Information Management*, *33*(4), 769–789. https://doi.org/10.1108/JEIM-02-2019-0062

Castrillón, H. D. C., Aguilar, C. M. G., & Álvarez, B. E. A. (2021). Circular economy strategies: Use of corn waste to develop biomaterials. *Sustainability*, *13*(15), 8356. https://doi.org/10.3390/su13158356

Chavan, S., Yadav, B., Atmakuri, A., Tyagi, R. D., Wong, J. W., & Drogui, P. (2022). Bioconversion of organic wastes into value-added products: A review. *Bioresource Technology*, *344*, 126398. https://doi.org/10.1016/j.biortech.2021.126398

Confente, I., Scarpi, D., & Russo, I. (2020). Marketing a new generation of bio-plastics products for a circular economy: The role of green self-identity, self-congruity, and perceived value. *Journal of Business Research*, *112*, 431–439. https://doi.org/10.1016/j.jbusres.2019.10.030

Daigle, C., & Vasseur, L. (2019). Is it time to shift our environmental thinking? A perspective on barriers and opportunities to change. *Sustainability*, *11*(18), 5010. https://doi.org/10.3390/su11185010

Daria, M., Krzysztof, L., & Jakub, M. (2020). Characteristics of biodegradable textiles used in environmental engineering: A comprehensive review. *Journal of Cleaner Production*, *268*, 122129. https://doi.org/10.1016/j.jclepro.2020.122129

Darmayanti, N., Febrianti, D. I., & Lestari, S. A. P. (2020). Pemanfaatan Limbah Kulit Jagung Untuk Meningkatkan Perekonomian Di Desa Pejok Kecamatan Kepohbaru Kabupaten Bojonegoro. *Ekobis Abdimas: Jurnal Pengabdian Masyarakat*, *1*(1), 68–75. https://doi.org/10.36456/ekobisabdimas.1.1.2343

Devi, A., Bajar, S., Kour, H., Kothari, R., Pant, D., & Singh, A. (2022). Lignocellulosic Biomass Valorization for Bioethanol Production: A Circular Bioeconomy Approach. *BioEnergy Research*, *15*(4), 1820–1841. https://doi.org/10.1007/s12155-022-10401-9

Donner, M., Verniquet, A., Broeze, J., Kayser, K., & De Vries, H. (2021). Critical success and risk factors for circular business models valorising agricultural waste and by-products. *Resources, Conservation and Recycling*, *165*, 105236. https://doi.org/10.1016/j.resconrec.2020.105236

Fikri, R., & Yuniwati, M. (2022). Pemanfaatan Kulit Jagung Dan Tongkol Jagung (*Zea mays*) Sebagai Bahan Dasar Pembuatan Kertas Seni Dengan Penambahan Natrium Hidroksida (NaOH)(Variabel Konsentrasi NaOH dengan Waktu Pemasakan). *Jurnal Inovasi Proses*, *7*(2), 75–81. https://doi.org/10.34151/jip.v7i2.4226

Fitriani, S. O., & Amalia, A. (2024). Efisiensi Serbuk Kulit Jagung dan Kulit Bawang Merah Sebagai Adsorben dalam Menurunkan Kadar BOD dan COD pada Air Sungai. *Jurnal Serambi Engineering*, *9*(4). https://jse.serambimekkah.id/index.php/jse/article/view/548

Food and Agriculture Organization. (2021). *World Food and Agriculture – Statistical Yearbook 2021*. FAO. https://doi.org/10.4060/cb4477en

Fornari, A., Rossi, M., Rocco, D., & Mattiello, L. (2022). A review of applications of nanocellulose to preserve and protect cultural heritage wood, paintings, and historical papers. *Applied Sciences*, *12*(24), 12846. https://doi.org/10.3390/app122412846

Franco, M. A. (2019). A system dynamics approach to product design and business model strategies for the circular economy. *Journal of Cleaner Production*, *241*, 118327. https://doi.org/10.1016/j.jclepro.2019.118327

Francolini, I., Galantini, L., Rea, F., Di Cosimo, C., & Di Cosimo, P. (2023). Polymeric wet-strength agents in the paper industry: An overview of mechanisms and current challenges. *International Journal of Molecular Sciences*, *24*(11), 9268. https://doi.org/10.3390/ijms24119268

García-Lara, S., & Serna-Saldivar, S. O. (2019). Corn history and culture. *Corn*, 1–18. https://doi.org/10.1016/B978-0-12-811971-6.00001-2.

Grote, U., Fasse, A., Nguyen, T. T., & Erenstein, O. (2021). Food security and the dynamics of wheat and maize value chains in Africa and Asia. *Frontiers in Sustainable Food Systems*, *4*, 617009. https://doi.org/10.3389/fsufs.2020.617009

Hao, Y., Liu, H., Chen, H., Sha, Y., Ji, H., & Fan, J. (2019). What affect consumers' willingness to pay for green packaging? Evidence from China. *Resources, Conservation and Recycling*, *141*, 21–29. https://doi.org/10.1016/j.resconrec.2018.10.001

Hearon, S. E., Wang, M., McDonald, T. J., & Phillips, T. D. (2021). Decreased bioavailability of aminomethylphosphonic acid (AMPA) in genetically modified corn with activated carbon or calcium montmorillonite clay inclusion in soil. *Journal of Environmental Sciences*, *100*, 131–143. https://doi.org/10.1007/s10845-020-01715-6

Hossain, M. I., & Tuha, M. A. S. M. (2020). Biodegradable plastic production from daily household waste materials and comparison the decomposing time with synthetic polyethylene plastic. *International Journal of Advancement in Life Sciences Research*, 16–19. https://doi.org/10.31632/ijalsr.20.v03i03.002

Ibrahim, M. I. J., Sapuan, S. M., Zainudin, E. S., & Zuhri, M. Y. M. (2019). Potential of using multiscale corn husk fiber as reinforcing filler in cornstarch-based biocomposites. *International Journal of Biological Macromolecules*, *139*, 596–604. https://doi.org/10.1016/j.ijbiomac.2019.08.015

Irwin, M., Fajriansyah, A., Qamariah, N., Agusta, R., Aminah, A., & Hasiah, H. (2024). Penerapan Ekonomi Sirkular pada Industri Kreatif: Peluang dan Tantangan di Era Digital. *J-CEKI: Jurnal Cendekia Ilmiah*, *3*(5), 4489–4502. https://doi.org/10.56799/jceki.v3i5.4980

Jayawati, D., Taufik, A., & Taryana, U. (2020). Manajemen Rantai Pasok dalam Mendukung Ekonomi Sirkular: Sebuah Literatur Study. *Prosiding Seminar Nasional Manajemen Industri Dan Rantai Pasok*, *1*(1), 85–94. https://jurnal.poltekapp.ac.id/index.php/SNMIP/article/view/788

Jiang, J., Xiong, Y., Zhang, Z., & Rosen, D. W. (2022). Machine learning integrated design for additive manufacturing. *Journal of Intelligent Manufacturing*, *33*(4), 1073–1086. https://doi.org/10.1007/s10845-020-01715-6

Jiao, Y., Chen, H.-D., Han, H., & Chang, Y. (2022). Development and utilization of corn processing by-products: A review. *Foods*, *11*(22), 3709. https://doi.org/10.3390/foods11223709

Jin, C., Hu, J., Wu, J., Liang, H., & Li, J. (2021). Innovative and Economically Beneficial Use of Corn and Corn Products in Electrochemical Energy Storage Applications. *ACS Sustainable Chemistry & Engineering*, *9*(32), 10678–10703. https://doi.org/10.1021/acssuschemeng.1c02613

Kambli, N., Basak, S., & Deshmukh, R. (2021). Cornhusk fibers, its properties, and value addition. In *Green Chemistry for Sustainable Textiles* (pp. 471–480). Elsevier. https://www.sciencedirect.com/science/article/pii/B9780323852043000063

Kaur, G., Kaur, P., Kaur, G., & Kaur, J. (2024). Valorization of Rice Straw and Husk for Food Packaging. *Agro-Wastes for Packaging Applications*, 42.

Kementerian Pertanian RI. (2020). *Outlook komoditas pertanian subsektor tanaman pangan: Jagung*. https://satudata.pertanian.go.id/details/publikasi/219

Kumar, R., Verma, A., Shome, A., Sinha, R., Sinha, S., Jha, P. K., Kumar, R., Kumar, P., Shubham, & Das, S. (2021). Impacts of plastic pollution on ecosystem services, sustainable development goals, and need to focus on circular economy and policy interventions. *Sustainability*, *13*(17), 9963. https://doi.org/10.3390/su13179963

Lamba, P., Kaur, D. P., Raj, S., & Sorout, J. (2022). Recycling/reuse of plastic waste as construction material for sustainable development: A review. *Environmental Science and Pollution Research*, *29*(57), 86156–86179. https://doi.org/10.1007/s11356-021-16980-y

Li, B., Liu, J., Yu, B., & Zheng, X. (2022). The environmental impact of plastic grocery bags and their alternatives. *IOP Conference Series: Earth and Environmental Science*, *1011*(1), 012050. https://doi.org/10.1088/1755-1315/1011/1/012050

Lingga, L. J., Yuana, M., Sari, N. A., Syahida, H. N., Sitorus, C., & Shahron, S. (2024). Sampah di Indonesia: Tantangan dan solusi menuju perubahan positif. *INNOVATIVE: Journal Of Social Science Research*, *4*(4), 12235–12247. https://doi.org/10.31004/innovative.v4i4.14542

Mainardis, M., Cecconet, D., Moretti, A., Callegari, A., Goi, D., Freguia, S., & Capodaglio, A. G. (2022). Wastewater fertigation in agriculture: Issues and opportunities for improved water management and circular economy. *Environmental Pollution*, *296*, 118755. https://doi.org/10.1016/j.envpol.2021.118755

Masturi, H., Hasanawi, A., & Hasanawi, A. (2021). Sinergi dalam Pertanian Indonesia untuk Mitigasi dan Adaptasi Perubahan Iklim. *Jurnal Inovasi Penelitian*, *1*(10), 2085–2094. https://doi.org/10.47492/jip.v1i10.424

Mihai, F.-C., Gündoğdu, S., Markley, L. A., Olivelli, A., Khan, F. R., Gwinnett, C., Gutberlet, J., Reyna-Bensusan, N., Llanquileo-Melgarejo, P., & Meidiana, C. (2021). Plastic pollution, waste management issues, and circular economy opportunities in rural communities. *Sustainability*, *14*(1), 20. https://doi.org/10.3390/su14010020

Moshood, T. D., Nawanir, G., Mahmud, F., Mohamad, F., Ahmad, M. H., & Abdul Ghani, A. (2021). Expanding policy for biodegradable plastic products and market dynamics of bio-based plastics: Challenges and opportunities. *Sustainability*, *13*(11), 6170. https://doi.org/10.3390/su13116170

Nairfana, I., Afgani, C. A., & Munandar, I. (2023). Inovasi Kemasan Kertas Benih Ramah Lingkungan Berbahan Dasar Kulit Jagung dan Ampas Tebu. *Bioscientist: Jurnal Ilmiah Biologi*, *11*(1), 375–385. https://doi.org/10.33394/bioscientist.v11i1.6724

Noor, S. M., Anuar, A. N., Tamunaidu, P., Goto, M., Shameli, K., & Ab Halim, M. H. (2020). Nanocellulose production from natural and recyclable sources: A review. *IOP Conference Series: Earth and Environmental Science*, *479*(1), 012027. https://doi.org/10.1088/1755-1315/479/1/012027

Novia, M., Makki, A. I., & Arafah, N. (2022). *Karakterisasi Serat Ampas Tebu (Bagasse) Sebagai Alternatif Bahan Baku Tekstil Dan Produk Tekstil (Tpt) Terbarukan*. https://repository.unar.ac.id/jspui/handle/123456789/4262

Ntifafa, Y., Ji, Y., & Hart, P. W. (2024). Polyamidoamine epichlorohydrin (PAAE) wet-strength agent: Generations, application, performance, and recyclability in paperboard and linerboard. *BioResources*, *19*(2), 3895. https://doi.org/10.15376/biores.19.2.Ntifafa

Oberoi, G., & Garg, A. (2021). Single-use plastics: A roadmap for sustainability? *Supremo Amicus*, *24*, 585. https://www.unep.org/resources/report/single-use-plastics-roadmap-sustainability.

Partini, P., & Sari, I. (2022). Kebijakan Pengembangan Ketahanan Pangan Lokal. *Jurnal Agribisnis*, *11*(1), 78–83. https://doi.org/10.32520/agribisnis.v11i1.1988.

Patil, H., & Athalye, A. (2023). Valorization of Corn Husk Waste for Textile Applications. *Journal of Natural Fibers*, *20*(1), 2156017. https://doi.org/10.1080/15440478.2022.2156017

Paul, S. S., Anirud, R., Bahl, B., Maheshwari, K., & Banerjee, A. (2023). Impact of plastics in the socio-economic disaster of pollution and climate change: The roadblocks of sustainability in India. In *Visualization Techniques for Climate Change with Machine Learning and Artificial Intelligence* (pp. 77–100). Elsevier. https://www.sciencedirect.com/science/article/pii/B9780323997140000017

Prasetia, R., Purbawati, P., & Halikianoor, H. (2022). Potensi Ampas Kelapa (*Cocos nucifera* L.) Sebagai Alternatif Bahan Pembuatan Kertas Komposit. *Journal of Sustainable Transformation*, *1*(1), 22–26. https://doi.org/10.59310/jst.v1i1.9

Prasetyo, Y. E., & Nurainy, F. (2024). Karakteristik Biodegradable Film Berbasis Selulosa Kelobot Jagung (*Zea mays*) Dengan Penambahan Gliserol Dan Carboxy Methyl Cellulose (CMC) Characteristics Of Biodegradable Film Based On Corn Husk (*Zea mays*) With The Addition Of Glycerol And Carboxy Methyl Cellulose (CMC). *Jurnal Agroindustri Berkelanjutan*, *3*(1), 158–171. https://doi.org/10.59310/jst.v1i1.9

Ratna, A. S., Ghosh, A., & Mukhopadhyay, S. (2022). Advances and prospects of corn husk as a sustainable material in composites and other technical applications. *Journal of Cleaner Production*, *371*, 133563. https://doi.org/10.1016/j.jclepro.2022.133563

Sahal, R., Breslin, J. G., & Ali, M. I. (2020). Big data and stream processing platforms for Industry 4.0 requirements mapping for a predictive maintenance use case. *Journal of Manufacturing Systems*, *54*, 138–151. https://doi.org/10.1016/j.jmsy.2019.11.004

Sandak, A., Sandak, J., & Modzelewska, I. (2019). Manufacturing fit-for-purpose paper packaging containers with controlled biodegradation rate by optimizing addition of natural fillers. *Cellulose*, *26*(4), 2673–2688. https://doi.org/10.1007/s10570-018-02235-6

Sari, N. H., & Suteja, S. (2020). Corn husk fibers reinforced polyester composites: Tensile strength properties, water absorption behavior, and morphology. *IOP Conference Series: Materials Science and Engineering*, *722*(1), 012035. https://iopscience.iop.org/article/10.1088/1757-899X/722/1/012035/meta

Setiawan, A., Mahfud, R. N., Mayangsari, N. E., Widiana, D. R., Iswara, A. P., & Dermawan, D. (2024). The potential of using sweet corn (*Zea mays* Saccharata) husk waste as a source for biodegradable plastics. *Industrial Crops and Products*, *208*, 117760. https://doi.org/10.1016/j.indcrop.2023.117760

Sherwood, J. (2020). The significance of biomass in a circular economy. *Bioresource Technology*, *300*, 122755. https://doi.org/10.1016/j.biortech.2020.122755.

Singh, N., Ogunseitan, O. A., Wong, M. H., & Tang, Y. (2022). Sustainable materials alternative to petrochemical plastics pollution: A review analysis. *Sustainable Horizons*, *2*, 100016. https://doi.org/10.1016/j.biortech.2020.122755

Stathatou, P. M., Corbin, L., Meredith, J. C., & Garmulewicz, A. (2023). Biomaterials and Regenerative Agriculture: A Methodological Framework to Enable Circular Transitions. *Sustainability*, *15*(19), 14306. https://doi.org/10.3390/su151914306

Suleman, R., Amjad, A., Ismail, A., Javed, S., Ghafoor, U., & Fahad, S. (2022). Impact of plastic bags usage in food commodities: An irreversible loss to environment. *Environmental Science and Pollution Research*, *29*(33), 49483–49489. https://doi.org/10.1007/s11356-022-21091-3

Tahat, M., M. Alananbeh, K., A. Othman, Y., & I. Leskovar, D. (2020). Soil health and sustainable agriculture. *Sustainability*, *12*(12), 4859. https://doi.org/10.3390/su12124859

Tang, Y., Shao, Y.-F., & Chen, Y.-J. (2019). Assessing the mediation mechanism of job satisfaction and organizational commitment on innovative behavior: The perspective of psychological capital. *Frontiers in Psychology*, *10*, 2699. https://doi.org/10.3389/fpsyg.2019.02699

Tarumingkeng, R. C. (2024). *Untuk Pembangunan Berkelanjutan*. https://rudyct.com/ab/Ekonomi.Hijau-Integrasi.Kebijakan.Makroekonomi.pdf

Toplicean, I.-M., & Datcu, A.-D. (2024). An Overview on Bioeconomy in Agricultural Sector, Biomass Production, Recycling Methods, and Circular Economy Considerations. *Agriculture*, *14*(7), 1143. https://atrium.lib.uoguelph.ca/items/03ce4fd6-9c8f-457a-8ad8-5402cdf0c23a

Ubene, M. (2023). *Graphene Oxide Assisted Hydrothermal Carbonization of Corn Fibre for High-Quality Activated Carbon and its Application for Water Purification using Rapid Small-Scale Column Testing* [PhD Thesis, University of Guelph]. https://atrium.lib.uoguelph.ca/items/03ce4fd6-9c8f-457a-8ad8-5402cdf0c23a

Velenturf, A. P., & Purnell, P. (2021). Principles for a sustainable circular economy. *Sustainable Production and Consumption*, *27*, 1437–1457. https://doi.org/10.3390/en14175540

Wangyao, K., Sutthasil, N., & Chiemchaisri, C. (2021). Methane and nitrous oxide emissions from shallow windrow piles for biostabilisation of municipal solid waste. *Journal of the Air & Waste Management Association*, *71*(5), 650–660. https://doi.org/10.1080/10962247.2021.1880498

Wowa, F. A. Y., & Yuniwati, M. (2021). Pemanfaatan Kulit Jagung Dan Tongkol Jagung (*Zea mays*) Sebagai Bahan Dasar Pembuatan Kertas Seni Dengan Penambahan Natrium Hidroksida (NaOH)(Variabel Perbandingan Berat Bahan Kulit Jagung Dan Tongkol Jagung Dengan Kecepatan Pengaduk). *Jurnal Inovasi Proses*, *6*(2), 50–58. https://ejournal.akprind.ac.id/index.php/JIP/article/view/3767

Yanti, T. (2024). Kolaborasi Strategis antara Industri Perbankan dan Perguruan Tinggi: Memaksimalkan Peluang di Era Bonus Demografi. *Jurnal Manajemen Riset Bisnis Indonesia*, *13*(2). https://jmrbi.stiembi.ac.id/index.php/lppm/article/view/119

Zhang, N., Tian, C., Fu, P., Yuan, Q., Zhang, Y., Li, Z., & Yi, W. (2022). The fractionation of corn stalk components by hydrothermal treatment followed by ultrasonic ethanol extraction. *Energies*, *15*(7), 2616. https://doi.org/10.3390/en15072616

Zhang, S., Wang, H., Liu, M., Yu, H., Peng, J., Cao, X., Wang, C., Liu, R., Kamali, M., & Qu, J. (2022). Press perturbations of microplastics and antibiotics on freshwater micro-ecosystem: Case study for the ecological restoration of submerged plants. *Water Research*, *226*, 119248. https://doi.org/10.1016/j.watres.2022.119248.

Zheng, M., Zhang, K., Zhang, J., Zhu, L., Du, G., & Zheng, R. (2022). Cheap, high yield, and strong corn husk-based textile bio-fibers with low carbon footprint via green alkali retting-splicing-twisting strategy. *Industrial Crops and Products*, *188*, 115699. https://doi.org/10.1016/j.indcrop.2022.115699

Zuorro, A., Lavecchia, R., González-Delgado, Á. D., García-Martinez, J. B., & L'Abbate, P. (2019). Optimization of enzyme-assisted extraction of flavonoids from corn husks. *Processes*, *7*(11), 804. https://doi.org/10.3390/pr7110804

Biographies of Authors

Fahmi Azrial, Department of Biology, Faculty of Science and Technology, Raden Intan Islamic State University of Lampung, Bandar Lampung City, Lampung 35131, Indonesia.

- Email: fahmiazrial77@gmail.com
- ORCID: 0009-0005-3090-606X
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: https://scholar.google.com/citations?user=-LhRmf4AAAAJ&hl=en

Febrian Afrida, Department of Biology, Faculty of Science and Technology, Raden Intan Islamic State University of Lampung, Bandar Lampung City, Lampung 35131, Indonesia.

- Email: febrianafrida160204@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A

Olivia Jindani Al-Mupidah, Department of Biology, Faculty of Science and Technology, Raden Intan Islamic State University of Lampung, Bandar Lampung City, Lampung 35131, Indonesia.

- Email: oliviajindani03@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: https://scholar.google.com/citations?user=Tz_MS40AAAAJ&hl=id

Rosya Diyaul Aulya, Department of Biology, Faculty of Science and Technology, Raden Intan Islamic State University of Lampung, Bandar Lampung City, Lampung 35131, Indonesia.

- Email: rosyadiyaul@gmail.com
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: https://scholar.google.com/citations?user=HOU3TzYAAAAJ&hl=en