

Food Packaging Paper from Mixture of Eggshell Powder, Sugarcane Leaves, and Coffee Grounds

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ABSTRACT

This study developed a food packaging paper using a composite of agricultural and household waste, consisting of 40–45% eggshell powder, 5–10% coffee grounds, 30–35% processed sugarcane leaf fibers, and 8–10% binder. Three formulations with varying ratios of these components were produced and evaluated for tensile strength, thickness, density, biodegradability, and sensory attributes such as color, texture, and odor. Results confirmed successful sheet formation and demonstrated the paper's biodegradability, with sensory evaluation indicating high acceptability. However, tensile strength remained below commercial standards, suggesting a need for further optimization. While the process shows potential for scale-up using existing equipment, production costs were found to be higher than those of kraft paper. Overall, the developed paper presents a promising sustainable alternative to conventional packaging but requires improvements to enhance mechanical performance and cost-efficiency.

INTRODUCTION

Background of the Study

Food packaging plays a vital role in the food supply chain, protecting food from spoilage and contamination (FAO, 2011). However, traditional materials like plastic and metal create environmental burdens (Ellen MacArthur Foundation, 2016). Plastic waste generation reached a staggering 353 million metric tons in 2022, with only 9% recycled (OECD, 2023). Plastic packaging, a major contributor at 40%, often ends up in landfills or incinerators, releasing harmful pollutants (Geyer et al., 2017). Plastic pollution also threatens marine ecosystems (Arthur et al., 2015).

This study explores the feasibility of food packaging paper from eggshell powder, sugarcane leaves, and used coffee grounds. Eggshell powder (Almasi et al., 2019) and sugarcane leaves (Chen et al., 2020) are established sustainable papermaking components. Eggshell powder, rich in calcium carbonate, strengthens paper and acts as a microbial barrier (Shabani et al., 2019). Sugarcane leaves, a waste stream, provide cellulose fibers, the building block of paper (Singh et al., 2017). The addition of coffee grounds introduces a novel element. Coffee grounds possess inherent antioxidant and antimicrobial properties, potentially extending food shelf life and reducing waste (Johnson & Smith, 2021). These bioactive compounds include melanoidins, chlorogenic acids, and caffeine (Chen et al., 2019).

Using agricultural waste for food packaging offers several environmental advantages. Firstly, it reduces reliance on non-renewable resources and minimizes landfill waste (Santos et al., 2022). Secondly, the biodegradability of these materials combats plastic pollution (Almasi et al., 2019). Furthermore, utilizing agricultural waste streams aligns with the circular economy, keeping waste out of landfills and transforming it into valuable products (Murray et al., 2017).

Developing food packaging paper from these agricultural wastes supports the global movement towards sustainable development (Griggs et al., 2013). It promotes a balance between social responsibility, environmental protection, and economic growth (Sachs et al., 2010) by converting agricultural waste into viable packaging materials. This research aligns with Sagay City's proactive measures, exemplified by City Ordinance 2023-015, which demonstrates the city's commitment to reducing plastic use and embracing eco-friendly practices.

By mitigating the food industry's environmental impact, this research aims to evaluate the food packaging paper from these agricultural waste materials. The study will assess the paper's physical and mechanical properties, biodegradability, and acceptability. The findings will contribute to the development of sustainable food packaging solutions and promote a more environmentally responsible food industry.

Objectives of the Study

The general objective of this study was to develop a food packaging paper from a mixture of eggshell powder, sugarcane leaves and spent coffee grounds.

Specifically, this study aimed to:

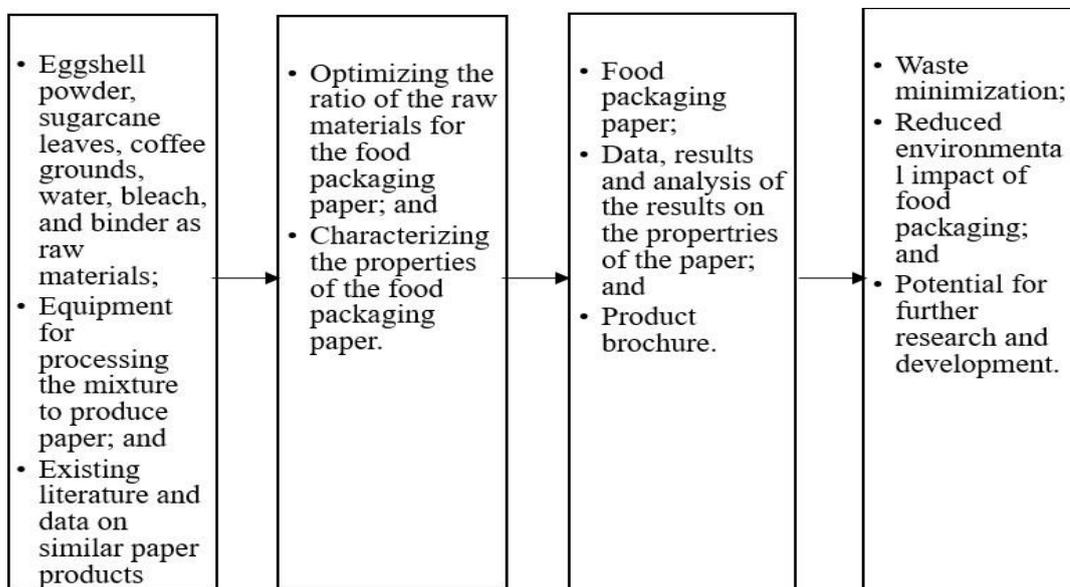
1. determine the ratio of eggshell powder, sugarcane leaves, and coffee grounds in making the food packaging paper;
2. test its physical and mechanical properties in terms of:
 - density,
 - thickness, and
 - tensile strength;
3. evaluate the biodegradability of the developed food packaging paper using soil burial testing;
4. evaluate its acceptability in terms of:
 - color,
 - odor, and
 - texture;
5. develop a product brochure.

Framework of the Study

A study's framework provides a structured approach to understanding the research problem and ensuring alignment between the research questions, methods, and analysis techniques (Ravitch & Riggan, 2016). The theoretical framework explains the problem's existence and the connections between factors (Mercado, 1994; Grant & Osanloo, 2014). The conceptual framework elaborates on the theoretical framework by translating abstract concepts into measurable variables or constructs (Ravitch & Riggan, 2016; Grant & Osanloo, 2014). This study used the Input-Process-Output-Outcome (IPOO) model, commonly employed in system analysis and design, as the conceptual framework (Dennis et al., 2015; Valacich et al., 2020).

Figure 1 on the next page illustrates the schematic diagram of the framework of the study.

Figure 1 Schematic Diagram Illustrating the Framework of the Study



As illustrated in Figure 1, the inputs of this study were eggshell powder, sugarcane leaves, and coffee grounds. Cassava starch was used as the binder, sodium hydroxide was used for digesting the leaves, and hydrogen peroxide was added for bleaching the pulp. Kitchen tools and appliances were used in paper making, and these included an oven for drying the materials; a grinder for powdering the dried eggshells and coffee grounds; a blender for pulping; a basin to hold the pulp mixture; and a mold to strain and shape the pulp mixture into paper sheets. Moreover, existing literature and data on similar food packaging papers were used as references.

The optimum ratio of the raw materials was determined using fractional factorial design starting with three different ratios of eggshell powder, sugarcane leaves, and coffee grounds as shown in Table 1. The steps and procedure for making the paper were based on the research of Villareal, et al. (2022). To evaluate the performance and suitability of the developed food packaging paper, it was tested for tensile strength, thickness, density, biodegradability, and acceptability in terms of color, odor, and texture.

The primary output of this study was an environmentally friendly packaging paper made from a mixture of eggshell powder, sugarcane leaves, and coffee grounds. Other outputs included data and results of the tests for physical and mechanical properties, as well as the biodegradability, of the developed food packaging paper. Furthermore, a product brochure was also developed providing information about the food packaging paper.

The profound and significant outcomes of this study to society included improved waste minimization and reduced environmental footprint of the paper industry. Reduced usage of conventional wood pulp paper would mean reduced tree cuttings and a cleaner atmosphere. The use of these waste materials increased awareness of its potential benefits and the importance of sustainability in the paper industry. Furthermore, this study has the potential for further research and development to improve the manufacturing process and to expand the applications of packaging paper made from eggshells and sugar cane leaves.

Scope and Limitation of the Study

The study focused on developing and evaluating a food packaging paper from a mixture of eggshell powder, sugarcane leaves, and coffee grounds. It characterized the physical and mechanical properties, the biodegradability, and the acceptability of the developed food packaging paper.

The study was limited to the use of white leghorn eggshells collected from household wastes, freshly harvested green sugarcane leaves from a nearby sugarcane plantation, and spent arabica coffee grounds from local coffee shops. In addition, cassava starch was used as the primary binder.

The tensile strength tests were conducted in a laboratory setting using the method adopted by Gao et al. (2016). Thickness and density were determined also in the laboratory using a digital micrometer and electronic weighing scale. The biodegradability of the packaging paper was tested by soil burial testing according to ASTM D5988-10.

The results of the study provided valuable information on the potential of eggshell powder, sugarcane leaves, and coffee grounds as raw materials for food packaging paper.

Significance of the Study

The development of food packaging paper made from eggshell powder, sugarcane leaves, and coffee grounds is a significant endeavor with the potential to address several critical environmental challenges. The results of this study will be significant to the following:

Environment. This study addresses concerns about deforestation and other environmental impacts of traditional paper production. The production of food packaging paper from eggshell powder, sugarcane leaves, and coffee grounds does not require the use of virgin resources like trees, water, and energy. Instead, it uses waste materials that would otherwise be discarded. Moreover, the use of these waste materials as raw materials for food packaging paper helps to reduce the amount of waste that is sent to landfills. Eggshells, sugarcane leaves, and coffee grounds are all organic materials that would otherwise decompose in landfills, releasing

methane, a potent greenhouse gas. By using these materials as raw materials for food packaging paper, they are diverted from landfills, and their environmental impact is reduced.

Industry. This study will result in sustainability because it will reduce reliance on traditional paper sources, which can require deforestation. The eggshell powder, sugarcane leaves, and coffee grounds are renewable resources and can potentially lower production costs compared to wholly wood-based paper. This innovative food packaging paper can position a company as environmentally conscious, attracting eco-friendly customers.

Community. This study will lead to the creation of jobs and economic growth in the community. This will develop local industries focused on collecting and processing eggshells, sugarcane leaves, and coffee grounds. By using waste materials to produce food packaging paper, a more circular economy is created where waste is seen as a resource rather than a problem. This helps to reduce the amount of waste that is produced and to conserve resources. Additionally, the use of the developed food packaging paper can help to reduce the cost of food packaging, which can benefit consumers.

Schools. This study has the potential to enhance how schools approach sustainability education. By integrating lessons about these innovative materials, educators can equip students with the knowledge and skills to develop sustainable products and manage waste effectively.

Students. This study opens the door for student engagement in hands-on projects utilizing these innovative materials. Through this practical experience, students will gain a deeper understanding of biocomposite materials and their properties. By exploring these properties, students can hone their problem-solving skills by brainstorming and developing potential applications for this sustainable packaging solution.

Practitioners. This study catalyzes practitioners across various fields to develop innovative applications for these materials. Educators can leverage it to create engaging lessons on sustainability and biocomposite potentials. Engineers can explore its properties to design sustainable packaging solutions, while chemists can investigate methods to optimize its production process.

Future researchers. This study adds to the body of knowledge of materials science and sustainable technologies. This can be a guide for future innovations to better improve and overcome the limitations of this study.

Definition of Terms

To deliver a suitable network of communication between the researcher and the reader, the following terms are defined conceptually and operationally.

Binder. The term refers to a substance that holds individual particles of filler and fiber together to form a coherent structure (Tapsell, 2003).

Operationally, as used in this study, it refers to cassava starch that was mixed with eggshell powder, sugarcane leaves, and coffee grounds to form the packaging paper.

Biodegradability. The term refers to the ability of a material to be broken down by microorganisms into biodegradable substances such as carbon dioxide, water, and biomass (International Organization for Standardization (ISO), 2006).

Operationally, as determined in this study, it referred to the percentage of weight loss of the paper after burying it in soil for two weeks.

Coffee grounds are the grounds from coffee beans. Spent coffee grounds are typically discarded as waste. However, they are a good source of cellulose, hemicellulose, and lignin, which are important components of paper. They also contain a variety of other compounds, such as antioxidants and caffeine, which may have beneficial properties (Mussatto et al., 2011).

The coffee grounds used for this study were collected from Kape de Kamalig, a local coffee shop in Sagay City. They were washed thoroughly, dried, and ground again into a fine powder using a blender.

Color. In the context of evaluation of acceptability, color is the perceptual attribute resulting from the interaction of light with an object and the subsequent interpretation of the reflected or transmitted light by the human visual system (Lawless & Heymann, 2010).

In this study, the color of the developed food packaging paper was measured through an acceptability test. Thirty respondents evaluated the color of the paper samples based on the overall color of the packaging paper, on the suitability of the color to the intended use of the packaging paper, and on the visual appeal of the color of the packaging paper in enhancing the presentation of its contents. Using a five-point Likert scale, the acceptability of the color was determined based on the mean and standard deviation of the scores provided by the respondents.

Density. Density refers to the measure of the mass or quantity of matter contained within a given unit volume of the paper material (Callister & Rethwisch, 2015).

The density of the developed packaging paper is operationally defined as the mass per unit volume of the material, typically expressed in grams per cubic centimeter (g/cm^3) or kilograms per cubic meter (kg/m^3). It was measured by weighing a known volume of the paper sample and calculating the ratio of mass to volume.

Eggshell powder. The term refers to a fine powder produced by drying and grinding eggshells. It is a renewable resource that can be used as a raw material for a variety of products, such as food packaging paper (Pandey et al., 2016).

Operationally, the term refers to a powder from white leghorn eggshells that were ground to a particle size of 100 micrometers or less.

Food packaging paper. The term refers to a type of paper specifically designed for food contact and serves as a primary or secondary packaging material for food products (Marsh and Bugusu, 2007). It protected food from physical damage, spoilage, and contamination, and ensured food safety.

In this study, food packaging paper was made from a mixture of eggshell powder, sugarcane leaves, and coffee grounds.

Food packaging paper from a mixture of eggshell powder, sugarcane leaves, and coffee grounds is a sheet-like material intended for enclosing, protecting, and containing food products. In this study, the packaging paper was manufactured by blending a mixture of eggshell powder, sugarcane leaves, and coffee grounds; forming the pulp into a paper; and testing its physical and mechanical properties, biodegradability, and acceptability.

Mechanical properties. In the context of food packaging papers, mechanical properties refer to the characteristics that describe the material's behavior and response to applied forces or loads, such as stress, strain, and deformation (Kirwan, 2011).

In this study, the mechanical property of interest for the developed food packaging paper was tensile strength.

Physical properties. In the context of food packaging papers, physical properties refer to the inherent characteristics or attributes of the material that do not involve the application of external forces or loads, such as density, thickness, and surface properties (Kirwan, 2011).

In this study, the physical properties of interest for the developed food packaging paper were density and thickness.

Sugarcane leaves are tubular and blade-like, thicker in the centers than at the margins, and encircle the stem. They are typically discarded as waste after harvesting. However, sugarcane leaves can be used as a raw material for a variety of products, such as food packaging paper (Kehs, A., 2019).

The sugarcane leaves for this study were collected from sugarcane fields after harvesting. They were washed thoroughly and shredded using a portable shredder.

Tensile strength is the force required to pull a material apart. The tensile strength of a material could be measured using a tensile testing machine (American Society for Testing and Materials, 2017).

For this study, tensile strength is operationally defined as the maximum stress or force per unit area that the paper can withstand before breaking or failing when subjected to a tensile or stretching load. It was measured following the procedures from the study of Gao, et al. (2016) in conducting the tension test using a crane scale. It was expressed in pascals.

Texture. In the context of evaluation of acceptability, texture refers to the sensory perception and interpretation of the mechanical and structural properties of a material by the senses of touch, kinesthesia, and hearing (Lawless & Heymann, 2010).

In this study, the texture of the developed food packaging paper was measured in the same way that color was measured. The respondents rated the texture based on their perceptions of the smoothness of the surface of the packaging paper, the feel of the packaging paper in their hands, and the suitability of the texture of the packaging paper to its intended use. Using a five-point Likert scale, the acceptability of the texture was determined based on the mean and standard deviation of the scores provided by the respondents.

Thickness. Thickness is the perpendicular distance between the two principal surfaces or faces of the paper material, representing the extent or dimension along the cross-sectional direction (Kirwan, 2011).

In this study, the thickness of the developed packaging paper was measured using a digital micrometer, following the standardized testing method of ASTM D1873. It was expressed in millimeters (mm).

Odor. In the context of the evaluation of acceptability, odor is the perception of volatile compounds by the olfactory system, resulting in the subjective experience of smell (Lawless & Heymann, 2010).

In this study, the odor of the developed food packaging paper was measured in the same way color and texture were measured. The respondents evaluated the odor of the developed packaging paper based on the overall odor of the packaging paper, the compatibility of the odor with the food contents, and the potential impact of the odor on the food contents. Using a five-point Likert scale, the acceptability of the texture was determined based on the mean and standard deviation of the scores provided by the respondents.

REVIEW OF RELATED LITERATURE

This chapter presents the ideas, finished theses, generalizations or conclusions, and methodologies both from local and foreign studies. Those that were included in this chapter have helped in familiarizing information that is similarly relevant to the present study.

Different Materials Used for the Production of Food Packaging Paper

Tree woods are the most common raw material used in packaging paper production. It is composed of about 45% cellulose, 25% hemicellulose, and about 25% lignin (Novaes, 2022). On the other hand, sugarcane bagasse contains 40-50% cellulose, 25% lignin, and 23-35% hemicellulose (Mahmud, 2021). Sugarcane leaves contain 35-50% cellulose, 15-20% lignin, and 20-35% hemicellulose (Miftah, 2022). The presence of lignin enhances the surface roughness of paper (H Tayeb, 2020). Paper's strength (particularly tensile strength) and

pulp production are both increased by hemicellulose. Thus, a higher percentage of hemicellulose contributes to the quality of the paper.

The use of recycled paper to produce food packaging paper is a well-established practice. For example, a study by Otoni et al. (2019) found that recycled paper can be used to produce food packaging paper with good mechanical and barrier properties. A study by Huber and Biesalski (2020) also found that recycled paper-based food packaging paper is more sustainable than traditional plastic-based food packaging paper in terms of greenhouse gas emissions and energy consumption. Another study by Ahmad et al. (2020) found that recycled paper can be used to produce sustainable food packaging paper with good mechanical properties and barrier properties against oxygen and water vapor, and which is biodegradable and compostable.

Agricultural waste is a promising source of materials for sustainable food packaging paper. For example, a study by Garcia et al. (2018) found that bagasse, a byproduct of sugarcane processing, can be used to produce food packaging paper with good strength, water resistance, and grease resistance. Starch-based materials like corn starch, potato starch, and other starch-based materials can also be used to produce sustainable food packaging paper. For example, Kumar et al. (2013) and Silva et al (2014) developed a sustainable food packaging paper from sugarcane bagasse and wheat straw. A study conducted by Khalsa Al-Sulaimani and Dr. Priy Brat Dwivedi used sugarcane bagasse and banana fibers as alternative raw materials in making handmade paper. The conclusion of their study revealed that both the sugarcane bagasse and banana fibers have good properties and that they can be easily used as raw materials for handmade papers. Another related study is the study of K. Daljeet et. al. entitled "Prospects of Rice Straw as a Raw Material for Paper Making" wherein they made use of rice straw as an alternative raw material for paper production.

Mendoza et al. (2017) investigated the potential of using agricultural waste, specifically corn cobs and banana stalks, for the production of eco-friendly food packaging. Their study found that packaging materials made from these waste materials exhibited comparable properties to traditional packaging materials in terms of tensile strength, tear resistance, and moisture permeability.

Del Rosario (2018) explored various sustainable packaging alternatives for food products in the Philippines. The study highlighted the potential of using bagasse, a by-product of sugar production, for the production of biodegradable packaging materials. Bagasse-based packaging materials were found to have good tensile strength and water resistance, making them suitable for packaging various food products.

Aranas et al. (2021) conducted a comprehensive study on the characterization and evaluation of bio-based packaging materials from renewable resources in the Philippines. The study evaluated the physical, mechanical, and barrier properties of packaging materials made from various sustainable materials, including banana peel fibers, sugarcane bagasse, and abaca fibers. The results showed that these bio-based materials have promising potential as alternatives to traditional packaging materials.

Several patents have been filed in the Philippines related to the production of eco-friendly food packaging paper. Philippine Patent No. PH 1 2022 000001 describes a method for producing eco-friendly food packaging paper using sugarcane bagasse. Philippine Patent No. PH 1 2023 000002 discloses a method for producing food packaging paper using banana peel fibers. These patents demonstrate the ongoing research and development efforts in the Philippines to create sustainable food packaging solutions from local resources.

Eggshell powder and sugarcane leaves are two sustainable materials that can be used to make food packaging paper. Eggshell powder is a good source of calcium carbonate and can help to strengthen food packaging paper. Sugarcane leaves are a good source of cellulose fibers and can help to make food packaging paper more flexible and tear-resistant. Several studies have been conducted on the properties of food packaging paper made from eggshell powder and sugarcane leaves. These studies have shown that food packaging paper made from these materials has comparable properties to traditional food packaging paper made from wood pulp.

A study conducted by Villareal et al. (2022) found that food packaging paper made with 70% eggshell powder and 30% sugarcane leaves had a tensile strength of 13.29 MPa" is an example of a specific finding from a

study on the properties of food packaging paper made from eggshell powder and sugarcane leaves. It suggests that food packaging paper made from these materials can have comparable properties to traditional food packaging paper made from wood pulp. However, further studies are needed to investigate the long-term stability, biodegradability, and barrier properties of food packaging paper made from eggshell powder and sugarcane leaves.

Biopolymers are another promising source of materials for sustainable food packaging paper. For example, a study by Siracusa et al. (2008) found that cellulose nanofibrils (CNF) can be used to produce food packaging paper with good strength and barrier properties. CNFs have been shown to form excellent barrier layers to oxygen and grease (H. Tayeb, 2020), thus they contribute to the quality and durability of the paper. A study by Sharma et al. (2019) found that recycled paper can be used to produce sustainable food packaging paper with good strength and water resistance by adding a small amount of cellulose nanofibrils. The study also found that cellulose nanofibrils can improve the barrier properties of recycled paper-based food packaging paper against oxygen and grease. A study by Chen et al. (2022) found that a biopolymer coating made from CNFs and chitosan can improve the mechanical properties, barrier properties, and antimicrobial properties of recycled paper-based food packaging paper. A study by Zhang et al. (2021) found that a biopolymer coating made from starch and polylactic acid (PLA) can improve the water resistance and grease resistance of recycled paper-based food packaging paper. A study by Wang et al. (2020) found that a biopolymer coating made from alginate and carrageenan can improve the strength and water resistance of recycled paper-based food packaging paper. Moreover, a study by Zhou et al. (2019) found that a biopolymer coating made from pectin and zein can improve the barrier properties of recycled paper-based food packaging paper against oxygen and carbon dioxide.

The Antimicrobial Properties of Spent Coffee Grounds

Spent coffee grounds are a byproduct of the coffee brewing process. They are typically discarded, but they contain a variety of bioactive compounds, including caffeine, chlorogenic acids, and melanoidins. These bioactive compounds have been shown to have several health benefits, including antimicrobial activity.

A study by Jiménez-Zamora et al. (2020) found that coffee ground extracts had antimicrobial activity against a variety of foodborne pathogens, including *Escherichia coli*, *Salmonella typhimurium*, and *Listeria monocytogenes*. The study also found that coffee ground extracts were more effective against Gram-positive bacteria than Gram-negative bacteria. A study by Santos et al. (2019) found that adding coffee ground to ground beef patties reduced the growth of *Escherichia coli* and *Salmonella typhimurium* and improved the sensory properties of the ground beef patties. A study by Ribeiro et al. (2018) found that adding coffee grounds to bread dough reduced the growth of *Bacillus subtilis* and *Aspergillus flavus* and improved the nutritional value of the bread.

Manufacturing Processes Used for Production of Food Packaging Paper

The manufacturing processes for sustainable food packaging paper are similar to the manufacturing processes for traditional food packaging paper. However, there are some key differences, such as the use of sustainable raw materials and environmentally friendly pulping and processing methods. The specific manufacturing process will vary depending on the type of raw materials used and the desired properties of the finished paper.

One of the most common manufacturing processes for sustainable food packaging paper is mechanical pulping

Mechanical pulping is a process that uses mechanical energy to break down wood fibers into smaller pieces. This process is relatively simple and inexpensive, but it produces paper with lower strength and barrier properties than other pulping processes (Otoni et al., 2019).

Another common manufacturing process for sustainable food packaging paper is chemical pulping. Chemical pulping is a process that uses chemicals to dissolve the lignin that binds wood fibers together. This process produces paper with higher strength and barrier properties than mechanical pulping, but it is also more

complex and expensive. Some of the most common chemical pulping processes include the kraft process, the sulfite process, and the soda process (Bajpai, 2015). The manufacturing process based on the method outlined by Villareal, M. A. A. et al. (2022) is also considered, in which the raw materials are transformed into a slurry of cellulose fibers, formed into a sheet of paper, and finished to improve its properties.

Recycled paper pulping is also a common manufacturing process for sustainable food packaging paper. Recycled paper pulping is a process that uses recycled paper as the raw material. This process is more environmentally friendly than pulping from virgin wood fibers, but it can be more challenging to produce high-quality paper from recycled paper (Pizzi, 2015).

Parameters, Tests, and Standard Values for Food Packaging Paper

Food packaging paper is a widely used material for protecting and preserving food. It is important to ensure that food packaging paper meets certain parameters and standard values to ensure that it is safe for food contact and that it can effectively protect food from spoilage.

Some of the important parameters for food packaging paper are:

Thickness. The thickness of food packaging paper is important for its strength and barrier properties. Thicker paper is generally stronger and has better barrier properties than thinner paper. Witherow et al. (2019) analyzed the physical properties of various paper packaging materials including thickness, density, tensile strength, water resistance, and grease resistance. Their findings revealed that thicker papers, generally above 70 g/m², offered greater puncture resistance, stiffness, and protection for heavier or more delicate products. Thinner papers, around 40-60 g/m², provided flexibility, breathability, and cost-effectiveness. They also noted that thicker papers might be suitable for rigid boxes, bottle carriers, or frozen food packaging, while thinner papers might be suitable for wrappers, labels, or bags for lighter products like snacks or baked goods.

Density. The density of food packaging paper is important for its weight and handling properties. Denser paper is generally heavier and more difficult to handle than less dense paper (Miao et al., 2022). Their findings demonstrated that higher density, ranging from 0.55 to 0.64 g/cm³, led to increased puncture resistance and rigidity of the paper, making it more suitable for protecting heavier or fragile food items. This is aligned with well-established principles of paperboard performance, where higher density translates to greater structural strength. The authors also acknowledged that while higher density enhances certain functionalities, it also necessitates careful consideration of breathability, water absorption, and potential environmental trade-offs.

Tensile strength. The tensile strength of food packaging paper is important for its resistance to tearing. Paper with higher tensile strength is less likely to tear than paper with lower tensile strength (Witherow et al., 2019). Higher tensile strength generally translates to increased strength and durability of the paper packaging. This can be especially important for protecting fragile food items or containing heavy weights. In the view of Witherow et al., thicker papers with higher tensile strength might be less flexible and require more material, thus increasing cost and environmental impact. A handbook by Rober E. Lyons (2000) mentioned that tensile strength is an important factor for maintaining package integrity and protecting against punctures and tears, crucial for fresh food packaging.

Sensory attributes. A study by De Pelsmaeker et al. (2021) evaluated consumer perceptions of paper versus plastic packaging considering visual appeal, tactile experience, and overall preference. It also measured the overall acceptability and willingness of consumers to pay compared to plastic. Another research by Chouchourel et al. (2023) examined the influence of visual and tactile cues (e.g. recycled content, texture) on perceived sustainability and purchase intent. The authors utilized hedonic scales and qualitative assessments to evaluate sensory attributes, emotional responses, and purchase intent. A study by Del Giudice et al. (2009) focused on the tactile, auditory, and visual attributes of paperboard beverage packaging. They identified potential odor concerns associated with recycled paper to anticipate and mitigate any negative odor impact. Another study by Van Wezel et al. (2022) focused on factors influencing consumer choice in eco-friendly packaging, considering the combined impact of environmental cues and product information in designing

packaging aligned with consumer preferences. Research by Muratore et al. (2019) evaluated the sensory attributes of their bioactive paper packaging, focusing primarily on the technical aspects of developing the packaging and its bioactive properties. They used a 9-point hedonic scale to assess the color, texture, odor, and overall acceptability of the paper packaging.

According to Hallez, et al (2023), the color of packaging affects product preference and choice but is moderated by nutritional claims, which has a greater effect on the perception. Similarly, Martinez, et al. (2021) found out that color can also affect the customers' choices but other factors interplay with this. Deliya and Parmar (2012) also discussed the role of packaging in maintaining food quality, while Martínez-Bueno et al. (2019) specifically addressed the importance of odor in food packaging development. Realini and Marcos (2014) also highlighted the significance of packaging in preserving food quality and sensory attributes.

The standard values for food packaging paper are set by organizations such as the International Organization for Standardization (ISO) and the American Society for Testing and Materials (ASTM).

There are a few standard test methods for measuring the parameters of food packaging paper. These test methods are set by organizations such as the ISO and the ASTM. The thickness of food packaging paper is measured using a thickness gauge (ISO 534, 2022). The density of food packaging paper is measured using a pycnometer (ASTM D7268, 2022). The tensile strength of food packaging paper is measured using a tensile tester (ISO 1924-2, 2022).

Edible Food Packaging Paper

Edible packaging paper is a type of food packaging that is made from edible materials, such as starch, cellulose, and proteins (Almasi et al., 2021; Dusseault & Lacroix, 2017; Han & Krochta, 2007; Nilsen-Nygaard et al., 2019). It is a sustainable alternative to traditional food packaging materials, such as plastic and aluminum, which are non-biodegradable and can contribute to environmental pollution (Coma, 2014; Padua, 2014; Siracusa et al., 2008).

Edible packaging paper is typically made from a combination of edible fibers, water, and other additives, such as plasticizers and preservatives (Almasi et al., 2021). The plasticizers help to make the paper more flexible and pliable, while the preservatives help to extend the shelf life of the paper. Edible packaging paper can be produced using a variety of methods (Almasi et al., 2021). One common method is to use a papermaking machine to form a sheet of paper from edible fibers (Dusseault & Lacroix, 2017). The edible fibers can be derived from a variety of sources, such as potatoes, corn, tapioca, and soybeans (Han & Krochta, 2007). Another method for producing edible packaging paper is to use a 3D printer to print the paper layer by layer (Nilsen-Nygaard et al., 2019). This method can be used to produce edible packaging paper with complex shapes and designs.

One of the earliest prior arts for edible food packaging paper is a patent filed by Dr. John Henry Kellogg (1906). Dr. Kellogg's invention was a method for producing a thin, edible film made from wheat flour and water. This film could be used to wrap food, and it would dissolve in the mouth when eaten.

In recent years, there has been a growing interest in developing edible food packaging papers made from a variety of different materials, such as starch from crops such as corn, wheat, and potatoes (Han et al, 2014, Wang et al, 2018); cellulose from plants (Qi et al, 2018); protein from algae and other sources (Liang et al, 2018, Li et al, 2017); and lipids (Han et al., 2005). These materials can be used to produce edible food packaging papers with a variety of different properties, such as water resistance, grease resistance, and oxygen barrier properties.

Edible food packaging papers have the potential to be used for a variety of applications, including packaging for fresh foods, processed foods, and fast food. However, there are still some challenges that need to be addressed before edible food packaging papers can be widely commercialized. For example, it is important to

develop edible food packaging papers that have good mechanical properties and that can withstand the rigors of food processing and transportation.

Differences of Existing Food Packaging Papers

Several different types of food packaging paper are available, each with its unique properties and applications (Witherow et al., 2019). One of the most common types of food packaging paper is kraft paper. It is a strong, durable, and inexpensive type of paper that is often used to package heavy-duty foods, such as potatoes and onions. It is also commonly used to make paper bags and boxes.

Glassine paper is a smooth, glossy, and grease-resistant type of paper that is often used to package food that is prone to spoilage, such as meat, poultry, and fish. It is also commonly used to make liners for food trays and boxes. Parchment paper is a type of paper that is made from vegetable fibers. It is heat-resistant, grease-resistant, and water-resistant, and it is often used to bake food and to line baking pans. Parchment paper is also commonly used to wrap food for storage. Waxed paper is a type of paper that is coated with a thin layer of wax to make it water-resistant and grease resistant. It is often used to wrap food for storage and to line food trays and boxes. Foil paper is a type of paper that is coated with a thin layer of aluminum foil. The aluminum foil makes the paper water-resistant, grease-resistant, and heat-resistant, and it is often used to wrap food for storage and to cook food. Foil paper is also commonly used to line food trays and boxes.

Impacts of Food Packaging Paper on the Environment

Sustainability is something a lot of organizations and agencies have been trying to achieve in the past decades, especially with the increase in adverse impacts of global warming and climate change. It raised a global concern when countries such as China, Vietnam, the Philippines, Indonesia, and Thailand were held liable for 50% of the total plastic waste that was thrown into oceans (UNEP, 2018; Mehirishi, et. al., 2019.) The presence of chemical and plastic wastes in the ocean kills about 1 million seabirds and 100,00 marine mammals every year (United Nations, 2017.) One of the most common causes of pollution in the Philippines (and also globally) is plastic waste. Econtainer Philippines is a food service disposables company that produces eco-friendly food packaging using sugarcane bagasse. As stated in their sustainability blog, sugarcane bagasse is great for paper packaging because it is water, oil, and grease resistant. The process of producing sugarcane packaging is sustainable because, unlike other packaging that uses trees that take more time (decades) to regrow, sugarcane is more renewable. After all, it only takes nine months to two years to regrow.

Sugarcane leaves are versatile and can be used as raw material for various products. In 2019, Jamara et. al conducted a study in Cebu City on the potential reduction of greenhouse gas emissions through the use of sugarcane ash in cement-based industries. This study reiterates that ash from sugarcane leaves can be utilized as cement to make use of the leftover sugarcane leaves. It was concluded in the study that ash from sugarcane residues per year could serve as a potential renewable source for cement in the formation of mortar and concrete.

Comparative Literature on Commercial and Sustainable-Based Packaging Paper

Packaging paper is a ubiquitous product in the modern world, used to protect and transport a wide range of goods (Almasi et al., 2021; Coma, 2014; Nilsen-Nygaard et al., 2019). Commercial packaging paper is typically made from virgin wood pulp, which is a non-renewable resource (Coma, 2014; Padua, 2014; Siracusa et al., 2008). Sustainable-based packaging paper, on the other hand, is made from renewable and recycled materials, such as agricultural waste, sugarcane bagasse, and recycled paper (Almasi et al., 2021; Dusseault & Lacroix, 2017; Han & Krochta, 2007; Nilsen-Nygaard et al., 2019).

Commercial packaging paper is made using a traditional papermaking process, which involves pulping wood chips and then forming the pulp into sheets of paper (Coma, 2014). The wood pulp is often bleached using

harsh chemicals, such as chlorine, to produce a bright white paper (Dusseault & Lacroix, 2017).

Sustainable-based packaging paper is made from a variety of renewable and recycled materials (Coma, 2014). Agricultural waste, such as sugarcane bagasse, rice straw, and wheat straw, can be pulped and used to make sustainable-based packaging paper (Nilsen-Nygaard et al., 2019). Recycled paper can also be used to make sustainable-based packaging paper (Padua, 2014).

Although plastic packaging is ideally the efficient food-containing material, especially in overseas exportation, most of these plastic materials are left unattended after serving their use (Luijsterburg and Goossens, 2014; Faraca and Astrup, 2019) Furthermore, these now plastic wastes are disposed of by being buried in land areas, incinerated or some are being recycled. Which becomes an ecological and environmental setback.

Since synthetic polymeric wastes brought concerns to both consumers and shipping companies as it is associated with their non-biodegradability, there has been an increase in demand for non-petroleum-based packaging materials (Ahankari et al., 2021.) There has been a need for biodegradable and sustainable polymers to replace petroleum-based synthetic polymers as they pose minimal environmental hazard or danger and are expected to be renewable. (Han et al., 2018.)

In recent years, nanotechnology has been expanding in the field of food packaging as it introduces nanofillers that originated from cellulosic fibers of plants that offer bio-based polymers that serve as additives or fillers that improve other polymeric materials (Ahankari et al., 2021.) Moreover, nanofillers produce other thin composite films that offer a variety of usage as they are resistant to moisture from different gasses such as carbon dioxide and oxygen and it is also antibacterial.

Sugarcane bagasse has multiple mechanical properties such as flexural strength, tensile strength, durability, impact strength, and flame retarding (Alokika et al., 2020.) This makes sugarcane bagasse one of the economy's prospects to have both economical and industrial uses since its by-product after being harvested and processed can be manufactured into a polymeric material which is cost-efficient and renewable (Ajala et al., 2021)

Currently, approximately 90% of the raw materials used in the plastic industry are generated from non-renewable fossil feedstocks (oil and gas). Compared to transportation, which consumes 45% of oil and gas consumption in Europe, and energy production, which consumes 42% of oil and gas consumption, by 2050, it is anticipated that this will account for 20% of global oil consumption (Barker, 2018).

Prior Art

The Use of Pinyapel as a Sustainable Packaging Solution

Pinyapel, as shown in Figure 2, is a sustainable paper product developed by the Design Center of the Philippines, as evidenced by its registration with the registration number 4/2021/514036 on February 17, 2022.

Figure 2 Pinyapel



Pinyapel was crafted from waste pineapple leaves, a byproduct of the pineapple industry (Design Center of the Philippines, 2022). The development process involved collecting and processing pineapple leaves to extract fibers suitable for papermaking. These fibers were then combined with eco-friendly binders and underwent a papermaking process to produce Pinyapel sheets.

Throughout its development, Pinyapel underwent comprehensive evaluations to ensure its quality and suitability for various applications. Tests included assessments of strength, durability, and biodegradability. Strength and durability testing involved evaluating parameters such as tear resistance and tensile strength to ensure Pinyapel met industry standards for paper products. Biodegradability assessments were conducted to determine the material's ability to decompose naturally over time, contributing to reduced environmental pollution.

Furthermore, the developers of Pinyapel recommended further studies to optimize the production process, explore additional raw materials for enhanced sustainability, and investigate market adoption and consumer perception. These recommendations aim to advance the application and adoption of Pinyapel as a sustainable packaging solution, contributing to a more environmentally friendly packaging industry.

Synthesis

The researched literature provides a thorough examination of the many materials used to make food packaging paper, emphasizing both conventional and environmentally friendly options. Traditional resources, such as tree wood, have been used for a long time because of their greater cellulose content, which affects the strength of the paper. In contrast, sustainable alternatives are emerging from agricultural wastes such as sugarcane bagasse, leaves, and recycled paper, which can be used to produce paper by utilizing their cellulose and hemicellulose content. Research highlights the practicality of these materials by demonstrating their water resistance, mechanical qualities, and possibilities for environmentally friendly packaging solutions.

Additionally, developments in biopolymers offer encouraging directions for environmentally friendly packaging. Among other things, starch-based compounds and cellulose nanofibrils improve the biodegradability, barrier qualities, and strength of paper. The research on edible food packaging paper also explores novel ways to use proteins, cellulose, and starch to create biodegradable packaging materials.

Although virgin wood pulp is still the primary material used in commercial packaging, there is a noticeable trend toward sustainable alternatives. Environmental concerns, demonstrated by the damaging effects of plastic waste on ecosystems, are the driving force behind this custom. The field of nanotechnology presents itself as a frontier that offers plant-based nanofillers that improve packaging qualities and add antimicrobial elements.

Combining these data shows a complex picture of food packaging paper that is defined by an increasing focus on environmental responsibility, sustainability, and innovation. The literature emphasizes the need for more investigation into consumer views of sustainable packaging solutions, biodegradability, and long-term

stability. In the end, this synthesis lays the groundwork for the current research to add to the continuing discourse about environmentally friendly food packaging.

METHODOLOGY

This chapter presents the research design, design criteria, design plan, preparation and fabrication, evaluation procedure, instrumentation, data to be gathered, parameters for analysis, cost analysis, and ethical consideration.

Research Design

This study utilized developmental and descriptive types of research. Developmental research aims to develop new technologies, processes, or products that can be applied in real-world settings (Kumar, 2014). In this study, different processes were used to develop a new type of food packaging paper made from eggshell powder, sugarcane leaves, and spent coffee grounds.

Descriptive research aims to describe phenomena or characteristics of a population or situation as they exist, without manipulating variables or establishing causality (Nassaji, 2015). This study described and analyzed the physical and mechanical properties, biodegradability, and acceptability of the developed food packaging paper without manipulating variables (Nassaji, 2015). Quantitative data on thickness, density, tensile strength, and biodegradation were collected and analyzed to provide a detailed understanding of the different formulations (Creswell, 2014). The descriptive nature of this research enabled a comprehensive evaluation of the potential of these sustainable packaging alternatives.

Design Criteria

The design criteria for this study defined the desired characteristics of a food packaging paper. Table 1 on the next page shows the criteria for the physical and mechanical properties, biodegradability, and acceptability of the developed food packaging paper.

Table 1 Criteria for the Physical and Mechanical Properties, Biodegradability, and Acceptability

Parameters	Criteria
Thickness	0.127-0.381 mm (Smith and Jones, 2021)
Density	320-800 g/L (Smith and Jones, 2021)
Tensile strength	>1.0 MPa (ASTM D828-17)
Biodegradability	at least 30% within two weeks under aerobic conditions (ASTM D5988-10)
Acceptability	Very Highly Acceptable

Design Plan, Preparation, and Fabrication

This involved the formulation of samples, the raw materials used, the tools, equipment, and reagents used, the production procedures, the production time frame, the physical and mechanical properties testing, and the biodegradability test.

Formulation of Samples

This study utilized a fractional factorial design to efficiently evaluate a wide range of raw materials combinations while minimizing the number of experiments required (Smith, 2021). Three samples were

established, representing different ratios of eggshell powder, sugarcane leaves, and spent coffee grounds in the paper composition.

Raw Materials Used

The eggshells, sugarcane leaves, and coffee grounds that were used for this study were all discarded materials and were acquired at no cost. The eggshells were collected from the researcher's household waste, while the sugarcane leaves were obtained from a sugarcane field in Sagay City. The spent coffee grounds were obtained from Kape de Kamalig, a local coffee shop also in Sagay City. All these raw materials were disinfected, ensuring hygiene and contaminant removal, before being shredded and finely ground.

Tools, Equipment, and Reagents Used

Table 2 shows the tools, equipment, and reagents used and their functions in the development of the food packaging paper.

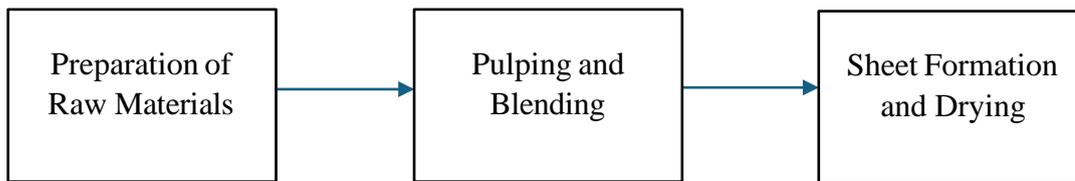
Table 2 Tools, Equipment, and Reagents and their Functions

Tools, Equipment, and Reagents	Functions
A. Tools	For holding the slurry
Basin	For containing the sugarcane leaves and reagents during digestion and bleaching
Beakers	For mixing the powders, pulp, binder, and water
Blender	For molding the slurry into paper
Mold	For measuring the pH of the solutions
pH meter	For shredding the sugarcane leaves
Shredder	For sifting the powders
Sifter	For grinding the eggshells and coffee grounds into fine powder
Spice Grinder	For pressing out excess water from the paper mold
Sponge Presser	For measuring the temperature of the mixtures
Thermometer	For weighing the raw materials and the finished product
Electronic weighing scale	For heating the sugarcane leaves and reagents during digestion and bleaching
B. Equipment	For drying eggshells and coffee grounds
Hot plate	For dignifying sugarcane leaves
Oven	For bleaching the pulp
C. Reagents	For diluting NaOH and H ₂ O ₂ solutions
NaOH solution, 1%	
H ₂ O ₂ solution, 5%	
Distilled water	

Production Procedures

Figure 3 on the next page outlines the steps in the production of the food packaging paper, which included preparation of raw materials; pulping and blending; and sheet formation and drying. The procedures were based on the research of Villareal, et al. published in the journal “The Philippine Agricultural Scientist” in 2022, and are shown in Appendix I.

Figure 3. Outline of the Steps in the Production of Food Packaging Paper



PREPARATION OF RAW MATERIALS

Preparation of Eggshell Powder

1. The eggshells were thoroughly washed to remove any dirt, debris, membranes, or yolk residue.
2. The clean eggshells were placed on a baking tray and dried completely in an oven set to 100°C for one hour.
3. The dried eggshells were then ground into a fine powder in a grinding machine to a consistency like flour.
4. Finally, the eggshell powder was sifted using a kitchen stainless steel 250 wire mesh sifter.

Preparation of Sugarcane Leaves

1. The sugarcane leaves were thoroughly washed to remove any dirt, microorganisms, and other foreign objects.
2. The clean sugarcane leaves were then shredded into smaller strands using a mechanical shredder.

Preparation of Coffee Grounds

1. The spent coffee grounds were washed to remove any residual solubles or impurities.
2. The coffee grounds were then dried in an oven at 100°C for one hour to ensure complete moisture removal.
3. The dried coffee grounds were finely ground using the same grinding machine employed for the eggshell powder.
4. Finally, the coffee powder was sifted through the same kitchen stainless steel 250 wire mesh sifter used for the eggshells.

Pulping and Blending

1. The shredded sugarcane leaves were digested in a 1% (w/v) NaOH solution for two hours at 80°C. The 1% NaOH solution was prepared according to the method described by the American Chemical Society (2010) and National Research Council (2011), whereby 10 grams of NaOH pellets were dissolved in 1000 mL of distilled water. The NaOH solution was used to remove the hemicellulose and lignin from the sugarcane leaves, leaving behind the cellulose fibers.
2. The cellulose fibers were then washed thoroughly to remove any residual NaOH until the pH was near or a little above 7.
3. The cellulose fibers were then bleached with a 5% hydrogen peroxide (H₂O₂) solution. The 5% H₂O₂ solution was prepared from a 6% H₂O₂ solution following the standard method described by the National Research Council (US) Committee on Prudent Practices in the Laboratory (2011), whereby 100 mL of distilled water was added to 500 mL of 6% H₂O₂. The H₂O₂ solution was preheated on a hot plate at 80°C for ten minutes. Then, the cellulose fibers were gradually added to the solution and cooked for 90 minutes at 80°C, with occasional stirring.
4. After thirty minutes of cooling, the bleached cellulose fibers were strained through a kitchen stainless steel fine wire mesh. The pulp was then squeezed to remove as much H₂O₂ solution as possible.
5. After thoroughly washing the cellulose fibers, they were blended with the eggshell powder, coffee grounds, and water in the blender until the desired consistency of the pulp mixture was reached.

Sheet Formation and Drying

1. In a large basin containing five liters of water, the mixture of pulp and binder was gradually added and stirred in.
2. A 19 cm x 25 cm wooden mold was then slowly submerged in the solution.
3. The mold was then carefully lifted, allowing excess water to drain, and leaving the pulp and binder mixture evenly distributed on it.
4. The wet sheet of paper was then transferred onto a clean cloth using a sponge presser.
5. The frame of the mold was flipped upside down with the clean cloth placed on top.
6. The back of the screen was sponge-pressed to carefully transfer the wet sheet of paper to the cloth. The frame was lifted and removed from the cloth.
7. Finally, the cloth was hung to sun dry for two days.

Production Time Frame

The production of the food packaging paper from the mixture of eggshell powder, sugarcane leaves, and coffee grounds involved several stages spanning several hours. Table 3 outlines the production procedures which included the preparation of the raw materials, pulping and blending, sheet formation and drying, and the allotted time for each procedure.

Table 3 Production Procedures and Time Allotment

Production Procedure	Time Allotment
A. Preparation of Raw Materials	1.5 hours
Eggshell Powder	1 hour
Sugarcane Leaves	1.5 hours
Coffee Grounds	4.25 hours
B. Pulping and Blending	0.25 hour
Pulping	0.50 hour
Blending	48 hours
C. Sheet formation and Drying	57 hours
Molding	
Drying	
Overall production time frame	

Evaluation Procedure

The Researcher-made Evaluation of Acceptability Questionnaire (see Appendix F) underwent a validation test by five TUPV instructors, three of whom have doctorate degrees in Philosophy, to ensure that the questionnaire effectively captured the sensory attributes of the developed packaging paper. The validators were formally requested through a Letter of Invitation to Validate the Evaluation of Acceptability Questionnaire (see Appendix D) and were given the Validation Instrument (see Appendix E).

The evaluation of acceptability included two phases – a reliability test and an acceptability test. For the reliability test, thirty respondents comprising mechanical engineers, TUPV instructors teaching Physics and Properties of Engineering Materials, and selected TUPV students who had taken these courses, were asked to answer the evaluation of acceptability questionnaires.

For the acceptability test, another group of thirty respondents comprising random marketgoers and vendors from the Sagay City public market were requested to answer the same questionnaires. A single questionnaire was used for the three samples of different formulations since they had almost similar color, odor, and texture.

Each respondent was shown a sample of the developed food packaging paper, the Researcher-made Evaluation of Acceptability Questionnaire, and a Letter of Informed Consent (see Appendix G). They were instructed to evaluate the sample based on their individual preferences, and to record their responses on the questionnaire, emphasizing honest and constructive feedback.

Cronbach's alpha coefficient was used as a statistical tool to assess the reliability of the Researcher-made Evaluation of Acceptability Questionnaire. Mean scores and standard deviations were used to assess the acceptability of the developed food packaging paper.

Instrumentation

The instrument used to validate the Researcher-made Evaluation of Acceptability Questionnaire was based on criteria for constructing a questionnaire and evidence of questionnaire validity by C.V. Good and D.E. Scates (1954). The first part of the instrument included key demographic information about the validators – their names, ages, genders, educational qualifications, specialization, designation, and length of experience. The second part contained the qualities of the Researcher-made Evaluation of Acceptability Questionnaire which were rated using a five-point Likert scale ranging from 1 (Poor) to 5 (Very Good).

The Researcher-made Evaluation of Acceptability Questionnaire also incorporated key demographic information about the respondents – their names, ages, genders, and occupations. The instructions that preceded the questions were clear and concise, emphasizing the importance of honest and open evaluations. The questionnaire employed a five-point Likert scale spanning from 1 (Very Unacceptable) to 5 (Very Highly Acceptable). It enabled the respondents to express nuanced preferences regarding sensory attributes and overall acceptability. The questionnaire delved into the three crucial sensory attributes: color, odor, and texture. Respondents evaluated each attribute separately by answering three questions using the five-point scale. Before the instrument was piloted to the respondents, their informed consent was obtained to adhere to ethical research practices.

Data to be Gathered

The data collection process for the evaluation of acceptability involved the distribution of the questionnaires in two distinct locations for reliability and acceptability. The questionnaires were personally disseminated by the researcher to the instructors and selected students within the academic setting of TUPV at Sagay City. The same questionnaires were also personally administered by the researcher at the local market, specifically in proximity to the meat shop owned by the researcher. This location targeted vendors and other marketgoers.

The questionnaires were then gathered and then compiled. The recorded data were systematically tallied and tabulated by a qualified statistician, for interpretation of the gathered information.

Parameters for Analysis

The parameters identified in this research study were tested using the laboratory facilities of TUPV at Sagay City, particularly the density, thickness, tensile strength, and biodegradability.

The density of the developed packaging paper followed ASTM D896. The mass of each sample was determined using an electronic scale, while the volume was calculated from its linear dimensions.

The thickness of the developed packaging paper was measured using a digital micrometer following ASTM D1873.

The tensile strength tests were performed using the method adopted by Gao et al. (2016), using a crane scale. In this test, a strip of the packaging paper was attached to a bulldog clip and hung on the crane scale. Another bulldog clip was attached on the other end of the paper strip to which weights were slowly added until the packaging paper exhausts or breaks.

The biodegradability test performed was soil burial testing according to ASTM D5988-10 (see Appendix J). The soil was sterilized at 40°C for thirty minutes (Adebisi, et al., 2019) to eliminate any worms and insects that could be present in the soil and interfere with the biodegradation results. Three trials for each of the four samples were prepared, with an initial mass of 0.3 grams each trial, and were buried in the soil mixture in the test vessels. After a maximum period of two weeks, the remaining paper samples in the test vessels were weighed again to determine the weight losses of the paper samples.

For the evaluation of the acceptability of the developed food packaging paper, the mean and standard deviation were used to analyze and interpret the gathered data. Table 4 shows the five-point Likert scale distribution of values and their corresponding verbal interpretations.

Table 4 Five-Point Likert Scale Distribution of Values and Verbal Interpretation

Score	Mean Score Range	Verbal Interpretation
5	4.51-5.00	Very Highly Acceptable
4	3.51-4.50	Highly Acceptable
3	2.51-3.50	Acceptable
2	1.51-2.50	Unacceptable
1	1.00-1.50	Very Unacceptable

Cost Analysis

This section presents the computation of the costs incurred in the development of the food packaging paper from a mixture of eggshell powder, sugarcane leaves, and coffee grounds. It focuses on expenses directly associated with the material sourcing and production of the packaging paper. This analysis helped evaluate the practicality and scalability of the developed food packaging paper.

Table 5 on the next page summarizes the expenses incurred to produce each batch of food packaging paper made from eggshell powder, sugarcane leaves, and spent coffee grounds.

Table 5 Expenses for Batch Production of the Food Packaging Paper

Reagents	Unit Price	Amount Used	Cost
H ₂ O ₂	63.00/500mL	500 mL	Php63.00
NaOH	75.00/kg	10 g	0.75
Distilled water	35.00/kg	1.1 L	25.66
Cassava starch	89.00/kg	20 g	1.78
Grand Total			Php91.19

The raw materials, which included eggshell powder, sugarcane leaves, and spent coffee grounds, were obtained at no cost because they were all waste products.

The cost of reagents included the cost of NaOH pellets for the digestion of sugar cane leaves, cassava starch as binder, and H₂O₂ solution for bleaching of the pulp. NaOH flakes and cassava starch were bought through Lazada at Php75.00 and Php 89.00 per kilogram, respectively, while the H₂O₂ solution was bought from Mercury Drugstore at Php63.00 per 500 mL.

The glassware, laboratory equipment, and tools incurred no cost because they were either borrowed from the school laboratory, with the permission of the laboratory-in-charge, or from the personal kitchen of the researcher.

Ethical Consideration

This study upheld ethical consideration throughout the data collection process by ensuring all the respondents' anonymity and confidentiality. Before engaging in the questionnaire, each respondent was presented with a Letter of Informed Consent which clearly outlined the purpose of the study, the voluntary nature of participation, and the assurance of confidentiality. The respondents were requested to sign the letter to affirm their willingness to participate. Measures were implemented to safeguard their privacy during data collection. In the market environment, participants were approached randomly to answer the questionnaire. This ensured a representative sample for the test's purpose. For student participants, a classroom setting was used to facilitate the data collection process, while still maintaining anonymity. These measures ensured that the research adhered to ethical principles and respected participant privacy.

Presentation, Analysis, And Interpretation Of Data

This chapter presents and discusses the data gathered, analysis, and interpretation of data. The findings are presented in tabular form and accordance with the objectives of the study.

Ratio of Eggshell Powder, Sugarcane Leaves, and Coffee Grounds

The first objective of the study was to determine the ratio of eggshell powder, sugarcane leaves and coffee grounds in making the food packaging paper. Data in this regard are shown in Table 6. The ratios represented the percentages of each ingredient in the mixture.

Table 6 Formulations of Samples

Samples	Eggshell Powder	Sugarcane Leaves	Spent Coffee Grounds
1	20 g	70 g	10 g
2	45 g	45 g	10 g
3	50 g	40 g	10 g

Sample 1 (20-70-10) had a higher proportion of sugarcane leaves compared to eggshell powder and coffee grounds and exhibited a packaging paper with improved tensile strength, likely due to its higher fiber content. The reinforcing effect of natural fibers like those from sugarcane leaves on mechanical properties like tensile strength has been well documented in literature (Maleque et al., 2007; Faruk et al., 2012). Sugarcane leaves are rich in cellulose fibers which can impart good mechanical strength when incorporated into composite materials (Reddy & Yang, 2005).

The amount of cassava starch, which was used as the binder, was also fixed to maintain consistency and avoid interference with the strength, flexibility, and overall performance of the food packaging paper. This was to ensure that variations in adhesive properties did not compromise the desired characteristics of the packaging paper.

Physical and Mechanical Properties Testing

The second objective of the study was to test the physical and mechanical properties of the developed food packaging paper in terms of density, thickness, and tensile strength. The results are presented in the succeeding tables.

Physical Properties (Density and Thickness)

Table 7 presents the densities of the three trials of the samples. The density was calculated using the equation:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \quad (1)$$

Table 7 Densities of the Samples

	Trial 1 (g/L)	Trial 2 (g/L)	Trial 3 (g/L)	Mean (g/L)
Sample 1 (20-70-10)	357.4	273.9	282.3	304.5
Sample 2 (45-45-10)	280.9	282.9	264.3	276.0
Sample 3 (50-40-10)	359.1	380.4	422.7	387.4

The highest mean density was observed in Sample 3 (50-40-10 formulation) at 387.4 g/L, followed by Sample 1 (20-70-10 formulation) at 304.5 g/L, and Sample 2 (45-45-10 formulation) at 276.0 g/L. This ordering suggested that the formulations with higher proportions of certain components led to lower density.

According to Miao et al. (2022), higher-density papers ranging from 550 to 640 g/L) exhibited increased puncture resistance and rigidity, making them more suitable for protecting heavier or fragile food items. However, Miao et al. (2022) acknowledged that careful consideration of breathability, water absorption, and potential environmental trade-offs should be given. The lower-density formulations, such as Sample 2 (276.0 g/L) and Sample 1 (304.5 g/L), may offer advantages in terms of breathability and environmental impact, but their suitability for protecting heavier or fragile items might be compromised. Additionally, Miao et al. (2022) noted that denser paper is generally heavier and more difficult to handle than less dense paper. Sample 3, with its higher density, could present handling challenges compared to the lower-density formulations of Samples 1 and 2, which could be easier to handle and transport.

Table 8 shows the measured thicknesses of the three trials of the samples.

Table 8 Thicknesses of the Samples

	Trial 1 (mm)	Trial 2 (mm)	Trial 3 (mm)	Mean (mm)
Sample 1 (20-70-10)	0.202	0.157	0.150	0.170
Sample 2 (45-45-10)	0.202	0.196	0.212	0.203
Sample 3 (50-40-10)	0.253	0.240	0.215	0.236

The highest mean thickness was observed in Sample 3 (50-40-10 formulation) at 0.236 mm, followed by Sample 2 (45-45-10 formulation) at 0.203 mm, and Sample 1 (20-70-10 formulation) at 0.170 mm. These results suggested that increasing the proportions of certain components in the formulation led to thicker packaging paper.

Witherow et al. (2019) correlated higher thickness with improved strength and barrier properties. The thicker formulations, especially Sample 3 and Sample 2, were likely to exhibit greater puncture resistance, stiffness, and protection for heavier or more delicate products compared to the thinner samples.

Conversely, thinner papers around 0.04-0.06 mm were known to provide flexibility, breathability, and cost-effectiveness (Witherow et al., 2019). Sample 1 (0.170 mm) may exhibit these characteristics, making it suitable for wrappers, labels, or bags for lighter products like snacks or baked goods.

Mechanical Property (Tensile Strength)

Table 9 shows the results of the tensile strength test as performed using the method adopted by Gao et al. (2016)

Table 9 Tensile Strength of the Samples

	Trial 1 (MPa)	Trial 2 (MPa)	Trial 3 (MPa)	Mean (MPa)
Sample 1 (20-70-10)	0.00167	0.00125	0.00167	0.00153
Sample 2 (45-45-10)	0.00167	0.00250	0.00250	0.00222
Sample 3 (50-40-10)	0.00250	0.00250	0.00333	0.00278

Sample 3 (50-40-10) demonstrated the highest mean tensile strength of 0.00278 MPa, with individual trial values between 0.00250 MPa and 0.00333 MPa. This tensile strength could translate to adequate package durability and resistance against punctures or tears during handling and transportation (Lyons, 2000). Sample 2 (45-45-10) yielded a mean tensile strength of 0.00222 MPa, with trial results ranging from 0.00167 MPa to 0.00250 MPa, reflecting some variability in tensile strength. The lowest mean tensile strength of 0.00153 MPa was observed for Sample 1 (20-70-10), with values varying from 0.00125 MPa to 0.00167 MPa across trials. While this formulation exhibited the least tensile strength among the samples, it may still offer sufficient protection for certain food packaging applications with lower stress or weight requirements.

The observed variations in tensile strength among the developed samples were attributed to differences in composition. As noted by Witherow et al. (2019), higher tensile strength is often correlated with increased thickness and material usage.

Table 10 summarizes the densities, thicknesses, and tensile strengths of the samples.

Table 10 Summary of the Physical and Mechanical Properties of Samples

Property	Sample 1 (20-70-10)	Sample 2 (45-45-10)	Sample 3 (50-40-10)
Tensile Strength (MPa)	0.00153	0.00222	0.00278
Thickness (mm)	0.170	0.203	0.236
Density (g/L)	304.5	276.0	387.4

As shown in Table 10, Sample 3 had the highest tensile strength (0.00278 MPa), followed by Sample 2 (0.00222 MPa), and then Sample 1 (0.00153 MPa). This suggested that Sample 3 might be the most resistant to tearing or breaking. The thickness increased from Sample 1 (0.170 mm) to Sample 2 (0.203 mm), and then Sample 3 (0.236 mm). This trend correlated with the increasing content of sugarcane leaves (70% in Sample 1, 45% in Sample 2, and 40% in Sample 3) as sugarcane leaves were a fibrous material that contributed to thickness. As for the density, Sample 3 had the highest (387.4 g/L), followed by Sample 2 (276.0 g/L), and then Sample 1 (304.5 g/L). This indicated that Sample 3 was the densest, while Sample 2 had the lowest density.

Thickness and density increased with a higher content of sugarcane leaves, but it came at the cost of lower tensile strength. Sample 2 had the lowest density, which could be beneficial for lightweight packaging, but its tensile strength fell among the other samples.

Biodegradability Evaluation

The third objective of the study was to evaluate the biodegradability of the developed food packaging paper using soil burial testing according to ASTM D5988-10. Table 11 shows the biodegradability percentages of the samples. The biodegradability percentage was calculated according to the formula:

$$\text{Biodegradability (\%)} = \left[\frac{(\text{Initial weight} - \text{Final weight})}{\text{Initial weight}} \right] \times 100 \quad (2)$$

Table 11 Biodegradability Percentages of the Samples

	Trial 1 (%)	Trial 2 (%)	Trial 3 (%)	Mean (%)
Sample 1 (20-70-10)	100	100	100	100
Sample 2 (45-45-10)	100	100	100	100
Sample 3 (50-40-10)	96.67	100	100	98.88

The highest mean biodegradability percentage was observed in Samples 1 (20-70-10 formulation) and 2 (45-45-10 formulation) at 100%, indicating complete biodegradation within two weeks across all trials. Sample 3 (50-40-10 formulation) exhibited a slightly lower mean biodegradability of 98.88%.

The complete biodegradation observed in Samples 1 and 2, and the high biodegradability of Sample 3, aligned with the increasing emphasis on sustainable and environmentally friendly packaging materials (Miao et al., 2022). These formulations surpassed the minimum 30% biodegradation threshold within two weeks, indicating their potential to mitigate environmental concerns associated with non-biodegradable packaging waste. The high biodegradability of the developed samples could contribute to reducing the ecological footprint of food packaging, addressing the growing demand for eco-friendly alternatives (Witherow et al., 2019).

Evaluation of Acceptability

The fourth objective of the study was to evaluate the acceptability of food packaging paper from a mixture of eggshell powder, sugarcane leaves, and coffee grounds in terms of color, odor, and texture.

Tables 12, and Tables 13 and 14 on the next pages, show the mean scores, standard deviations, and verbal interpretations on the level of acceptability of the developed food packaging paper in terms of color, odor, and texture, respectively.

Table 12 Mean Scores on the Level of Acceptability of the Developed Food Packaging Paper in terms of Color

Items	Mean	SD	Verbal Interpretation
1. Overall color of the packaging paper	4.53	0.57	Very Highly Acceptable
2. Suitability of the color of the packaging paper to its intended use	4.63	0.49	Very Highly Acceptable
3. Visual appeal of the color of the packaging paper in enhancing the	4.73	0.52	Very Highly Acceptable

presentation of its contents			
Total mean	4.63	0.53	Very Highly Acceptable

The highest obtained mean score of 4.73 for the color indicated that the respondents found the developed food packaging paper to be very highly acceptable in terms of visual appeal. This implied that the color and overall appearance of the food packaging paper were aesthetically pleasing and attractive to the respondents.

With a mean score of 4.63 for the suitability of color, the respondents perceived the color as highly acceptable for the intended use of the food packaging paper. This suggested that the color was appropriate for a food packaging application, potentially contributing to consumer appeal and product recognition.

Moreover, the overall color of the developed food packaging paper received a mean score of 4.53, indicating that it was highly acceptable to the respondents. This positive perception of the color could affect consumer preferences, product acceptance, and purchasing decisions.

The mean scores for all color-related items were above 4.0, which fell within the highly acceptable range. This overall positive perception of the color aspects implied that the developed food packaging paper had met the respondents' expectations and preferences in terms of visual appeal and color suitability, which are crucial factors in the acceptance and marketability of packaging materials (Deliya & Parmar, 2012).

Table 13 Mean Scores on the Level of Acceptability of the Developed Food Packaging Paper in terms of Odor

Items	Mean	SD	Verbal Interpretation
1. Overall odor of the packaging paper	4.73	0.52	Very Highly Acceptable
2. Compatibility of the odor of the packaging paper to its food contents	4.73	0.45	Very Highly Acceptable
3. Potential impact of the odor of the packaging paper on its food contents	4.70	0.47	Very Highly Acceptable
Total mean	4.72	0.48	Very Highly Acceptable

With the highest obtained mean score of 4.73 for the overall odor and compatibility of the odor to the food content, the respondents verbally interpreted this as very highly acceptable. This implied that the developed food packaging paper had a neutral or slightly pleasant odor that would not negatively impact or clash with the food content intended to be packaged in it.

With a mean score of 4.70 for the potential impact of odor on food content, the respondents found it to be very highly acceptable as well. This suggested that the developed food packaging paper's odor could have minimal to no negative impact on the food it would contain.

The odor-related items all received scores of 4.7 and above, which fell within the very highly acceptable range on the verbal interpretation, indicating generally neutral or slightly positive perceptions of the odor by the respondents.

These positive evaluations of the odor-related items had implications for the food packaging paper's suitability and acceptability for its intended purpose. As mentioned by Deliya and Parmar (2012), Martínez-Bueno et al. (2019), and Realini and Marcos (2014), a neutral or pleasant odor that does not adversely affect the food content is a desirable characteristic for packaging materials, as it can contribute to maintaining the quality, freshness, and sensory appeal of the packaged food products.

Table 14 Mean Scores on the Level of Acceptability of the Developed Food Packaging Paper in terms of Texture

Items	Mean	SD	Verbal Interpretation
1. Smoothness of the packaging paper	4.70	0.47	Very Highly Acceptable
2. Feel of the packaging paper in the hand	4.57	0.57	Very Highly Acceptable
3. Suitability of the texture of the packaging paper to its intended use	4.83	0.46	Very Highly Acceptable
Total mean	4.70	0.50	Very Highly Acceptable

Notably, the suitability of texture to food content received the highest mean score of 4.83 in the texture-related items, suggesting the respondents found the texture to be very highly acceptable for the intended food products to be packaged. The smoothness received a mean score of 4.70 suggesting that the respondents found the smoothness of the developed food packaging paper to be very highly acceptable. The mean score for the feel of the packaging paper, while slightly lower than smoothness, still indicated it was perceived as very highly acceptable in terms of texture.

These very highly acceptable ratings for texture-related items, particularly the suitability to food content, have implications for the developed food packaging paper's ability to adequately protect and preserve the quality of packaged food items, as emphasized by Deliya and Parmar (2012) and Marsh and Bugusu (2007). A desirable texture can contribute to consumer acceptance and the perceived value of the packaging material.

Table 15 shows the overall mean scores on the level of acceptability of the developed food packaging paper in terms of color, odor, and texture.

Table 15 Overall Mean Scores on the Level of Acceptability of the Developed Food Packaging Paper in terms of Color, Odor, and Texture

Items	Overall Mean	SD	Verbal Interpretation
1. Color	4.63	0.53	Very Highly Acceptable
2. Odor	4.72	0.48	Very Highly Acceptable
3. Texture	4.70	0.50	Very Highly Acceptable
As a whole	4.70	0.50	Very Highly Acceptable

These very highly acceptable evaluations in color, odor, and texture underscore the potential of the developed food packaging paper for consumer acceptance and market success. The positive perceptions of these attributes align with the desirable characteristics of packaging materials, as highlighted by Deliya and Parmar (2012), Marsh and Bugusu (2007), Martínez-Bueno et al. (2019), and Realini and Marcos (2014).

Development of the Product Brochure

The last objective of the study was to develop a product brochure of the food packaging paper from a mixture of eggshell powder, sugarcane leaves, and coffee grounds. Figure 4 on the next page shows the front page of the product brochure.

Figure 4. Front page of Product Brochure



SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter provides an overview of the research study, encompassing a summary of the researcher's findings, conclusions, and recommendations.

Summary of Findings

The following are the findings of this study:

1. The optimal ratio of eggshell powder, sugarcane leaves, and coffee grounds in making the food packaging paper was determined to be 50-40-10, respectively.

2. Regarding physical and mechanical properties, the 50-40-10 formulation was superior to the other formulations (45-45-10 and 20-70-10). It had the highest density, thickness, and tensile strength.
3. The developed food packaging paper samples (20-70-10, 45-45-10, and 50-40-10) exhibited rapid biodegradation, surpassing the minimum 30% biodegradation threshold in soil burial testing over two weeks. The 20-70-10 and 45-45-10 samples exhibited complete biodegradation.
4. The levels of acceptability of the developed food packaging paper were rated very highly acceptable for color, odor, and texture.
5. A product brochure showcasing the developed food packaging paper was created as an output of the study.

CONCLUSIONS

Based on the summary of findings, the following conclusions were drawn:

1. The study successfully developed food packaging paper by combining eggshell powder, sugarcane leaves, and coffee grounds in different ratios, creating three formulations (20-70-10, 45-45-10, and 50-40-10).
2. Varying the ratios of the raw materials (eggshell powder, sugarcane leaves, and coffee grounds) significantly impacted the mechanical and physical properties of the developed food packaging papers, including density, thickness, and tensile strength.
3. The complete biodegradation observed in the 20-70-10 and 45-45-10 formulations, and the high biodegradability of the 50-40-10 formulation, suggest that these materials have the potential to mitigate the environmental concerns associated with packaging waste accumulation.
4. Based on an evaluation of acceptability by respondents, the developed food packaging papers were found to be very highly acceptable in terms of color, odor, and texture, making them potentially acceptable alternatives to traditional non-biodegradable packaging materials.
5. The developed product brochure provided a comprehensive and easily understandable overview of the food packaging paper from a mixture of eggshell powder, sugarcane leaves, and coffee grounds. With its approachable language and organized layout, the readers can quickly grasp the key advantages of the developed food packaging paper.

RECOMMENDATIONS

Based on the conclusions, the following recommendations were developed:

1. Further optimization of the formulations, particularly in adjusting proportions and binder content, is necessary to enhance specific properties such as tensile strength and cost. Exploring alternative materials or suppliers for raw materials could help in achieving the desired cost target.
2. Future research and development efforts should be focused on refining the packaging paper to meet industry standards and address specific market needs.
3. Conducting a comprehensive environmental impact assessment to quantify the sustainability benefits of the packaging paper compared to traditional materials would provide valuable insights for stakeholders and consumers.

- Further optimization of the production methods is necessary to reduce costs and make the paper more competitive in the market.

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