Sustainable Solution Economically for The Production of Paper Pulp from Peanut Shell

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***Abstract*—The increasing demand for sustainable and eco-friendly materials has prompted researchers to explore alternative sources for paper pulp production. This research paper investigates the feasibility of utilizing peanut shells, an abundant agricultural waste, as a potential raw material for paper pulp production. The study focuses on the process of converting peanut shells into high-quality pulp through various methods such as chemical and mechanical pulping. The paper further discusses the potential benefits, challenges, and environmental implications of using peanut shell pulp as a sustainable alternative to conventional wood-based pulps. The findings of this research contribute to the growing body of knowledge on sustainable resource management and promote the utilization of agricultural waste for value-added applications.**
Keywords— Peanut Shell, Kraft's and Soda process, Pulp,Cellulose, SDGs.

INTRODUCTION

Paper production has a significant environmental impact due to its heavy reliance on wood-based cellulose pulp. To address sustainability concerns and reduce deforestation, alternative sources of cellulose pulp have gained attention. This research paper focuses on the production of paper pulp from peanut shells, an abundant agricultural waste material. Peanut shells have great potential for commercial use, and their utilization as a raw material for paper pulp can provide a sustainable solution.

The paper begins with a historical overview of papermaking and the significance of cellulose as a major component. It then highlights the potential of peanut shells as a raw material for pulp production, emphasizing their availability and sustainability. Peanut shells are a byproduct of the peanut processing industry, and their utilization can help reduce waste and maximize resource efficiency.

The research paper explores different methods of producing paper pulp from peanut shells, including chemical and mechanical pulping techniques. Chemical pulping methods such as Kraft, soda, and organosolv pulping are discussed, along with their suitability for peanut shell pulp production. Mechanical pulping methods like stone ground wood and refiner mechanical pulping are also explored.

The optimization of the pulping process and the key parameters affecting pulp quality are examined. The paper emphasizes the importance of achieving high-quality pulp while considering process efficiency and cost-effectiveness. Characterization of peanut shell pulp, including fiber morphology and physical properties, is also discussed. The potential of peanut shell pulp for papermaking and its applications are addressed, focusing on the mechanical and physical properties of the resulting paper. The limitations and challenges associated with peanut shell pulp utilization are also highlighted. Environmental and economic considerations play a vital role in evaluating the feasibility of peanut shell pulp production. The paper discusses the sustainability aspects, waste reduction potential, and life cycle assessment of using peanut shells as a raw material. Economic feasibility and market opportunities for peanut shell pulp are also examined. The research paper concludes by summarizing the findings, implications, and future prospects of producing paper pulp

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from peanut shells. The potential benefits of utilizing peanut shell pulp as a sustainable alternative to wood-based pulps are highlighted. Overall, this research contributes to the growing body of knowledge on sustainable resource management and promotes the utilization of agricultural waste for value-added applications in the paper industry.

II.MATERIAL AND METHODS

Cellulose and lignin are important components of plant cell walls, and their presence and proportions can vary among different plant materials. Here's a comparison of cellulose and lignin content in walnut, peanut, banana, and wood:

Walnut:

Walnut shells, which are the hard outer coverings of the walnut fruit, contain cellulose and lignin. However, the cellulose content in walnut shells is relatively low compared to other plant materials. Lignin content in walnut shells is relatively higher, providing strength and rigidity to the shells.

Peanut:

Peanut shells, or peanut hulls, are the outer coverings of peanuts. They contain cellulose and lignin, similar to walnut shells. The cellulose content in peanut shells is relatively higher compared to walnut shells, making them a potentially suitable raw material for paper pulp production. Lignin content in peanut shells is present but needs to be removed or modified during the pulping process for paper production.

Banana:

Banana stems and leaves are rich in cellulose, making them a potential source of cellulose fibers. The cellulose content in banana fibers is relatively high, making them suitable for paper and textile production. However, lignin content in banana fibers is relatively low compared to other plant materials, which may affect their strength and durability.

Wood:

Wood is composed mainly of cellulose and lignin. Cellulose is the primary component of wood cell walls, providing strength and rigidity. Lignin, on the other hand, acts as a binding material and gives wood its characteristic hardness and resistance to decay. The proportions of cellulose and lignin in wood can vary depending on the tree species, age of the wood, and specific parts of the tree (e.g., heartwood vs. sapwood).

Overall, while walnut and peanut shells contain cellulose and lignin, their cellulose content may be relatively lower compared to other plant materials such as banana fibers or wood. However, peanut shells, with their higher cellulose content, can be a suitable source for paper pulp production.

Fig. 1. Peanuts

Source: naropeanut .org, April 2022.

There are several reasons why peanut shells may be chosen as a raw material for pulp production:

1. Abundance and availability: Peanut shells are readily available as a byproduct of peanut processing. They are generated in large quantities as agricultural waste, making them a potentially abundant and easily accessible source of raw material for pulp production.
2. Sustainability: Utilizing peanut shells as a raw material for pulp production can contribute to sustainable practices. By using an agricultural waste product, it helps to reduce waste and promote

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resource efficiency. It provides an alternative to traditional wood-based pulping, which involves cutting downtrees.

3. Similar composition: Peanut shells contain cellulose, which is a key component required for paper production. Cellulose is the primary structural material in plants and is responsible for providing strength and rigidity. Peanut shells contain a significant amount of cellulose, making them a potential source for pulp production.

4. Economic considerations: Peanut shells, being a waste product, may be available at a lower cost compared to traditional wood sources. Utilizing peanut shells as a raw material for pulp production can offer cost advantages, especially if they are locally sourced.

5. Potential for value addition: By converting peanut shells into pulp, which can then be used for paper production, value can be added to an otherwise underutilized waste material. This can create economic opportunities and contribute to a circular economy approach.

A. Raw Materials:

Wood:

Wood is classified into two types: hardwood and softwood. Coniferous trees provide softwood, while dicotyledonous trees (e.g., oak) offer hardwood. The distinction between hardwood and softwood does not solely depend on their hardness. For example, balsa wood is softer than any commercial softwood, and some softwoods are harder than many hardwoods. Wood consists of three main components:

a) Cellulose:

Cellulose is the primary component of wood, predominantly found in the form of fibers. After the pulping process, cellulose fibers are obtained as pulp. Cellulose is a long chain polymer with the chemical formula $C_6H_{10}O_5$.

b) Ash:

Ash refers to the inorganic content present in wood, such as minerals and other impurities. It remains after the combustion or burning of wood.

c) Lignin:

Lignin is a complex organic polymer that provides rigidity and woody characteristics to plant cell walls. It is deposited in the cell walls of many plants, including wood.

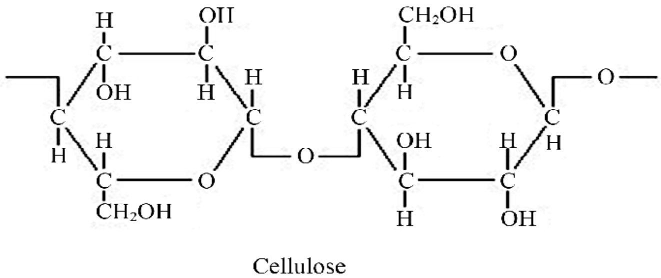

Fig. 2 Cellulose

B. Chemicals Used:

The chemicals used in the paper pulp production process include:

Sodium Hydroxide (NaOH):

Sodium hydroxide, also known as caustic soda, is a strong alkaline compound. It is used in various stages of the pulping process.

Sodium Hypochlorite (NaOCl):

Sodium hypochlorite is a chemical compound commonly used as a bleaching agent in the paper industry. It helps to remove color and impurities from the pulp.

Sodium Sulphide (Na_2S):

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Sodium sulphide is a reducing agent used in the pulping process. It aids in the removal of lignin and improves the quality of the pulp.

Sodium Carbonate (Na_2CO_3):

Sodium carbonate, also known as soda ash, is used in the pulping process as an alkali. It helps to break down the lignin and facilitates the separation of cellulose fibers.

C. Processes:

Kraft Pulping Process:

The Kraft pulping process is the most widely used chemical pulping method. It involves the use of a strong alkaline solution, typically consisting of sodium hydroxide (NaOH) and sodium sulfide (Na_2S), to break down the lignin in wood fibers. The process operates at high temperatures and pressures.

The main characteristics of the Kraft pulping process include:

High cooking temperature: The temperature in the Kraft pulping process ranges from 130 to 180°C, which helps to dissolve the lignin effectively.

Strong alkaline environment: The presence of sodium hydroxide and sodium sulfide creates a highly alkaline environment that breaks down the lignin and separates it from the cellulose fibers.

Efficient lignin removal: The Kraft process achieves a high degree of lignin removal, resulting in strong and high-quality pulp.

Soda Pulping Process:

The soda pulping process, also known as the alkaline pulping process, utilizes a solution of sodium hydroxide (NaOH) or other alkaline chemicals to extract lignin from wood fibers.

Compared to the Kraft process, the soda process operates at lower temperatures and pressures.

Key features of the soda pulping process include:

Moderate cooking temperature: The cooking temperature in the soda process ranges from 140 to 170°C, which is lower than the Kraft process.

Less severe cooking conditions: The soda process requires milder conditions compared to the Kraft process, resulting in less fiber degradation.

Lower lignin removal efficiency: The soda process removes lignin to a lesser extent than the Kraft process, resulting in pulp with slightly higher lignin content.

Organosolv Pulping Process:

The organosolv pulping process is a relatively newer method that combines the use of organic solvents and an alkaline solution to remove lignin from lignocellulosic materials. This process offers some advantages in terms of environmental impact and product quality.

Key characteristics of the organosolv pulping process include:

Use of organic solvents: Organic solvents, such as ethanol or methanol, are employed along with an alkaline solution to dissolve lignin and extract it from the fibers.

Lower cooking temperature: The organosolv process operates at lower temperatures, typically around 100 to 180°C, depending on the specific conditions and solvents used.

Selective lignin removal: The organosolv process can selectively remove lignin while preserving the cellulose and hemicellulose components, resulting in high-quality pulp with enhanced cellulose content.

Potential for lignin recovery: The use of organic solvents allows for the possibility of recovering and utilizing lignin as a valuable byproduct.

The reasons why we chose the Kraft process:

1. High lignin removal: The Kraft process is known for its efficient lignin removal capability. It breaks down lignin effectively, resulting in pulp with low lignin content. This leads to the production of strong and high-quality paper.

2. Wide range of raw materials: The Kraft process can be used with a variety of wood species, including both hardwoods and softwoods. This flexibility in raw material selection makes it suitable

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for different geographical regions and ensures a consistent supply of pulp.

3. Production of strong pulp: The Kraft process produces pulp with excellent strength properties, making it suitable for various paper grades, including packaging materials and paperboard. The resulting pulp has goodtear resistance and tensile strength.

4. Recovery of chemicals: The chemicals used in the Kraft process, such as sodium hydroxide and sodium sulfide, can be recovered and reused through chemical recovery systems. This reduces chemical consumption, lowers operational costs, and minimizes environmental impact.

5. Energy generation: The byproduct of the Kraft process, known as black liquor, can be used to generate energy through the recovery boiler. This process produces steam and electricity, which can be utilized within the pulp mill or sold to the grid, improving energy efficiency and reducing dependenceon external energy sources.

Mechanical pulping methods, such as stone groundwood (SGW) and refiner mechanical pulping (RMP), are techniques used to produce pulp by mechanically separating the fibers from wood. Here's an explanation of these two methods:

1) *Stone Groundwood (SGW):*

Stone groundwood is a mechanical pulping method that has been used for many years. In this process, logs or wood chips are fed into a grinder where they are ground against a rotating stone or abrasive surface. The grinding action mechanically separates the wood fibers from each other, producing a pulp mixture that contains both fibers and other wood components like lignin and extractives.

The advantages of stone groundwood pulping include high yield and relatively low energy consumption compared to chemical pulping methods. However, the resulting pulp is often darker in color and has lower strength properties compared to chemically pulped fibers. Due to the presence of lignin and other impurities, stone groundwood pulp is primarily used in the production of newsprint, packaging materials, and other low-grade paper products.

2) *Refiner Mechanical Pulping (RMP):*

Refiner mechanical pulping, also known as thermomechanical pulping (TMP), is a more modern mechanical pulping method that involves the use of refining equipment. Wood chips are steamed under pressure to soften the lignin, making it easier to separate the fibers. The softened chips are then mechanically treated in refiners, which consist of rotating discs or refining plates. The shearing action of the refiner plates separates the fibers, creating a fine pulp.

Refiner mechanical pulping offers several advantages, including higher strength properties and brighter pulp compared to stone groundwood pulp. It has a higher yield and energy efficiency compared to chemical pulping processes. Theresulting pulp is used for a variety of paper products, includingprinting and writing papers, tissue papers, and paperboard.

Characterization of peanut shell pulp involves the analysis of various properties, including fiber morphology and physical characteristics. Here are some aspects that can be considered during the characterization process:

1) Fiber Morphology:

Fiber Length: The length of the fibers in peanut shell pulp can be measured using microscopy techniques, such as optical or scanning electron microscopy. Fiber length is an important parameter that affects paper properties like strength and drainage.

Fiber Width: The width of the fibers can also be determined using microscopy. It provides insights into the size distributionof fibers in the pulp.

Fiber Shape: The shape of the fibers, such as cylindrical or irregular, can be observed and analyzed. Fiber shape influencesthe bonding ability and paper formation.

Fiber Wall Thickness: The thickness of the fiber walls can be measured to evaluate the mechanical strength of the fibers.

2). Physical Properties:

Fiber Yield: The amount of pulp obtained from peanut shells can be determined by calculating the percentage of pulp obtained from the initial weight of the raw material

Bulk Density: The bulk density of the pulp refers to its weight per unit volume and is an important factor in papermaking processes.

Water Absorption: The water absorption capacity of the pulp can be evaluated to understand its ability to retain moisture andinteract with water during paper production.

Porosity: The porosity of the pulp indicates the presence of void spaces or pores within the fibers, which affects the drainage and drying characteristics of the pulp.

Tensile Strength: The tensile strength of the paper made from peanut shell pulp can be measured to assess its resistance to breaking or tearing.

Bursting Strength: The bursting strength measures the ability of the paper to withstand pressure without bursting and can be determined for papers made from peanut shell pulp.

III. EXPERIMENT AND RESULT

The experimental procedure for the production of pulp from peanut shells involves several steps.

Preparation of Raw Material:

1. Take 20g of peanut shells and wash them thoroughly with distilled water to remove any dust or soil particles.
2. Crush the shells and size them using a mesh sieve with a size range of 230 to 270 (53 microns to 63 microns).
3. Dry the peanut shells at 80°C for approximately 30 minutes to remove moisture content.
4. Kraft's Process:

Prepare the cooking liquor by weighing the required chemicals ($NaOH$, Na_2SO_4, and Na_2CO_3) in the correct proportions according to the Kraft's process.

The composition of the solids in the cooking liquor is as follows: $NaOH$ (58.6%), Na_2SO_4 (27.1%), Na_2CO_3 (14.3%).

Heat the cooking liquor to about 90°C and maintain the temperature for 4 hours and 30 minutes while continuously stirring.

Since the cooking liquor is weaker compared to the Kraft's process, extend the heating time for an additional hour to enhance the effectiveness of the heat in breaking down lignin molecules.

The total weight of the three chemicals required for a 1000 ml solution of cooking liquor can be calculated based on their percentages. In this case, the weights are: $NaOH$ = 73.25 grams, Na_2SO_4 = 33.875 grams, Na_2CO_3 = 17.875 grams.

After digestion, the resulting mixture forms brown stock (containing cellulose and small amounts of lignin) and black liquor (containing dissolved lignin and cooking chemicals).

Filter the mixture using filter paper to separate the black liquor waste from the brown stock.

Repeat the filtration process and wash the brown stock severaltimes with 1000 ml of water to reduce the lignin content.

The final product obtained after filtration should have minimal lignin traces.

1. Bleaching:

Dissolve the washed pulp in 100 ml of water.

Add 100 ml of sodium hypochlorite or hydrogen peroxide in a 1:1 ratio to the dissolved pulp to remove the brown color and obtain white paper grade pulp.

Bleaching helps to further reduce lignin content and achievethe desired color for the pulp.

2. Filtration:

Perform filtration to determine the yield of the process.

Filter the pulp to remove any remaining water content after the bleaching process.

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Process:

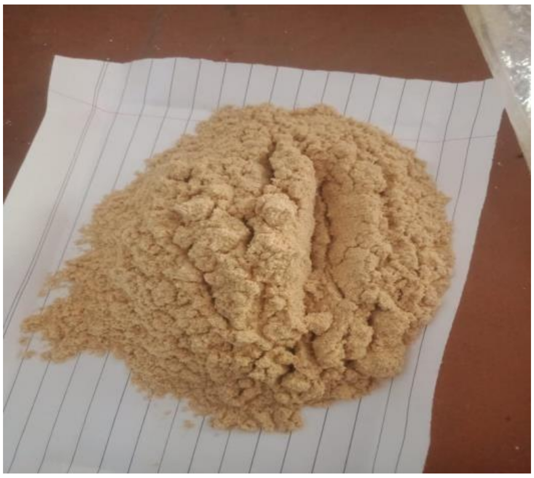

Fig.3 Peanut shell husk of 20gms weighted on (weighing balance).

Fig.4 Kraft's Process

Chemicals *[NaOH, Na_2CO_3 & Na_2SO_4] (magnetic stirrer)*

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Fig.5 Continuously stirred at 90°C for 4hrs

Fig.6 Removal of lignin

Fig.7 Cellulose and lignin separation

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Fig.8 ***Bleaching of Pulp***
[Hydrogen Peroxide]

Fig.9 Paper

IV. CONCLUSION

We have bought peanut shells from a local market at very low price which they consider as a waste and we used it as our rawmaterial after that we have done some chemical processes in our lab. As a result we obtain 8.875 grams of pulp from 20 grams of peanut shells. The pulp was then taken to the regional paper manufacturing company where we get a desired product as a paper. Further research and development should be conducted to explore the full potential of peanut shells as a raw material for pulp production. The high percentage of cellulosic fibers obtained from peanut shells indicates that they can be a valuable alternative to traditional wood sources.

Using peanut shells as a raw material for pulp production offers several advantages. Firstly, it provides an alternative to the over-reliance on wood, which contributes to deforestation and

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environmental degradation. By utilizing agricultural waste such as peanut shells, we can reduce the pressure on forests and promote sustainable practices.

Secondly, peanut shells are a waste product that is typically discarded or used for low-value applications. By converting them into pulp for paper production, we can add value to this waste material and contribute to a more circular economy.

Moreover, peanut shells have properties similar to hardwood and bamboo, which are commonly used for pulp production. This means that peanut shells can potentially offer comparable quality and performance in paper manufacturing processes.

Paper production from waste materials aligns with several Sustainable Development Goals (SDGs) by promoting sustainable practices, responsible consumption and production, and environmental conservation. Here are the SDGs that are particularly relevant to paper production from waste materials:

SDG 12: Responsible Consumption and Production - This goal aims to ensure sustainable consumption and production patterns. Producing paper from waste materials reduces the need for virgin resources and minimizes waste generation, contributing to more sustainable consumption and production practices.

SDG 13: Climate Action - Paper production from waste materials can help mitigate climate change. By reducing reliance on traditional wood-based pulp, which requires tree harvesting, it helps preserve forests that act as carbon sinks. Additionally, recycling waste materials into paper reduces energy consumption and greenhouse gas emissions associated with traditional paper production.
SDG 14: Life Below Water - Paper production from waste materials can indirectly support this goal by reducing deforestation, which can have negative impacts on marine ecosystems. Preserving forests helps maintain water quality, protect biodiversity, and support the overall health of marine habitats.

SDG 15: Life on Land - Preserving forests by using waste materials for paper production supports this goal. It helps protect terrestrial ecosystems, preserve biodiversity, and maintain the ecological balance of land-based habitats.

SDG 9: Industry, Innovation, and Infrastructure - Paper production from waste materials promotes innovation in the paper industry. It encourages the development of new technologies and processes for utilizing waste materials, improving resource efficiency, and reducing environmental impacts.

SDG 17: Partnerships for the Goals - Collaborative efforts between governments, businesses, and communities are crucial for promoting sustainable paper production from waste materials. Partnerships can help drive innovation, knowledge sharing, and the adoption of best practices in the industry.

By aligning paper production with these SDGs, we can contribute to sustainable development, environmental protection, and the transition towards a more circular economy.

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