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DEPARTMENT OF NATURAL RESOURCES

EXLORING THE EFFECTIVENESS OF MAIZE HUSKS AS AN ALTERNATIVE TO PAPER PRODUCTION

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DECLARATION

I, Tariroyashe Bunu, hereby declare that I have read and understood the University's regulations regarding academic integrity and plagiarism. I affirm that this dissertation is my original work and has not been submitted elsewhere for academic credit.

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DEDICATION

I dedicate this study to my family, as they are the main focus of this study endeavor.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my supervisor, Mr. Kundhlande for his unwavering support and guidance throughout my entire study. I would also like to thank my family for supporting me and for being inspirational.

Above all, I give thanks to the Almighty God for giving me wisdom and insight throughout my studies.

ABSTRACT

The increasing demand for paper has prompted a need for sustainable and eco-friendly alternatives to traditional paper production. This study aimed to investigate the efficacy of maize (*Zea mays*), husks as a viable alternative to conventional wood-based paper production. The study was conducted from January 2024 to May 2024, at Bindura University of Science Education, Astra campus laboratories. The maize husks that were used for this research were randomly collected from the local farmers' fields in Bindura. After collection, the maize husks were processed to create the maize husks paper samples. The paper samples were then evaluated for their functionality and physical properties including fold endurance, ink absorbance, opacity and transparency. The findings of the tests were analyzed using T. Test, a tool found in the Statistical Package for Social Sciences application, version 20 of 2011. From the results that were obtained, the maize husks paper had a low fold endurance, a high ink absorbance, a slightly low but good opacity, and a slightly low but good transparency. These findings proved that the paper is a viable alternative for paper production, and can be used in various applications which includes printing. However, the results also proved that there is need to introduce treatments and coatings to the maize husks paper production in order to increase its durability and efficiency.

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CHAPTER 1: INTRODUCTION

1.1. BACKGROUND TO THE STUDY

Paper is one of the most essential commodities in our day to day lives that is used in schools, offices, companies, just to mention a few. As the world population keeps expanding, the endless need and demand for paper is also increasing. According to (Statista 2023), 417 million tons of paper were consumed in the year 2022, worldwide, and it is anticipated that the consumption will increase during the next ten years to 476 million tons.

Wood pulp paper production has a negative environmental impact over its whole life cycle. The sector is one of the largest industries that struggles to maintain the balance between production and sustainability. The industry contributes significantly to deforestation, as paper production is a complex process that requires the cutting down of trees for pulp, (Jons 2017). According to the world counts, it is estimated that 42% of the world's wood harvest is used to make paper. In order to achieve sustainability as well as meeting the demand for paper, there is need to come up with other alternatives for paper production which are environmental friendly and sustainable. In keeping with this demand, agricultural waste such as maize husks can be used to make paper.

Maize husks are the green leaves that are found on the outside of the maize cob. They are usually peeled off and discarded as manure or burnt which is not beneficial for the crop and results in resource waste and pollution. The husks have natural fibers which contain lignin, cellulose and hemicellulose, (Suseno, et al, 2021). These properties make the maize husks suitable for paper production.

The world documentation of maize husk production is not as comprehensive as that of maize production. Nonetheless, it is well known that maize is grown all over the world and that it produces more grain annually than other grain crops. Also, maize is the second largest crop that is grown in the world, (Food and Agriculture Organization, 2019). This implies that a sizable quantity of maize husks are produced as a byproduct of this extensive maize production.

The aim of this research project is to assess the effectiveness of maize husks as an alternative to paper production. This project involved the production of sample maize husks papers, which were

then tested for different properties such as fold endurance, ink absorbance, opacity and transparency.

1.2. PROBLEM STATEMENT

Paper being a versatile and multipurpose material that is used around the world, it has led to the destruction of forests, as most papers employ tree fibers as their main component, and as a result, trees are cut down on a bigger scale. Maize husks are considered as postharvest waste in maize production, which have no particular use. In most cases, maize husks are either burned, or used as manure after they are separated from the maize cob. In addition, there is no specific evidence that anyone has tried to test the efficacy of maize husks as an alternative to paper production, in Zimbabwe.

1.3. JUSTIFICATION

The use of maize husks as a raw material for paper production can alleviate the strain on forest resources and conventional paper sources, as the husks are widely available. The production of paper using maize husks can also promote the transformation of agricultural waste into a useful resource. Since the aim of this research is to assess the effectiveness of maize husks as a substitute for paper production, extensive testing and analysis will be done to make sure that the paper made from husks satisfies industrial standards and is accepted in a variety of applications.

1.4. AIM

The aim of this study is to evaluate the efficacy of maize husks as an alternative for paper production.

1.5. OBJECTIVES

1.5.1. To test the quality and functionality of the paper made from maize husks, in terms of fold endurance and ink absorbance and comparing them with industrial standards for traditional wood pulp paper

1.5.2. To assess the physical properties of the paper made from maize husks, in terms of paper opacity and transparency, comparing them with industrial standards for traditional wood pulp paper

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1.6. HYPOTHESES

1.6.2. Hypothesis 1: There is no significant difference in the fold endurance and ink absorbance between the paper made from maize husks and the industrial standards for traditional wood pulp paper.

1.6.1. Hypothesis 2: There is no significant difference in the physical properties, that is, opacity and transparency, between the paper made from maize husks and the physical industrial standards for traditional wood pulp paper.

CHAPTER 2: LITERATURE REVIEW

2.1. ENVIRONMENTAL IMPACTS OF MAIZE HUSKS PAPER PRODUCTION

The potential environmental benefits of using maize husks have also been explored by Cheng, Wang, and Liu, (2020). They conducted a study on the feasibility of using maize husks as a raw material for the paper industry in China. The study highlighted the potential of maize cultivation for paper production to contribute to carbon sequestration and reduce the demand for wood pulp, thereby mitigating deforestation and promoting sustainable agricultural practices.

The incorporation of maize husks in paper production presents an opportunity to mitigate greenhouse gas emissions. According to Ghatak, et al. (2020), the utilization of agricultural waste such as maize husks not only diverts organic waste from landfills but also reduces the release of methane, a potent greenhouse gas, through anaerobic decomposition. This process aligns with the principles of sustainable waste management and contributes to climate change mitigation efforts.

Furthermore, the utilization of maize husks for paper production can reduce agricultural waste and provide an additional source of income for maize farmers. The United Nations Food and Agriculture Organization, (FAO, 2019), emphasized the potential benefits of integrating maize husk utilization into agricultural practices.

Johnson et al, (2018), conducted a study in which they used a thorough life cycle assessment (LCA) to investigate the environmental effects of producing paper from maize husks as a raw material. These researchers evaluated husk collection, pulping, paper manufacture, waste management, and other steps of the paper production process. The Life Cycle Assessment (LCA) takes into account many environmental variables, including greenhouse gas emissions, energy consumption, water usage, and land occupation. In comparison to typical wood-based paper production, the study found that employing maize husks for paper production can minimize environmental impacts.

In comparison to other widely used raw materials like wood pulp and recycled paper, the environmental performance of maize husk pulp for paper manufacture was examined in a study that was conducted by Martinez, et al, (2017). The study assessed metrics like energy use, water usage, and carbon footprint. According to the research, maize husk pulp is a more

environmentally responsible option for creating paper because it has fewer negative effects on the environment, especially when it comes to water use and carbon emissions.

2.2. ECONOMIC VIABILITY OF MAIZE HUSKS PAPER PRODUCTION

Maize husks are an inexpensive and readily available raw material, and their use can create economic opportunities for farmers, rural communities, and industries involved in their production and processing, (Adedeji, et al. 2020). The economic viability of maize husks paper is a significant advantage, as it offers lower raw material costs, reduced energy and water costs and increased profit margins as compared to traditional wood pulp paper production.

2.3. MAIZE HUSKS AS A RAW MATERIAL FOR PAPER PRODUCTION

Maize, a staple crop in many parts of the world, leaves behind large amounts of byproducts including maize husks. Normally considered to have no value, maize husks have garnered attention as a potential raw material for paper production due to their fibrous composition. A study that was conducted by Smith et al., (2018), investigated the suitability of maize husks for paper production. The researchers revealed that maize husks contain essential components for the papermaking process, including cellulose, hemicellulose and lignin in their fibers. The percentage of these components in fiber varies with the age of the husk and the fiber extraction method.

Additionally, a study that was conducted by Fagbemigun, et al. (2014), which studied the fiber morphology of maize husks indicated that maize husks is a lingo-cellulosic material, which has short fibers with an average lignin content less than 20%. The low lignin content helps in reducing the amount of chemicals and energy needed for pulping.

In addition to paper production, maize husks have been investigated for their potential to produce biopolymers and nanomaterials. Maize husks have the potential to be used as a reinforcing agent in bio plastics and other industrial materials, (Ghatak et al 2020). Moreover, the versatility of maize husks extends to the production of particleboards, demonstrating their potential as a sustainable resource that can be reused as a raw material for various industries, (Makumba, 2020).

CHAPTER 3: METHODOLOGY

3.1. DESCRIPTION OF THE STUDY AREA

The study was carried out at the Bindura University of Science Education, Astra Campus laboratories. The University is located in Bindura, which is found in Mashonaland Central in Zimbabwe.

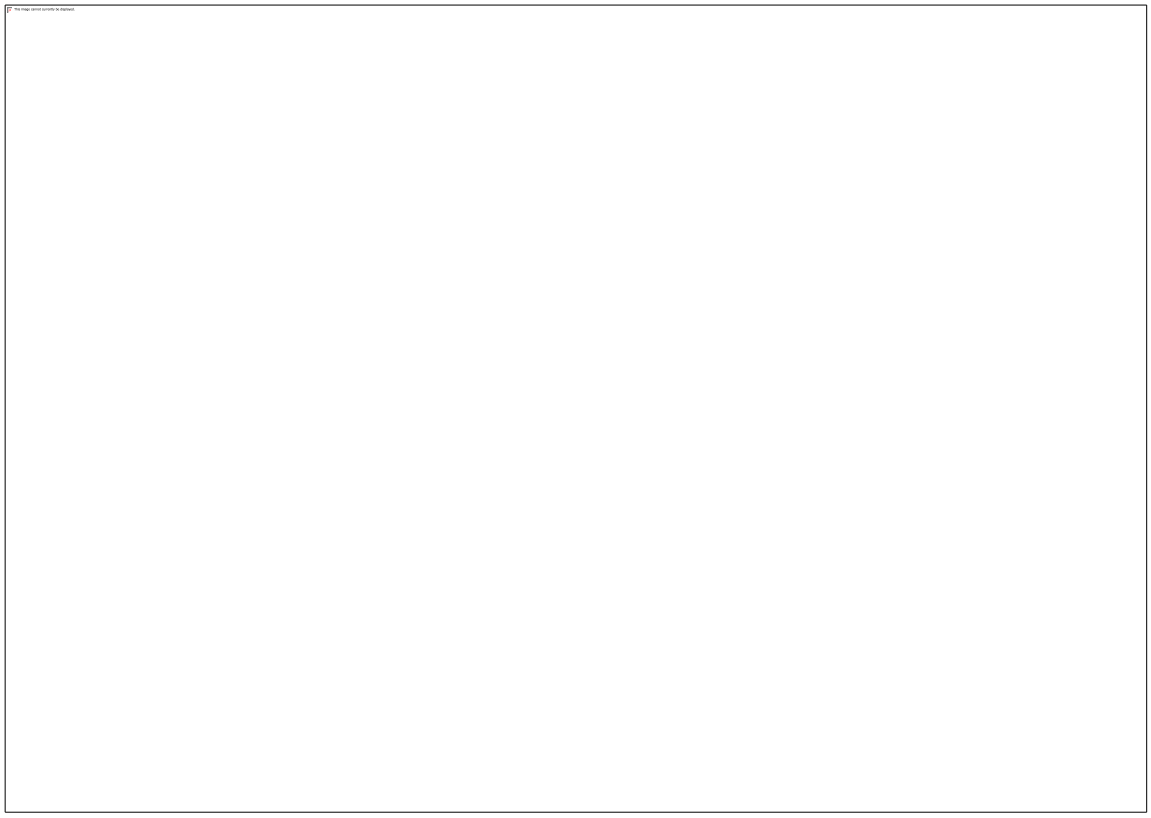

Figure 3.1. A map of Bindura showing the location of Astra Campus.

3.2. RESEARCH DESIGN

This study employed a quantitative research approach, utilizing methods of data collection such as graphs and figures to convey the results. The primary components of the study, which are the maize husks, were acquired from the farmers' fields in Bindura, Zimbabwe. The raw materials underwent a process of physical cleaning to eliminate debris, dust and extraneous objects.

3.3. SELECTION AND PREPARATION OF MAIZE HUSKS

Maize husks were collected from the local farmers' fields in sufficient quantities. The husks were randomly selected, ensuring they are free from contamination and damage. The collected maize husks were cleaned thoroughly with water to remove any dirt before proceeding to air drying. The most common method for drying maize husks is air drying. The maize husks were laid in a single layer on a clean, flat surface in a well-ventilated area, avoiding direct exposure to sunlight, as this can cause the husks to become brittle. The husks were periodically turned to ensure even drying. This helps prevent moisture buildup and reduce the risk of mold or mildew formation. The maize husks were properly dried before use because excess moisture can lead to issues such as mold growth or difficulties in the pulping process.

After the air drying process, the maize husks were cut into smaller pieces using a knife and a chopping board, (fig 3.2.1). After the cutting, the husks were then weighed and boiled.

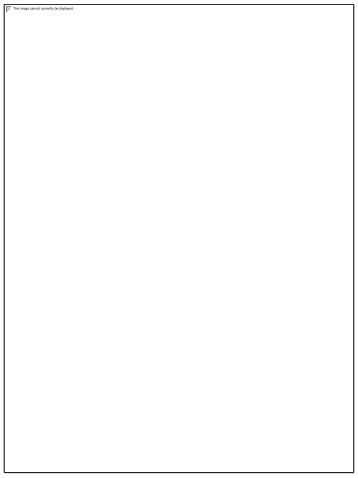

Plate 3.1. Maize husks after they were cut into smaller pieces.

3.4. PULPING PROCESS

For two hours, every 100 grams of maize husks were cooked in two liters of water with five grams of bicarbonate of soda at 80°C. When boiling maize husks for papermaking, bicarbonate of soda was added to change the pH of the mixture. Known by another name, baking soda, bicarbonate of soda is an alkaline substance that has the ability to change the boiling solution's acidity. This pH change could have an effect on how the components in the maize husks break down, which could

help with the fiber separation or other desired chemical processes that happen during the boiling process.

After boiling the maize husks for the specified duration, they were inspected to see if they were cooked thoroughly. This involves softening the husks to a point where they could be easily blended into a pulp suitable for paper production. Once the husks were thoroughly cooked, they were blended using a blender, to break down the fibers and create a pulp. The excess water from the pulp was removed using a sieve.

3.5. DRYING

After the pulp was ready, it was spread uniformly in molding trays, (fig 3.2.3), and placed into the air drier, where hot air was used to dry it under controlled conditions, in this case, the pulp was dried at 40°C 24 hours. While preserving the pulp's integrity, the air dryer creates an atmosphere that is ideal for effective moisture removal.

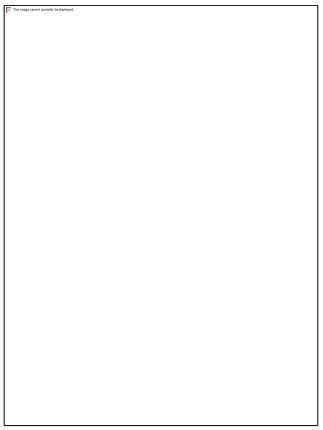

Plate 3.2. Picture of blended maize husks pulp ready for drying.

The utilization of warm air by the air drier makes it easier to extract moisture from the pulp of maize husks. The moisture in the pulp can be drawn from its surface by evaporating due to the heated air's promotion of this process.

Several testing processes were then applied to the paper once it had completely dried.

3.6. PAPER QUALITY TESTING

Tests were conducted on the manufactured paper to determine its strength (fold endurance), ink absorbance, opacity and transparency.

3.6.1. FOLD ENDURANCE

The paper was first put through a fold endurance test. This indicates how many folds the paper can sustain before breaking. Three maize husks paper samples were cut into rectangular shapes of equal size. Each sample was folded at a 180 degree angle along the longer side, ensuring that the fold is neat and precise. The paper was unfolded completely, to observe if there are any signs of cracks, tears or surface deterioration. The folding process was repeated but this time in the opposite direction (180 degrees) to the previous fold. The paper was again assessed for any damages. The folding continued, alternating the direction for each subsequent fold until the paper shows signs of failure or damage.

The total number of successful folds achieved without any significant damage were recorded for each sample.

3.6.2. INK ABSORBANCE

Three maize husks samples with identical rectangular shapes were tested using the water absorption test. Each sample was taken, and placed on a flat, clean surface. Using a dropper, a controlled amount of water was applied to the paper. The stopwatch was started as soon as the water made contact with the paper. Water was gradually added to the paper until the paper could no longer absorb more water. At this point, the stopwatch was stopped, and the time taken for absorption was recorded.

The diameter of the wet surface was then measured using a ruler. The absorption rate was then determined using the following formula:

Water absorbance rate = Diameter of wet area ÷ Time taken for absorption

3.6.3. OPACITY

Three maize husks paper samples were prepared. A dark surface was placed on a flat, well lit surface, (in this case, a black outer cover found on counter books was used). The first sample was taken and placed on the dark surface. After that, a light source, (in this case, light from a window

was used) was placed behind the sample, ensuring that the light shines through the paper evenly. The opacity of the paper was then determined by assessing if the dark surface is easily distinguishable through the paper or not. The process was repeated for the other 2 samples.

Numerically, the opacity was determined using a scale of 1 to 10, where 1 represented low opacity and 10 represented high opacity.

3.6.4. TRANSPARENCY

Three maize husks paper samples were cut into identical rectangular shapes. The first sample was taken and placed on a lined sheet of paper. The paper was placed facing the light coming through the window, ensuring that the light shined evenly through the paper. The visibility of the grid lines from the underlying sheet of paper through the maize husks paper was observed.

The results were determined using a scale of 1 to 10, where 1 represented high transparency and 10 represented low transparency.

3.7. ETHICAL CONSIDERATIONS

There are several ethical considerations that need to be taken into account when conducting research on the production of paper from maize husks. Firstly, it is important to ensure that the research is conducted in an ethical and responsible manner. This means ensuring that the paper production process does not cause any harm to the environment, and that any waste products from the process are disposed of properly, (Majid, 2011). Additionally, it is important to consider the impact of the research on the communities that are involved in the production of maize husks paper. This includes ensuring that the paper production process does not have a negative impact on the livelihoods of these communities.

3.8. METHODS OF DATA ANALYSIS

The data were analyzed using a statistical analysis tool, T. Test to compare the differences between the means of the maize husks test results against that of traditional wood pulp paper. This was done using a Statistical Package Software for Social Sciences (SPSS version 20 of 2011), and the results were presented in tables and graphs. The study used a significance level of 5%, which means that any differences between the data that were less than 5% were considered to be insignificant. This is an important part of research, as it allows for the comparison of results and

helps to build a body of knowledge on the topic. The obtained results were compared with the industrial standards for traditional wood pulp paper.

CHAPTER 4: RESULTS

4.1. FOLD ENDURANCE

With a mean of 9.33%, the fold endurance of the maize husks paper samples that were tested proved to be significantly lower than the industrial standard fold endurance of traditional wood pulp paper which is 25%, with a mean difference of 15, 667%, (Fig 4.1).

Fig 4.1. Difference between the mean fold endurance of the maize husks samples and the industrial standard fold endurance for wood based paper.

4.2. INK ABSORBANCE

The mean ink absorbance of the samples that were tested was 18%, indicating that the maize husks paper has a slighlty high ability to absorb ink as compared to the industrial standard ink absorbance for traditional wood pulp paper which is 15%, with a mean difference of 3%, (Fig 4.2).

Fig 4.2. Difference between the mean ink absorbance of the maize husks paper samples and the industrial standard ink absorbance for traditional wood pulp paper

4.3. OPACITY

The mean opacity of the maize husks paper samples was 94%, slightly lower than the industrial standard opacity of traditional wood pulp paper of 98%, with a mean difference of 4%, (fig 4.3).

Fig 4.3. Difference between the mean opacity of the maize husks paper samples and the industrial standard opacity for traditional wood pulp paper

4.4. TRANSPARENCY

With a mean of 13.33%, the transparency of the maize husks paper samples that were tested proved to be slightly lower than the transparency of traditional wood pulp paper which is 15%, with a mean difference of 1.66%, (fig 4.4).

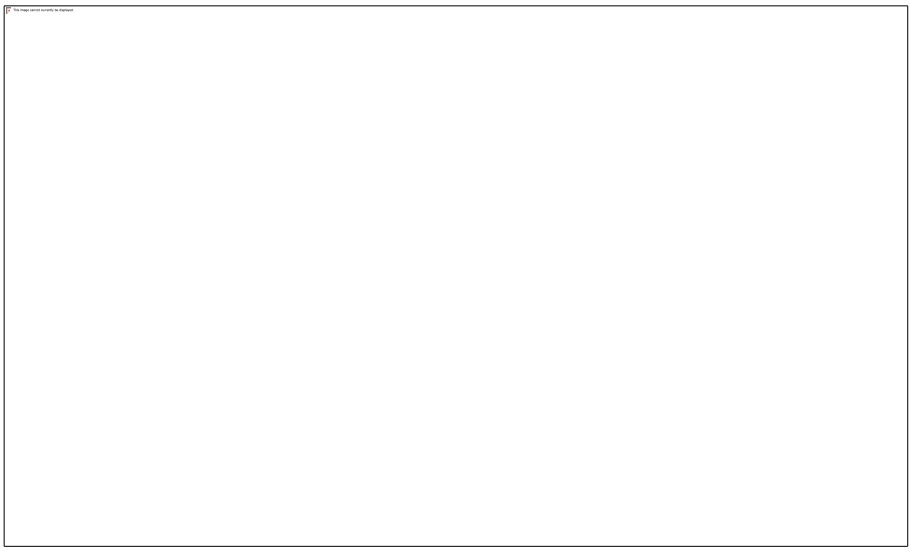

Fig 4.4. Difference between the mean transparency of the maize husks paper samples and the industrial standard transparency for traditional wood pulp paper

CHAPTER 5: DISCUSSION

5.1. FOLD ENDURANCE

Fold endurance is one of the important parameters that helps to measure the effectiveness of paper. It determines a paper's strength and durability. Based on the tests results, (fig 4.1), the maize husks paper proved to have a low fold endurance, as compared to the industrial standard traditional wood pulp paper . This can be supported by a study by Ekhuemelo, (2013), which also showed that maize husks paper has a low fold endurance compared to traditional wood pulp paper. Nonetheless, the desired fold endurance for paper depends on the intended use and application of the paper. The fold endurance results obtained from this study indicates that the paper may not be suitable for applications where repeated folding is necessary, such as brochures, and pop up cards. However the maize husks paper proved to be a viable alternative in applications where folding is less crucial, such as flyers.

The lower fold endurance might have been influenced by the alteration of the maize husks fibers during the production process such as the pulping process. The pulping process involves the breaking down of lignocellulose fibers, which can further lead to the damage of the fibers, (Jahan 2020). Additionally, the fiber length and thickness of maize husks might have led to a lower fold endurance, (Klash et al 2010). The fibers of maize husks which are shorter and thicker might not have been able to withstand the stress and strain of repeated folding and bending, resulting in a lower fold endurance.

5.2. INK ABSORBANCE

Ink absorbance is another crucial factor in determining the efficacy of paper, in terms of printability and vividness of colors on the paper, (Wang, 2020). Drawing judgment from the test results performed on the maize husk paper samples, (fig 4, 2), the paper had good ink absorbance capabilities. This implies that if a more subdued or muted color appearance is needed, the paper can be used for both writing and printing. The distinctive fiber structure of the maize husks paper, characterized by its high lignin content and porous surface, likely contributed to its enhanced ink absorbance, (Smith et al, 2018).

Additionally, the chemical properties of maize husks paper, such as the presence of hemicellulose, might have contributed to a higher ink absorbance, (Dong et al 2024). Hemicellulose is a type of carbohydrate than can interact with ink to improve the paper's absorption.

5.3. OPACITY

The results in fig 4.3 indicated that the maize husks paper could be a useful substitute for conventional paper, especially in situations where opacity is a desired quality. For example, high opacity paper improves the contrast of printed information, which makes it appropriate for uses in the printing of books, packaging, and other printed materials where readability and aesthetic appeal are crucial. Furthermore, the high opacity paper helps lessen show through and enhance overall print quality in situations where ink coverage is critical, such as labels and packaging, (Alagbe 2019).

The high opacity in maize husks paper might have been caused by a combination of factors, including its high lignin content, thicker fiber walls which absorbs and scatter light, leading to high opacity, (Adedeji et al 2020).

5.4. TRANSPARENCY

In certain applications, the low transparency of maize husk paper can be advantageous for privacy protection. Low transparency guarantees that information included in documents such as business documents that are confidential remain hidden from prying eyes, even when the document is brought up to a light source. This is especially crucial in sectors like finance, healthcare, and law that deal with sensitive data, (Magnan, 2020).

The lower transparency for the maize husks paper might have been caused by its higher light absorption coefficient, which is a measure of how much light is absorbed by the paper surface. Due to the high light absorption coefficient that is attributed by the composition and fiber structure the maize husks paper was able to absorb light hence reduced transparency (Eroglu 2020).

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1. CONCLUSIONS

This study indicated that the paper made from maize husks has several qualities that make it a viable substitute for conventional paper production in the paper and packaging sector. These qualities include desirable fold endurance qualities, high ink absorbance, high opacity and low transparency. A decent degree of strength and durability was indicated by the paper, which is important for a variety of paper-based products. The paper can successfully retain ink, as indicated by the results in Fig 4.2, which makes it appropriate for use in writing and printing. Its high opacity, transparency and advantageous fiber qualities make maize husks an attractive raw material with advantages in printability, ink coverage, and thermal properties for some paper based goods. These characteristics combined together highlight the potential effectiveness of paper made from maize husks as a sustainable and green substitute for conventional papermaking.

With further development, maize husks paper could become a viable option for various industries, contributing to a more environmentally friendly future. The production of paper from maize husks could also generate income and job opportunities for farmers and rural communities, while reducing waste and environmental impacts associated with traditional paper production. Overall, this study highlighted the potential of maize husks as an effective and sustainable paper production alternative.

6.2. RECOMMENDATIONS

6.2.1. To further enhance the production process and product quality, there is need to improve technologies and innovations, such as biotechnology to boost fiber strength and durability, or introduce treatments and coatings to broaden the maize husks paper's applications.

6.2.2. Additionally, collaborating with designers, manufacturers and brands, can help develop new products and uses for the maize husks paper, for example, eco-friendly packaging, paperboard or textiles, thereby increasing market and creating fresh market opportunities.

6.2.3. Moreover, introducing a certification program that ensures the paper's sustainability, quality and social responsibility can help differentiate the product and foster customer trust.

By implementing the above recommendations, the production of paper from maize husks can maintain sustainable paper production and maximize its positive effects and impacts on the environment and society.

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APPENDICES

APPENDICES 1: FOLD ENDURANCE

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Fold Endurance	3	9.33	1.528	.882

One-Sample Test

	Test Value = 25					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Fold Endurance	-17.764	2	.003	-15.667	-19.46	-11.87

APPENDICES 2: INK ABSORBANCE

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Ink Absorbance	3	18.00	3.606	2.082

One-Sample Test

	Test Value = 15					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Ink Absorbance	1.441	2	.286	3.000	-5.96	11.96

APPENDICES 3: OPACITY

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Opacity	3	94.00	4.583	2.646

One-Sample Test

	Test Value = 98					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Opacity	-1.512	2	.270	-4.000	-15.38	7.38

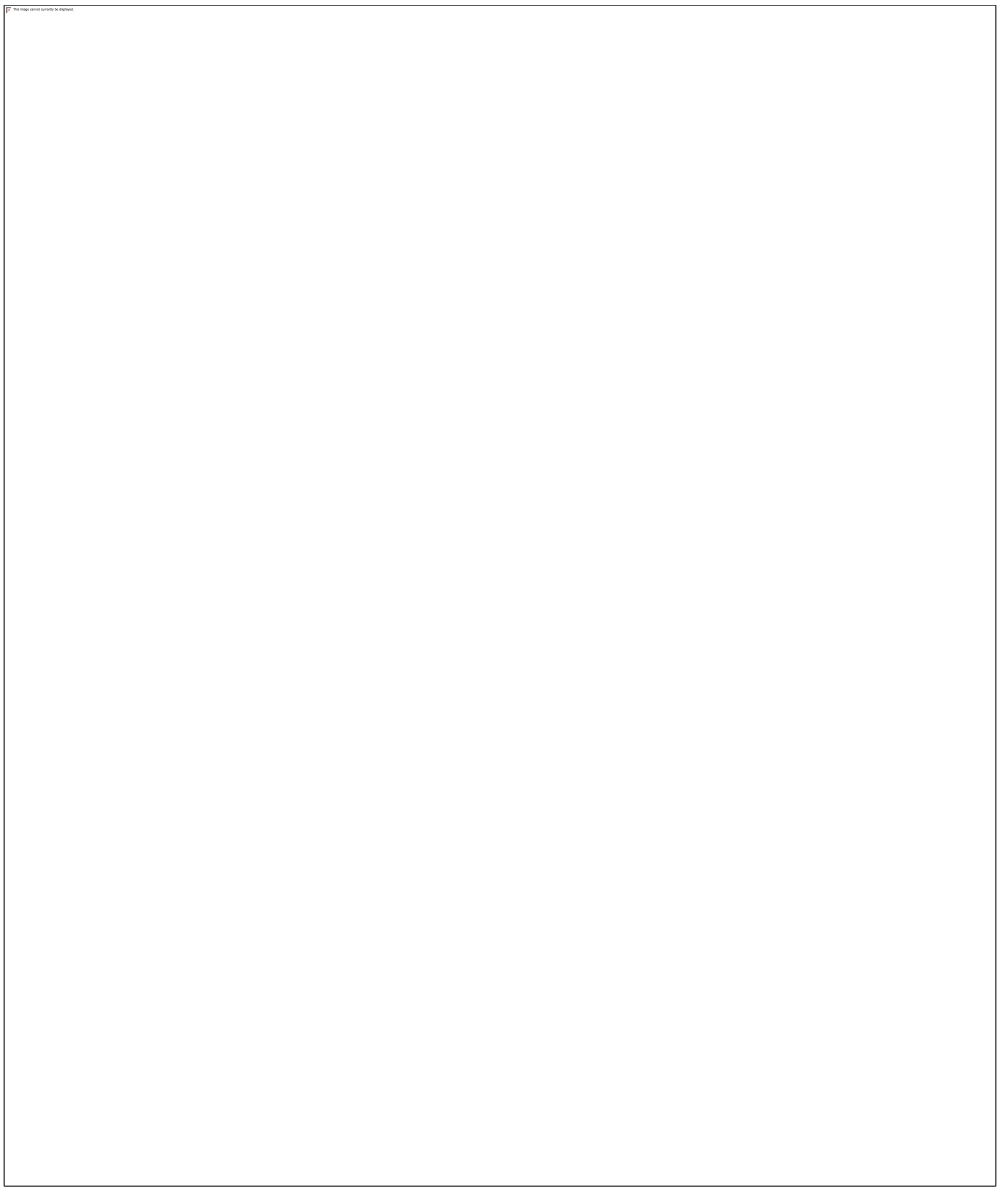
APPENDICES 4: TRANSPARENCY

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Transparency	3	13.33	1.528	.882

One-Sample Test

	Test Value = 15					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Transparency	-1.890	2	.199	-1.667	-5.46	2.13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