A RESEARCH STUDY ON THE PULP PRODUCTION FROM GROUNDNUT SHELLS

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ABSTRACT. The chemical pulping method has demonstrated its effectiveness in removing lignin and obtaining high-quality cellulose fibres from groundnut shells, thereby promoting environmental sustainability and resource efficiency in the pulp and paper industry. However, in the development of pulp from groundnut shells, three variables (types of groundnut shells, chemical pulping methods, and chemical solution consumption) are frequently insufficient for evaluation. Thus, this paper studies the effect of these three variables on pulp yield. Raw and roasted groundnut shells were mixed with a prepared chemical solution (200 ml, 400 ml, and 600 ml) using the kraft and soda chemical pulping methods to break down the lignin and obtain cellulose fibres. The results indicated that when utilising a 200 ml chemical solution, raw groundnut shells achieve the highest pulp yield of 96.2 % using the kraft pulping method, surpassing both roasted groundnut shells and the soda pulping method. Consequently, this analysis offers valuable insights into the optimal conditions for groundnut shell pulp production and potentially aids decision-making among pulp and paper industry players.

KEYWORDS: pulp; groundnut shells; kraft pulping method; soda pulping method

1 INTRODUCTION

Groundnut shells are the residue left when the groundnut seed is removed from the pod and are considered a significant agricultural waste that degrades relatively slowly in the environment (Zheng et al., 2013). Improper disposal methods, such as burning this waste, contribute to environmental degradation. To address this issue, it is necessary to find practical uses for groundnut shells. Duc et al. (2019) reported that groundnut shells have diverse applications, including paper production, bioethanol production, biodiesel production, hydrogen production, heavy metal adsorption, and many others. Ramgopal et al. (2016) have highlighted the suitability of groundnut shell fibre for paper production due to its strong physical characteristics. According to the Statista Research Department (2023), paper consumption is expected to rise further over the next ten years, reaching 476 million metric tonnes by 2032, as shown in Figure 1.

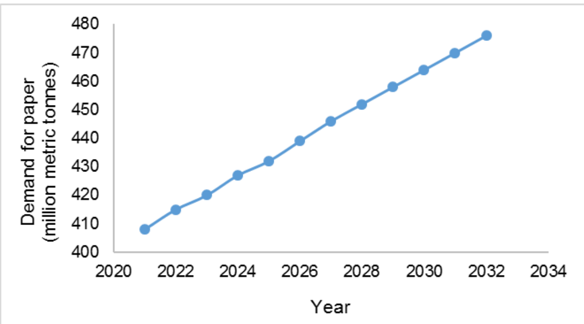

Figure 1: Demand for paper worldwide from 2021 to 2032 (Statista Research Department, 2023)

Groundnut shells could potentially be used as an alternative resource for pulp and paper production (Ramgopal et al., 2016). The possibility exists for groundnut shells to supplement current wood supplies (Musekiwa et al., 2020). As a bio-waste material, groundnut shells hold significant commercial potential, particularly in the pulp and paper industry. However, the main drawback of its usage in large-scale industrial processes is its high lignin concentration, which contributes to its resistance to biodegradation under typical environmental circumstances. Therefore, it is crucial to develop an efficient process for separating lignin from the cellulose fibres in groundnut shells.

Pulping is the common method used to obtain cellulose fibres and remove lignin content, either chemically or mechanically. Although mechanical pulping offers higher yields and lower costs, it is ineffective at removing lignin and results in low-quality pulp (Laftah & Rahman, 2016). Meanwhile, chemical pulping, as stated by Duc et al. (2019), yields higher-quality pulp. Additionally, it also binds the cellulose fibres together without significantly deteriorating them (Ramgopal et al., 2016). Moreover, Das & Houtman (2004) reported that approximately 75% of global wood pulp production is attributed to chemical pulping. Overall, chemical pulping is preferred for producing high-quality papers that require strength and durability, while mechanical pulping is suitable for producing other low-grade paper products where strength is not a primary concern. Therefore, in this study, chemical pulping (the kraft and soda pulping methods) is chosen to remove lignin from groundnut shells. This process involves mixing chemical solutions with groundnut shells and heating them to break down the lignin.

2 LITERATURE REVIEW

The properties of groundnut shells, as shown in Table 1, prove that groundnut shells contain a significant amount of cellulose for pulp production as well as being rich in lignin content. Thus, it is crucial to identify the most effective method for lignin removal and to obtain high-quality cellulose fibres.

Table 1: Groundnut shells properties

Authors (Year)	Properties (wt%)		
	Cellulose	Hemicellulose	Lignin
Ramgopal et al. (2016)	35.7	18.7	30.2
Bano & Negi (2017)	38.31	21.1	27.62
Ganguly et al. (2020)	40.5	14.7	26.4

Although groundnut shells have been studied for their potential in pulp and paper production, there is limited research specifically focused on the development of pulp and paper from groundnut shells. Ramgopal et al. (2016) and Kadre et al. (2018) compared the kraft and soda pulping methods to determine their suitability for pulp production from groundnut shells. The results revealed that the kraft pulping method achieved a pulp yield of 34.7 %, whereas the soda pulping method resulted in a lower yield of 25.5 %. Karthikeyan et al. (2019) reported a pulp yield of 40 % obtained from groundnut shells using the kraft pulping method. Musekiwa et al. (2020) studied the optimal conditions for the chemical treatment process in pulp production, specifically focusing on cooking time and temperature. The finding indicated that a high pulp yield of 64.39 % was achieved when using a lower temperature of 100 ºC and a longer cooking time of 3 hours. In summary, the kraft pulping method was deemed more suitable for producing a higher pulp yield and better paper quality.

Most research conducted on groundnut shell pulp production has primarily focused on the effect of chemical pulping methods, specifically kraft and soda pulping methods, on pulp yield. However, there are incomprehensive assessments that evaluate three key variables, such as types of groundnut shells, chemical pulping methods, and chemical solution consumption. The variation in groundnut shell waste depending on its usage can indeed affect the cellulose content present in the shells. As a further matter, the amount of chemical solution used in the pulping process is indeed an important factor to consider, as it can impact both the pulp yield and the production cost. Thus, this paper investigates the effect of three variables on pulp yield, including the types of groundnut shells (raw and roasted), the chemical pulping methods (kraft and soda), and the varying amounts of a chemical solution (200 ml, 400 ml, and 600 ml), would indeed fill a research gap in the existing literature. This analysis provides an understanding of the key variables involved in groundnut shell pulp production and supports the decision-making process in the pulp and paper industry by identifying the optimal conditions for producing pulp from groundnut shells.

3 METHODOLOGY

The experimental procedure in this study is divided into three main stages, which are the preparation of raw materials, the production of pulp, and the analysis of pulp samples.

3.1 Preparation of raw materials

The main raw materials used are raw and roasted groundnut shells. Firstly, the raw and roasted groundnut shells were separated and cleaned thoroughly with water to eliminate any dust and soil particles. Subsequently, the groundnut shells were dried in the sun and evenly ground.

3.2 Production of pulp

The pulp from groundnut shells was produced using chemical pulping through two different methods, which are the kraft soda pulping methods. In the kraft pulping method, a chemical solution with a concentration of 12.5 w/w% was prepared by mixing three chemicals, which are Sodium carbonate (Na_2CO_3), Sodium hydroxide (NaOH), and Sodium sulphate (Na_2SO_4), with 1 L of distilled water. The chemical solution consisted of 14.3 % Na_2CO_3, 27.1 % Na_2SO_4, and 58.6 % NaOH. On the other hand, the soda pulping method only utilised NaOH and 1 L of distilled water to produce a chemical solution with a concentration of 40 w/w%. The proportions of the chemicals used were based on a previous study by Kadre et al. (2018). Table 2 depicts the amounts of chemicals used to prepare the chemical solution for both methods.

Table 2: Amount of chemicals used in kraft and soda pulping methods

Types of pulping method	Amount of distilled water (L)	Weight of chemicals used (g)			Weight percent of chemical (w/w%)
		NaOH	Na_2CO_3	Na_2SO_4	
Kraft pulping	1	73.25	17.875	33.875	12.5
Soda pulping	1	400	-	-	40

In both the kraft and soda pulping methods, the prepared chemical solution was divided into beakers of 200 ml, 400 ml, and 600 ml. Then, 5 g of groundnut shells were added to each beaker. The mixture was heated at 90°C for approximately 270 minutes while being continuously stirred to break down the lignin bonds. The colour change of the solution to a dark brown indicated the dissolution of lignin. After the heating process, the mixture solution was filtered multiple times using a clean cloth to separate the waste black solution from the pulp. The pulp was then thoroughly rinsed with water to eliminate the remaining lignin. Finally, the pulp was dried in the sun until it was completely dry.

3.3 Analysis of Pulp Samples

First and foremost, the dried pulp was weighed using an electronic weighing scale to identify the pulp yield. Next, the colour of the pulp sample was visually observed. Additionally, Fourier Transform Infrared (FTIR) spectroscopy analysis is used in this research to identify the chemical functional groups present in the cellulose of the produced pulp. The samples were placed on a diamond crystal, and the reflected spectra were recorded. The FTIR spectra were collected within the wavenumber range of 4000 to 400 cm^{-1}.

4 RESULTS AND DISCUSSION

In this section, the pulp yield obtained from two different types of groundnut shells by using two different pulping methods, the colour of the pulp, and the FTIR analysis were discussed.

4.1 Pulp yield

This part discussed the effect of various factors, such as the types of groundnut shells, pulping methods, and chemical solution consumption, on the production of pulp. Table 3 presents the pulp yield obtained from both raw and roasted groundnut shells using the kraft and soda pulping methods.

Table 3: Pulp yield from groundnut shells

Amount of chemical solution (ml)	Pulp yield from raw groundnut shells				Pulp yield from roasted groundnut shells			
	Kraft method		Soda method		Kraft method		Soda method	
	gram	%	gram	%	gram	%	gram	%
200	4.81	96.2	3.75	75.0	2.64	52.8	2.13	42.6
400	3.31	66.2	2.49	49.8	2.96	59.2	2.47	49.4
600	4.36	87.2	3.99	79.8	3.49	69.8	1.95	39.0

According to the data presented in Table 3, the results show that raw groundnut shells achieve a significantly higher pulp yield of 96.2 % compared to roasted groundnut shells, which yielded a maximum of 69.8 %. The difference in pulp yield can be attributed to the potential impact of the roasting process on the structure of the roasted groundnut shells. Raw groundnut shells might have a higher cellulose fibre content or possess a different composition that makes them more suitable for pulp production compared to roasted groundnut shells.

In addition, the results obtained from treating raw groundnut shells with a 200 ml chemical solution reveal that the kraft pulping method yielded a significantly higher pulp percentage of 96.2 % compared to the soda pulping method, which yielded 75.0 %. This difference in pulp yield can be attributed to the utilisation of a strong chemical solution (Na_2CO_3, Na_2SO_4, and NaOH) in the kraft pulping method, which effectively breaks down the lignin bonds (Ramgopal et al., 2016). Meanwhile, the soda pulping method employing a weaker chemical solution (NaOH) is unable to effectively disrupt the lignin bonds. These findings align with previous studies conducted by Ramgopal et al. (2016) and Kadre et al. (2018). A similar trend was observed for different amounts of chemical solution, such as 400 ml and 600 ml, and this pattern remained consistent for the pulp obtained from roasted groundnut shells as well.

Furthermore, with respect to the consumption of chemical solutions, the results indicate that each method has an optimal amount of chemical solution that maximises pulp production. In the case of the kraft pulping method, the highest yield of pulp from raw groundnut shells (96.2 %) was obtained with the lowest amount of chemical solution (Na_2CO_3, Na_2SO_4, and NaOH), specifically 200 ml. However, to achieve a significant pulp yield from roasted groundnut shells (69.8 %), the highest amount of chemical solution (Na_2CO_3, Na_2SO_4, and NaOH), specifically 600 ml, was necessary. This might be due to the potential damage inflicted on the cellulose fibres in roasted groundnut shells during the roasting process, which could diminish their ability to bind together with a lower quantity of chemical solution.

Meanwhile, in the case of the soda pulping method, due to the relatively weak nature of the soda chemical solution (NaOH), 600 ml, which is the highest amount, was needed to attain a high pulp yield from raw groundnut shells (79.8 %). Nevertheless, to achieve a substantial pulp yield from roasted groundnut shells (49.4 %), a lesser amount of chemical solution (NaOH), specifically 400 ml, was sufficient. Further increasing the amount of chemical solution beyond this point might deteriorate the cellulose fibres. Hence, this indicates that the process can be optimised to reduce chemical solution consumption while maintaining desirable pulp production levels. In summary, the kraft pulping method employing a 200 ml chemical solution resulted in the highest pulp yield of 96.2 % from raw groundnut shells. Conversely, the soda pulping method using a 600 ml chemical solution yielded the lowest pulp yield of 39.0 % from roasted groundnut shells.

4.2 Colour of pulp produced

This section focuses on the evaluation of the colour of pulp obtained from both raw and roasted groundnut shells by using the kraft and soda pulping methods, as shown in Figure 2.

Figure 2: The colour of the pulp produced

The results indicate that the pulp derived from raw groundnut shells possesses a lighter colour compared to the pulp obtained from roasted groundnut shells. Additionally, the results demonstrate that pulp produced using the kraft pulping method exhibits a lighter colour in comparison to pulp produced using the soda pulping method. The difference in colour for the kraft and soda pulping methods has also been reported by Ramgopal et al. (2016), and a lighter colour of pulp indicated a lower presence of lignin. Consequently, the results support the notion that using raw groundnut shells and employing the kraft pulping method contribute to the production of pulp with a lower lignin content. This is an important aspect, as lignin can negatively impact the quality and appearance of pulp.

4.3 FTIR analysis

This part discussed the functional groups present in the pulp using FTIR analysis. The analysis was performed on the sample that achieved the highest pulp yield, amounting to 96.2 %, obtained from raw groundnut shells using the kraft pulping method with a 200 ml chemical solution (Na_2CO_3, Na_2SO_4, and NaOH). The results of the FTIR analysis for this sample are depicted in Figure 3, while Table 4 displays the primary chemical functional groups identified through the FTIR analysis.

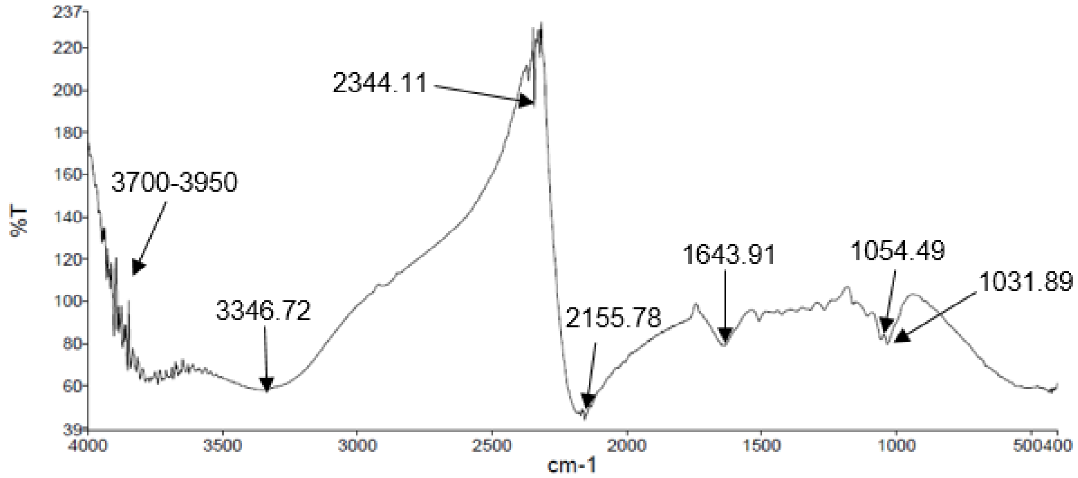

Figure 3: FTIR spectra of pulp sample

Table 4: Summary of the main chemical functional groups of pulp obtained from FTIR analysis

Peak wavenumber (cm^{-1})	Functional group	
3700 - 3950	O-H stretching	Hydroxyl group
3346.72	O-H stretching	Hydroxyl group
2344.11	O=C=O stretching	Carbon dioxide
2155.78	C≡C	Alkyne
1643.91	H-O-H	Adsorbed water
1054.49	C-O stretching	Primary alcohol
1031.89	C-O stretching	Carbonyl

The infrared absorption spectra of the pulp were captured from 4000 to 400 cm^{-1}, as shown in Figure 3. Notably, a significant number of peaks are observed in the range of 3700–3950 cm^{-1}, which corresponds to the O-H stretching of the hydroxyl group. Additionally, the peak observed at 3346.72 cm^{-1} is attributed to the O-H stretching of the hydroxyl group in alpha-cellulose. These findings align with the previous study by Salim et al. (2021), in which the presence of O-H peaks indicates the absence of lignin, providing further evidence of the comprehensive removal of lignin during chemical processing. Next, the peaks observed at 2344.11 cm^{-1} and 2155.78 cm^{-1} correspond to the presence of carbon dioxide and alkyne, respectively. These peaks arise as a result of the removal of lignin throughout the process (Salim et al., 2021). The band at 1643.91 cm^{-1} is associated with adsorbed water. The peaks at 1054.49 cm^{-1} and 1031.89 cm^{-1} correspond to the C-O stretching vibration from the cellulose. The FTIR analysis proves that a 200 ml chemical solution (Na_2CO_3, Na_2SO_4, and NaOH) in the kraft pulping method effectively removes lignin.

5 CONCLUSION

In conclusion, this study successfully demonstrated the production of pulp from both raw and roasted groundnut shells using kraft and soda pulping methods and varying amounts of chemical solution (200 ml, 400 ml, and 600 ml). The findings revealed that the utilisation of raw groundnut shells, the kraft pulping method, and the lowest amount of chemical solution (200 ml) resulted in the highest pulp yield (96.2 %). Furthermore, analysis of colour and FTIR showed that the effective removal of lignin from the pulp was obtained from raw groundnut shells using the kraft pulping method. Overall, this study contributes to the knowledge and understanding of pulp production from groundnut shells and offers practical recommendations for optimising the process. By utilising groundnut shells as a valuable resource for pulp production, this research promotes environmental sustainability and resource efficiency in the paper manufacturing sector. To further improve, future research should explore the possibilities of combining pulp from groundnut shells with other materials, such as recycled paper and wood. Such investigations could lead to the development of innovative and sustainable approaches in the pulp and paper industry.

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