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Comparative assessment of the pulping potentials of soda and mea processes for the development of paper-pulp from sugarcane bagasse

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Abstract

Pulping trials were carried out using MEA and the soda process comparing their pulping potentials. The operating conditions such as the concentration of the cooking liquor (50%, 75%, 100%) for MEA and (10%, 15%, 20%) for NaOH, the maximum cooking temperature (150°C, 160°C, 170°C) and cooking time (60, 90, 120minutes) for both processes were investigated systematically to establish optimal pulping conditions. The agro-biomass used in this investigation is Sugarcane Bagasse viewed as alternative raw material for pulp and paper production. The lignin content of Bagasse (19.5%) was low; indicating that Bagasse should be easier to pulp. The optimum cooking conditions (independent variables) for MEA pulping were 75% MEA concentration, 150°C cooking temperature and 90 minutes cooking time. Excel 2013 was used to analyze the effect of independent variables on yield of bagasse pulp and properties of furnished paper from MEA process in comparison with the Soda process which include tear index, tensile index, burst index and folding endurance with errors less than 15% in all cases. The Kappa number range (12.7-16.9), viscosity (270-870 ml/g) and brightness (62.1-93.2%) of bagasse pulp are appropriate for high-brightness printing and writing papers. The physical properties of furnished paper, tear index (13.4 $mN.m^2/g$), tensile index (71Nm/g), Burst index (4.8 KN/g) and folding endurance (82) recommend the cellulosic pulp from Sugarcane Bagasse obtained from the MEA process for strengthening the virgin fiber in recycled papers and also for developing certain types of printing and packaging papers. Due to the awareness towards the negative impact of kraft mill's effluent to the environment recently, soda pulping started to regain its popularity among the pulp mills especially non-wood based pulp mills. MEA process is more economically attractive given its high pulp yield, despite the significant increase in chemical demand for bleaching. MEA pulping is a good alternative to soda pulping furnishing high pulp yield with less cooking temperature, i.e. 150°C, thereby saving a considerable amount of energy with less odoriferous pollutants and pollution load associated with the soda process.

Keywords: Soda; Monoethanolamine (M.E.A.); Pulp Screen Yield; Kraft; Sugarcane Bagasse; Paper

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1. Introduction

The pulp and paper industry is one of the most polluting industries in the world facing social pressure related to its environmental and sustaining efficiency leading to technological evolutions. The emissions from pulp and paper mills either by air or water gives a serious impact on environmental quality that eventually affects the health of both human and ecosystems. The effluents usually generated from various stages of pulping and bleaching process are often discharged into the downstream. These effluents contains compounds such as resin acids, unsaturated acids, chlorinated phenolic, chlorinated dioxins and furans which are toxic to human bodies and aquatic life. In addition, the major air pollutants include fine and coarse particulates, sulfur dioxide, nitrogen oxides, volatile organic compounds (VOCs) from the black liquor oxidation process and reduced sulfur gases which emits unpleasant odor [1].

kraft pulping is the most dominant pulping process in the world of pulp and paper production and the dominance of this process is anchored upon its versatility to pulp almost any type of wood successfully, but prominent are the emission of some fowl smelling malodorous pollutant. Kraft pulping is always associated with severe environment pollution especially the air pollution. The air pollution from the kraft pulping is a major concern with the emission of sulphur gases into the atmosphere with a rate of 0.3-3 kilograms per metric tonne (kg/t) of air-dried pulp (ADP) (World Bank Group, 1998). The four reduced sulphur gases are hydrogen sulfide, methyl mercaptan, dimethyl sulfide and dimethyl disulfide. Obnoxious gaseous odor are released even from the advanced kraft mills. All the gases have extreme low odor thresholds, which indicated that long term exposure to these gases, the balance of ecosystem and even human health will be seriously interfered [2,3].

Due to environmental concerns, the kraft (dominating pulping) process has to be modified or substituted by a less polluting process. The substituted process must give good pulp yield and quality, yet compatible with the existing kraft process equipment and operations. One of the pulping processes that may be a good alternative to the kraft process is the soda process (Holton, 1977). Soda pulping is the dominant process for annual plants, but it is faced with severe drawbacks. Strongly alkaline cooking liquors dissolve carbohydrates to a great extent with negative impact on pulp yield. Most annual plants have a high content of silica, which is dissolved to a high extent in the strongly alkaline cooking liquor and thus creates serious problems in the evaporators, the recovery boilers and in the causticizing plant. These are the main reasons why soda pulping black liquor handling and recovery of chemicals is still problematic [5, 6 and 7].

Delignification by use of monoethanolamine (MEA) is an innovative, environmentally friendly chemical pulping process that works without the use of sulphur compounds, with a particular benefit of simple MEA recovery by distillation, allowing black liquor combustion to be dispensed and the dissolved lignin recovered. Apart from high selectivity of MEA which results in pulps with high yields, low kappa numbers and acceptable strength properties, the most important advantage of MEA pulping of annual plants is the direct MEA recovery by distillation. Monoethanolamine (MEA) has several advantages when compared to other popular methods such as kraft or sulfite pulping. In particular, the ability to obtain relatively high quality lignin adds value to a process stream otherwise considered as waste. Organic solvents are easily recovered by distillation, leading to less water pollution and elimination of the odor usually associated with Soda and kraft pulping. The objective of this research work was to develop an eco-friendly and energy saving biomaterials and processes that would lead to implementation of sustainable manufacturing strategies.

2. Experimental

2.1. Materials

In this research work, Nigeria-grown Agro-based Fibers (Sugarcane Bagasse) generated during post- harvest treatment of Sugarcane at a plantation in Minna, Niger State, Nigeria were used.

2.2. Production of Pulp from MEA and Soda Processes: Working plan

Figure 1 depicts the working plan. The agro-biomass was converted into brown pulp of two (2) different delignification degrees from two (2) different processes, kappa no. ranging from 12.7 to 16.9 from MEA Process and kappa no. ranging from 13.5 to 22.4 from soda Process. The resulting pulps were fully bleached by the D1-Ep-D2 sequence and characterized for their beatability, drainability and physical-mechanical properties.

2.3. Outline of the Production Process

Figure 1 illustrates the process of making paper from Agro-biomass. The Agro-wastes (sugarcane bagasse) was converted into brown pulp at a delignification degree of 18.2 kappa from MEA Process. The resulting pulps were fully bleached by the D1-Ep-D2 sequence and characterized for their beatability, drainability and physical-mechanical properties.

Figure 1 Steps in Agro-biomass Sugarcane (Bagasse) fractionation and conversion to paper

2.4. Experimental design for the pulping conditions

The pulping experimental design considered the following factors are described in table 1

Table 1 Experimental Design for both Processes

Experimental Conditions	Monoethanolamine (MEA) Process			Soda (NaOH) Process		
	MEA Charge (%)	Maximum Temp. (°C)	Maximum Cooking Duration (minutes)	Soda Charge (%)	Maximum Temp. (°C)	Maximum Cooking Duration (minutes)
Factor 1	50	150	60	10	150	60
Factor 2	75	160	90	15	160	90
Factor 3	100	170	120	20	170	120

The experimental design had 27 treatments (3×3×3) = 27 and 2 replicates

Table 2 Description of both pulping [Monoethanolamine (MEA) and the Soda (NaOH)] processes

Monoethanolamine (MEA) pulping
After a thorough cleaning process, 2kg of air-dry sample was loaded into a 15 L capacity batch reactor (digester) with eight (8) liter cooking liquor at liquor-sample ratio of 4:1. The digester is furnished with an outer electrical heating jacket. The lid of the digester was firmly bolted to prevent leakage, the digester was switched on and the time of rise of temperature and pressure was noted at intervals of five (5) minutes. The content of the digester was stirred while in operation by rotating the vessel via a motor connected through a rotary axle to a control unit, including measurement and control instruments of pressure and temperature, to facilitate attainment of the working temperature (5ºC/min). The pulping temperatures gradually rose and allowed to be steady at varying maximum temperatures of 150, 160 and 170°C. The digester was switched off after varying maximum cooking periods of 60, 90

and 120 minutes from start of operation and allowed to cool below 60oC before the content were blown down. The digester's initial temperature, pressure and starting time were all noted, and the various changes in these parameters were also recorded. The resultant pulp was subjected to thorough washing with plenty of water. When it was observed that subsequent washing resulted in no further change in color, the pulp was transferred into the valley beater for processing into a more refined pulp.

Soda pulping

After a thorough cleaning process, 2kg of air-dry sample was loaded into a 15 L capacity batch reactor (digester) with eight (8) liter cooking liquor at liquor-sample ratio of 4:1. The soda pulping was carried out using the batch reactor (digester). It's working principle was carried out as applied in the MEA process, aiming at producing pulps based on the following parameters: ratio of liquor/biomass 4 to 1, maximum temperatures 150,160 and 170°C and maximum cooking duration of 60, 90 and 120 minutes from start of operation. The pulping temperatures gradually rose and allowed to attain the various operational conditions stated above. The digester's initial temperature, pressure and starting time were all noted, and the various changes in these parameters were also recorded. The resultant pulp was subjected to thorough washing with plenty of water. When it was observed that subsequent washing resulted in no further change in color, the pulp was transferred into the valley beater for processing into a more refined pulp.

2.5. Beating Process

The beating process was conducted using the valley beater at 1000 and 8000 beating revolutions. The beating revolution was chosen based on the previous study from 1000 to 24000 beating revolution. It showed that after 8000 to 24000 beating revolution, there was no significant increasing of paper mechanical properties with the increasing of the beating revolution. That is the justification of this study for using 1000 beating as the basic beating process and 8000 as the optimum beating for achieving highest paper properties.

2.6. Totally Chlorine Free (TCF) Bleaching

The pulps resulting from the MEA and Soda pulping processes were fully bleached by a totally chlorine-free sequence performed in three stages to kappa number ranging from 12.7 to 16.9 and 13.5 to 22.4 respectively. Using a combination of 70% hydrogen peroxide and dilute sodium hydroxide at varying stoichiometric ratios in three (3) different stages at varying temperatures and reaction time. This sequence is represented in a shorthand form as D1-Ep-D2.

Table 3 Conditions of the Bleaching Process

Stage	D1	Ep	D2
Chemical charge	Hydrogen Peroxide (H_2O_2)	Hydrogen Peroxide (H_2O_2)	Hydrogen Peroxide (H_2O_2)
	-	NaOH (1.5%)	-
Pulp consistency	10%	10%	10%
Temperature	70 °C	-	70 °C
Time	15 minutes	8 minutes	12 minutes

2.7. Screening of Agro-biomass (Sugarcane Bagasse)

The pulp was passed through a screening process. Cooked sample chips were put through the screening machine. Only acceptable size of the sample fiber passed through the screen plate and the rejected or oversized fiber were left on the screen plate. This process is crucial in papermaking to ensure smooth and uniform paper texture. Pulp yield was determined in accordance with TAPPI standards T-257.

Table 4 Optimum Experimental Pulping Conditions of MEA & the Soda Process

Parameters	**Optimum Parameters (Best Conditions of Cooking Operation showing Values of Independent Variables)**	
	MEA Pulping	Soda Pulping
Air dry weight of Bagasse (kg) (A.D)	2	2
Ratio of liquor/biomass	4:1	4:1
Maximum temperature (degree Celsius)	150, 160, 170	150, 160, 170
Time to reach maximum temperature (minutes)	43, 55, 67	36, 47, 56
Time at maximum temperature (minutes)	17, 35, 53,	24, 43, 64
Liquor charge (%)	50, 75, 100	10,15, 20
Over-all cooking time (minutes)	60, 90, 120	60. 90. 120
Blow-down temperature (degree Celsius)	60	60

3. Results and discussion

Table 5 Experimental Conditions used in the MEA Pulping applied to the agro-based fiber (Sugarcane Bagasse) investigated, showing values of cooking/Independent and dependent variables for pulp properties.

Experiment	**Independent Variables**			**Dependent Variables**				
	Cooking Temp. (Degree Celsius)	**Cooking Time (minutes)**	**MEA % (D.W.)**	**TY (%)**	**SY (%)**	**Rejects (%)**	**Kappa No.**	**Viscosity ml/g**
1	150	60	50	39.51	36.24	3.27	54.64	470
2	150	90	75	49.09	47.23	1.86	36.28	650
3	150	120	100	52.99	48.46	4.53	20.01	400
4	160	60	50	41.31	37.98	3.33	69.30	518
5	160	90	75	53.60	51.02	2.58	23.45	630
6	160	120	100	55.56	52.00	3.56	19.87	480
7	170	60	50	39.08	38.65	0.33	76.09	490
8	170	90	75	54.72	51.48	3.24	24.02	500
9	170	120	100	55.12	50.97	4.15	27.50	460
10	150	60	50	49.49	48.30	1.19	37.07	450
11	150	90	75	49.55	47.52	2.03	24.99	630
12	150	120	100	53.25	52.70	0.55	48.11	425
13	160	60	50	53.33	51.14	1.19	17.98	450
14	160	90	75	47.53	45.74	1.79	24.03	580
15	160	120	100	52.01	50.55	1.46	47.04	480
16	170	60	50	53.04	50.68	2.36	17.77	465
17	170	90	75	51.61	41.89	9.72	23.49	560
18	170	120	100	51.14	49.01	2.13	45.97	530
19	150	60	50	44.40	43.89	0.51	39.67	609
20	150	90	75	54.73	53.27	1.46	16.20	435
21	150	120	100	49.59	42.16	7.43	43.99	535

22	160	60	50	49.01	44.49	4.52	51.40	818
23	160	90	75	52.73	52.27	0.46	19.02	470
24	160	120	100	50.22	41.21	11.01	49.08	525
25	170	60	50	49.56	46.12	3.44	57.58	420
26	170	90	75	54.44	52.94	1.50	17.20	510
27	170	120	100	52.45	43.74	8.71	46.06	505

TY= Total yield, SY= Screen yield

Table 6 Experimental Conditions used in the Soda Pulping applied to the agro-based fiber (Sugarcane Bagasse) investigated, showing values of cooking/Independent and dependent variables for pulp properties

Experiment	Independent Variables			Dependent Variables				
	Cooking Temp. (degree Celsius)	Cooking Time (minutess)	NaOH (%) (D.W.)	TY (%)	SY (%)	Rejects (%)	Kappa No.	Viscosity mL/g
1	150	60	10	44.51	44.24	0.27	19.64	360
2	150	90	15	49.09	43.23	5.86	36.28	530
3	150	120	20	53.99	37.46	16.53	70.01	310
4	160	60	10	44.31	33.98	10.33	19.30	428
5	160	90	15	49.60	47.90	1.70	17.50	440
6	160	120	20	42.56	32.00	10.56	54.87	390
7	170	60	10	42.08	41.65	0.43	20.09	400
8	170	90	15	46.72	44.48	2.24	24.02	410
9	170	120	20	52.12	40.97	11.15	34.50	370
10	150	60	20	42.49	37.30	5.19	27.07	460
11	150	90	10	47.55	45.52	2.03	24.99	540
12	150	120	15	42.25	36.70	5.55	48.11	335
13	160	60	20	44.33	44.14	0.19	17.98	340
14	160	90	10	47.53	45.74	1.79	24.03	450
15	160	120	15	51.01	46.55	4.46	27.04	390
16	170	60	20	55.04	44.68	10.36	17.77	375
17	170	90	10	47.61	45.89	1.72	23.49	470
18	170	120	15	51.14	44.01	7.13	25.97	450
19	150	60	15	44.40	43.89	0.51	17.67	519
20	150	90	20	47.32	45.59	1.73	22.09	345
21	150	120	10	41.59	32.16	9.43	43.99	445
22	160	60	15	45.01	44.49	0.52	17.40	708
23	160	90	20	46.73	45.27	1.46	21.02	380
24	160	120	10	42.22	38.21	14.01	49.08	435
25	170	60	15	44.56	44.12	0.44	17.58	330
26	170	90	20	47.44	45.94	1.50	23.16	420
27	170	120	10	42.45	33.74	8.71	46.06	415

TY= Total yield, SY= Screen yield

Table 7 Lack of Fit Tests analyzed for the Monoethanolamine Process

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Linear	55.86	11	5.08	0.39	0.9088	Suggested
2FI	47.33	8	5.92	0.46	0.8443	
Quadratic	38.77	5	7.75	0.60	0.7059	
Cubic	0.000	0				Aliased
Pure Error	64.66	5	12.93			

Table 8 Model Summary Statistics analyzed for the Monoethanolamine Process

Source	Std. Dev	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	2.74	0.2360	0.0928	-0.1768	185.64	Suggested
2FI	2.94	0.2901	-0.0376	-1.0153	317.92	
Quadratic	3.22	0.3444	-0.2457	-3.9424	779.67	

"Lack of Fit Tests": Want the selected model to have insignificant lack-of-fit. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case there are no significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those

required to support hierarchy), model reduction may improve the model. The "Lack of Fit F-value" of 0.51 implies the Lack of Fit is not significant relative to the pure error. Non-significant lack of fit is good because it is desired that the model should fit.

Table 9 ANOVA for Response Surface Mean Model analyzed for the Monoethanolamine Process [Partial sum of squares]

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F
Model	0.000	0			
Residual	157.75	19	8.30		
Lack of Fit	*93.09*	14	*6.65*	*0.51*	*0.8498*
Pure Error	*64.66*	5	*12.93*		
Cor Total	157.75	19			

Table 10 Sequential Model Sum of Squares analyzed for the Soda Process

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Mean	39295.00	1	39295.00			Suggested
Linear	5.61	3	1.87	0.37	0.7751	
2FI	1.01	3	0.34	0.055	0.9822	
Quadratic	34.95	3	11.65	2.61	0.1096	Suggested
Cubic	25.81	7	3.69	0.59	0.7481	Aliased
Residual	18.88	3	6.29			
Total	39381.26	20	1969.06			

Table 11 Model Summary Statistics analyzed for the Soda Process

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	2.25	0.0650	-0.1103	-0.5391	132.77	
2FI	2.48	0.0768	-0.3493	-2.1783	274.18	
Quadratic	2.11	0.4819	0.0157	-1.7050	233.35	Suggested
Cubic	2.51	0.7811	-0.3863	-19.3504	1755.53	Aliased

Table 12 ANOVA for Response Surface Quadratic Model analyzed for the Soda Process [Partial sum of squares]

Source	Sum of Squares	DF	Mean Square	F Value	Prob > F	
Model	41.57	9	4.62	1.03	0.4756	not significant
A	0.41	1	0.41	0.092	0.7675	
B	6.97	1	6.97	1.56	0.2401	
C	1.68	1	1.68	0.38	0.5533	
A^2	3.50	1	3.50	0.78	0.3971	
B^2	29.99	1	29.99	6.71	0.0269	
C^2	6.85	1	6.85	1.53	0.2441	
AB	0.21	1	0.21	0.046	0.8340	
AC	0.85	1	0.85	0.19	0.6720	
BC	0.53	1	0.53	0.12	0.7365	
Residual	44.69	10	4.47			
Cor Total	86.27	19				

The "Model F-value" of 1.03 implies the model is not significant. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case B2 are significant model terms.

Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy), model reduction may improve your model.

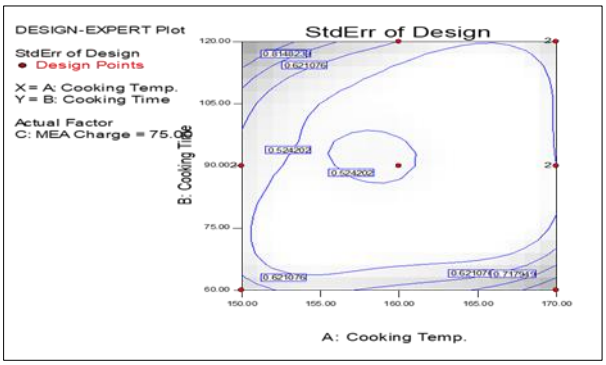

Figure 2 Standard Error of Design for the Monoethanoleamine Process

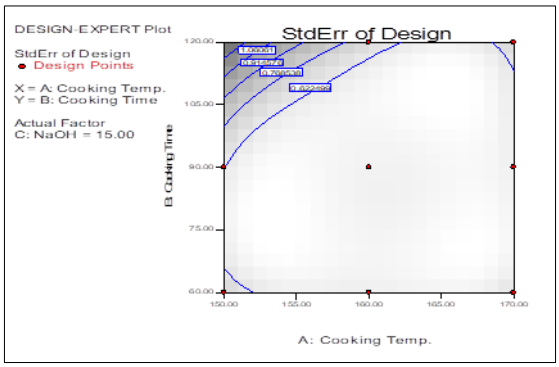

Figure 3 Standard Error of Design for the Soda Process

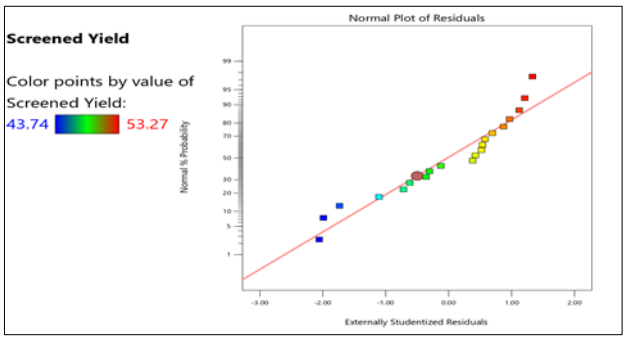

Figure 4 Diagnostic of Normal Plot of Residuals for MEA-process

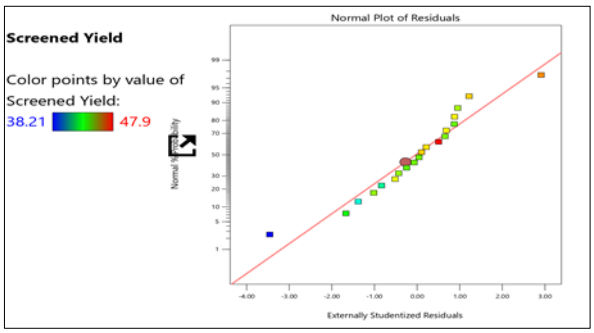

Figure 5 Diagnostic of Normal Plot of Residuals for Soda Process

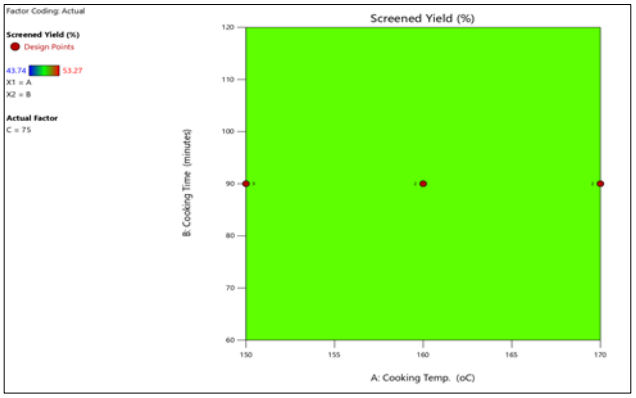

Figure 6 Model Graph of Contour of Screened Yield for MEA Process

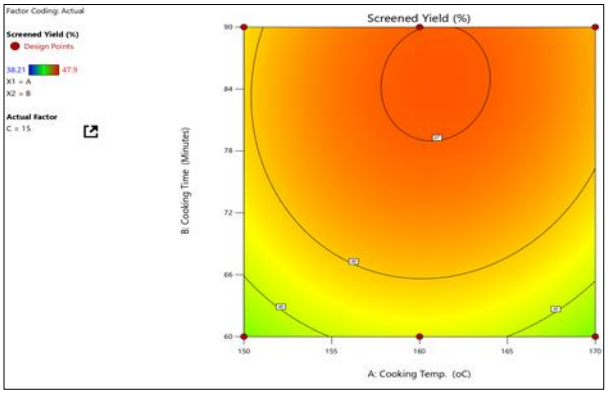

Figure 7 Model Graph of Contour of Screened Yield for Soda Process

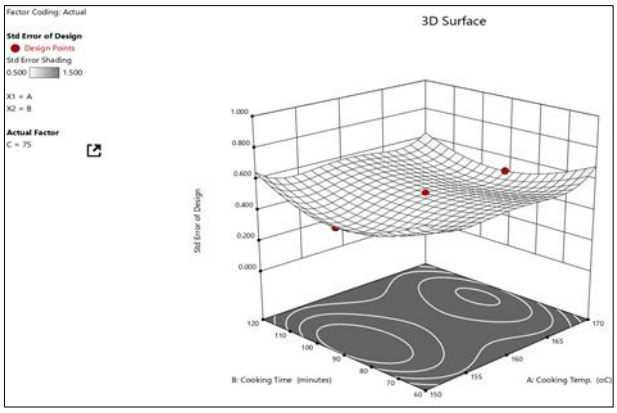

Figure 8 Desirability Plot of Numerical Optimization for MEA Process

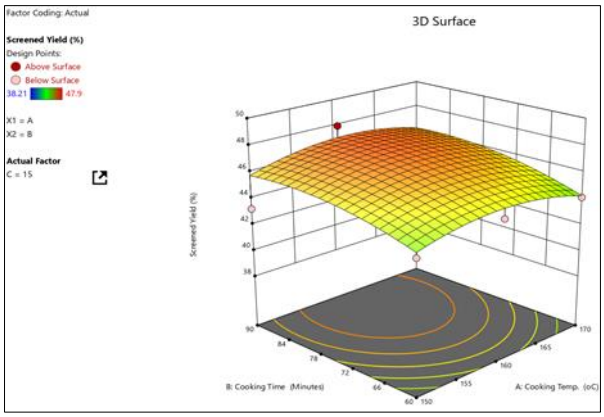

Figure 9 Desirability Plot of Numerical Optimization for Soda Process

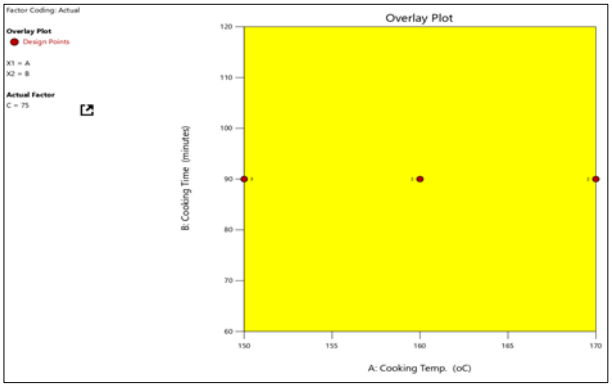

Figure 10 Overlay Plot of Graphical Optimization for MEA Process

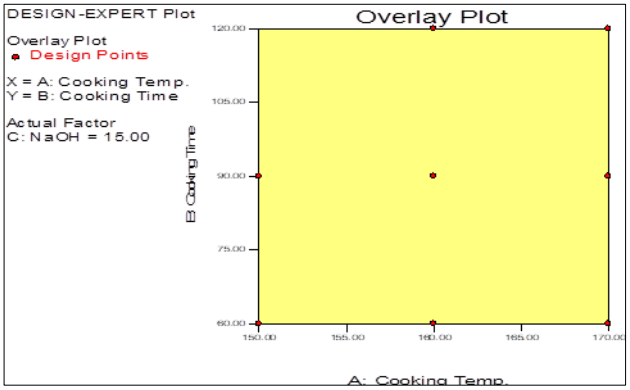

Figure 11 Overlay Plot of Graphical Optimization for Soda Process

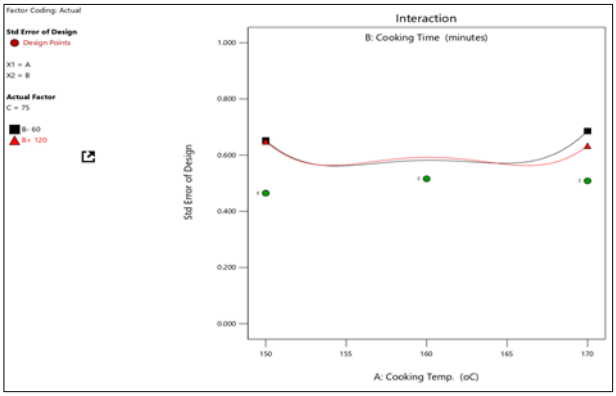

Figure 12 Plot of Multiple Interaction of Reactant for MEA Process

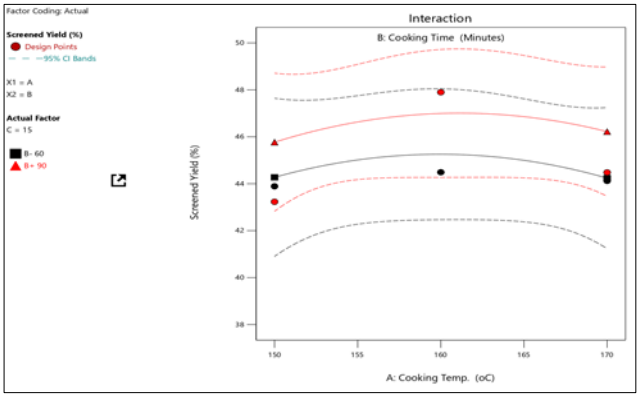

Figure 13 Plot of Multiple Interaction of Reactant for Soda Process

Figure 14 Unbleached EFB Pulp Samples and Pulp Sheets from MEA Process

Figure 15 Unbleached EFB Pulp Samples and Pulp Sheets from Soda Process

Figure 16 EFB Pulp Samples from MEA Process Bleached to 12.7 Kappa Number and Pulp sheets

Figure 17 EFB Pulp Samples from Soda Process Bleached to 13.5 Kappa Number and Pulp Sheets

In this study pulping of sugarcane bagasse with MEA was investigated in comparison to conventional soda pulping as reference. At optimum cooking conditions of temperature (150°C), cooking time (90 minutes) and with pure MEA

(75%), a sufficient delignification was achieved. The main focus laid on reduction of the MEA charge by partial substitution with water. A MEA/water ratio of 75/25 was successfully applied, furnishing a pulp yield of 54.73 with a screen yield of 53.27 and a reject as low as only 1.46. Under these conditions a kappa number of 12.7 was attained which means the pulp is still bleachable. When compared with results obtained for the soda process, it was observed that at a maximum cooking temperature of 160°C, maximum cooking time of 90 min., and with 15% soda concentration, a sufficient delignification was achieved, furnishing a pulp yield of 49.6%, screened yield of 47.9%, recording a reject of 1.70% and a kappa number of 13.5. Another focus of this research was laid on the reduction of temperature. Comparing the pulping potentials of these two processes, it was observed that soda pulping required more pulping energy to the advantage of the MEA which consumed less energy. MEA process furnished higher pulp yield at lower kappa number. Also, the strength properties of MEA pulps are comparable to that of soda pulps.

The pulps obtained in the MEA/water and soda cooks were selected for bleaching. ECF bleaching (DEpD) was applied. A similar brightness of 80% ISO was reached at a kappa number below 20 for both pulps. When brightness is not crucial or no bleaching is required, but a stronger pulp is desired, one can focus on obtaining a high holocellulose content and as high as possible a yield. If such a content is to be only 10% lower than optimum value, using a high Monoethanolamine concentration (75%), a short cooking time and a low liquid/solid ratio requires employing a temperature of 150oC in order to obtain a yield, holocellulose content, lignin content, and kappa number of 50-55, 75-85, 10-18 and 15-20%, respectively. If one also desires to ensure reasonable strength in the pulp and highly efficient use of the raw material, then the yield and holocellulose content should reach preset thresholds, and the lignin content and kappa number should be as low as possible. Thus, the yield and holocellulose content can only be allowed to decrease by 15% at most from their optimum value, and a moderately high MEA concentration and low liquid/solid ratio should be used to obtain a yield, holocellulose content, lignin content and kappa number of 51-56, 79-84, 14-22, and 12-20%, respectively, with a temperature, time, and MEA concentration of 145-155^{o}C, 60-90 minutes, and 70-80%, respectively. The pulp thus obtained is acceptably strong possessing high holocellulose content and is easily bleached (thanks to its low lignin content and kappa number); the raw material is inefficiently used (the low yield obtained is typical of chemical pulp), but the short time and small amount of raw material used result in immobilized capital savings and it has favorable effects also on reagent recovery from the wastewater.

4. Conclusion

Delignification by use of monoethanolamine (MEA) is an innovative, environmental friendly chemical pulping process that works without the use of sulphur compounds, with a particular benefit of simple MEA recovery by distillation, allowing black liquor combustion to be dispensed and the dissolved lignin recovered. The MEA process is suitable for pulping both hardwood and softwood. Compared with conventional processes, the MEA process has the advantage of achieving a high degree of delignification through an increase in temperature during pulping without any appreciable damage to the cellulose. MEA pulping is none polluting process compared with the soda process which is associated with heavy pollution load. MEA pulping was selected due to its environmental and economic advantages (such as little or no emission of fowl smelling malodorous gaseous pollutants – since no sulphur compounds are used, an increase in the pulp production – as lower cooking periods are needed to obtain the same pulp quality and quantity), making the implementation of this process possible in factories situated in the vicinity of agricultural areas, since it may be adapted for low productions and may be applied to any raw wood or non-wood material.

The search for local long fiber pulp material which can be easily propagated remains one of the most important key desirderatum for the eventual resuscitation of the present mom bund paper industries of Nigeria. One important way of stemming the tide of imports is to find a good substitute to fine pulp for the use of the paper companies when they eventually start producing. Besides being an innovation and new entry into the pulp map, sugarcane bagasse can become the best gift of FIIRO into the future pulp market of the tropical world. It can be concluded from these findings that comparable high strength paper can be produced from sugarcane bagasse pulp with more environmentally friendly pulping (MEA) process.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interest in this research work. All authors were in total agreement.

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