Identification Of The Appropriate Pulping Techniques And Optimization Of The Pulping Conditions For *The Cymbopogon Nardus* And *Paspalum Notatum*

Kamoga Omar Lwako M., Kirabira John Baptist, Byaruhanga Joseph K

ABSTRACT : The anxiety about the future supply wood as raw material for pulp has caused fresh search in non-conventional fibrous materials for pulp and paper production. But the quality and quantity of pulp and paper depend on the pulping methods and conditions. This study evaluated the pulping techniques and conditions for *Cymbopogon Nardus* and *Paspalum notatum* grasses. Soda and Kraft pulpingtechniques were evaluated at varied liquor charges and temperatures using the kappa number as the main response which significantly correlated with both control variables. Appreciable lignin removal occurred at soda charge of 15%. Kappa number of 24.4 was achieved for the two grasses at the soda charge of 25% and 160^{o}C; and 31.0 and 25.9 at a sulphidity of 30% and active alkali of 20% at the same temperature for *Cymbopogon Nardus* and *Paspalum notatum* respectively. The model equations agreed with experimental data. The two methods and conditions did not significantly differ for the two plant materials.

KEY-WORDS; Kappa number, Optimal, pulping, lignin,regression model

1.0 INTRODUCTION

WORLDWIDE the production of paper has continued to rise despite the development of the internet and other new information technologies that had caused a prediction of a decline in consumption of paper.Paper production has grownfrom 367 million tonnes in 2005 to 400 million tonnes in 2012 representing an increase of about 9% in 8years[1]. Although the rise of paper consumption in developed countries of Europe and North America is ondeclining rate but for the upcoming nations such china there is a growing rate of paper consumption.From 1998 to 2009, printing and writing paper demand grew only by 0.7% p.a. for developed countries given the shift to advanced technology. However, demand growth for emerging markets such as Asia and Latin America remained strong, growing by 6.9% over the same period[2].The lack of certainty of the future supply of wood as raw material for pulp has forced researchers and the paper industry to think of other non-conventional fibrous materials in the production of pulp[3]. Inorder to meet the increasing demand, a number of for pulp production evaluated[4][5].

- *Kamoga Omar Lwako M., MSc (Chem.) PGDE, BSc (Ind. Chem.) Makerere University Currently he is PhD Student at Makerere University, Department of Mechanical Engineering and a Lecturer at Busitema University. Currently researching on extraction pulp from non-wood materials for paper industry, kamogaol@yahoo.co.uk.*
- *Eng. Dr. John Baptist Kirabira PhD KTH. Currently a Senior Lecturer in the Department of Mechanical Engineering, Makerere University He has interest in engineering materials and minerals jbkirabira@cedat.mak.ac.ug ..*
- *Assoc. Prof. Joseph K. Byaruhanga B.Sc.(Eng), PhD, MUIPE, R. Eng., A senior Lecturer Department of Mechanical Engineering Makerere University. Also General Manager of Uganda Gatsby Trust, a small scale enterprises project,j by aruhanga@cedat.mak.ac.ug*

Among the alternative fibrous materialsare grasses such as *Cymbopogon Nardus*(L) (Rendle)and*Paspalum notatum*bothofthepoaceae family.*Cymbopogon Nardus*is perennial plant commonly referred to as Citronella, known commerciallyworldwidefor its essential oil.Citronella oil is traditionally known for its medicinal values and it used as fragrant in cosmetic industry as well as flavors of foods and alcohols.In Uganda it grows much as wild grass virtually in all regions of the country on fast- growing annual and perennial plants with high biomass must be identified, cultivated and their suitability well drained land mainly in the hilly areas. It grows to a high of 1-2m tall bush in about 8 months and can be harvested every three to four months. Not only when it colonies area it forms a big bush which is unpalatable by most animals including cattle but it also slows the growth of pasture and it a menace to herdsmen[6]. In some societies it used with less preference in thatching houses. After extracting the essential oil, the fibrous parts are discardedwithout any beneficial use.A study of the extraction pulp for paper and paper boards will give the crop additional value. This fibrous plant seems to have the potential to replace wood in many applications, paper production inclusive. *Paspalum notatumis* warm season perennial grass used as ground cover in compounds and play fields.It grows with length of 20cm – 50 cm and a width of 3-6mm. It is forage grass in natural pastures in all regions of Uganda. *Paspalum notatum* has high drought resistance and produces massive stolon-root systems that work as soil binders. Apart from being used as fodder for livestock, its fibrous nature makes it a potential pulp source for the paper industry[7]. The pulping techniques and conditions directly affect both the quality and the yield of pulp from different raw materials including grasses. Pulping involves the disintegration of the raw material's structure whereby isolating the cellulosic fibres from other phyto-Chemical components using chemicals, mechanical energy or micro-organismsThe pulping techniques of the non-wood plant materials such as grasses could be developed by modifying those which have been used in wood pulping depending on their chemical constituents. Therefore depending on the mechanism of fibre isolation, pulping techniques may be categorised as mechanical, thermal, chemical and Biopulping.The pulping conditions that affect the properties and yield of the pulp isolated from a particular plant materialsare the cooking temperature, cooking liquor charge/concentration and time. Soda AQ and Kraft pulpingare the most conversionallyknown chemical pulping techniques especially for wood. Globally 80% of chemical paper pulp is made using Kraft process. In this method the raw materials are treated with highly alkalinesolution of NaOH in combination with Na_2S to avoid undesirable breaking of hemicellulose[8],[9]. The Soda –Anthraquinone pulpingon other hand involves the use of NaOH solution in combination with anthraquinone as to avoid depolarisation of the fibres. The twopulping methods have been adopted by many scientists in pulping non-wood materials but directly as they are used in the pulping wood materials irrespective of the materials' constituents. But due to the fact that different raw materials most especially non-wood materials have different chemical composition, each material may need its own tailor made method and conditions. Efficiency of the pulping techniques and conditions may be evaluated by the measuring of rejects, kappa number and yield of the isolated pulp.Therefore appropriate pulping method and optimal conditions for a particular plant material need to be investigated[10]. The optimization of the pulping conditionsa particular fibrous material requires the knowledge of its constituents. The constituents of non-wood materials are the key determinantsin the selection of the pulping methods and conditions. The Chemical fractionation of the constituents of the two selected grasses was carried out in the previous studyand results are reported in Table 1[11]. Therefore this study was set to identify the appropriate methods and conditions that could be used in pulping some selected grasses by modifying the two conversional methods(Soda and Kraft pulping)alongsidethe varying pulping conditions such cooking temperature and cooking charge.

Table 1: Fractional constituents for both Cymbopogon and *Paspalum notatum* leaves[10]

Constituents	Hollocellulose (%)	Lignin Content (%)	Ethanol-benzene extractives (%)	Ash content (%)	α-Cellulose (%)	Cold water extractives (%)	Hot water extractives(%)	1% NaOH Extractives(%)
Cymbopogon nardus	68.51	27.38	5.14	3.66	35.00	15.00	20.00	25.99
Paspalum notatum	62.36	22.27	6.00	9.69	26.13	15.00	20.00	36.82

1.1 Pulping Process Optimisation Design

The most important subject of a research on a process is the design optimization of process conditions. The study of multiple –input multiple-output process requires an optimisation strategy to identify the best working parameters.In order to identify the best pulping conditions a combination of Taguchi optimization design method (TODM) and Space-Filling Maximum Entropy Design (SFMED) were employed in this study. The Taguchi optimization design involves the evaluation of the best pulping conditions and ranking of their significance towards the given response[12]. The Taguchi optimisation requires a minimal number of experiments to examine the quality characteristics of a process or a product as compared to the traditional experimental designs. The experimental results as based on the orthogonal array are then transformed into signal to noise (S/N) ratios and their deviations(dB) used to evaluate their quality characteristics[13]. SFMED is a collection of statistical and mathematical techniques useful in developing, improving and optimizing processes[14]. It consists of experimental strategy for exploring the spacing of the independent variables and empirical statistical modelling which develops into an appropriate approximating relationship between the responses and the process variables. In this study a combination of the two design optimisation strategies was employed to predict the best pulpingconditions for the two pulping methods of the two grasses.

2.0 MATERIALS AND METHODS

2.1 Raw Materials

The two grass materials were collected from theEastern region of Uganda (Busia and Tororo District). The selected grasses were *Cymbopogon Nardus* and Paspalum notatum. Mature plant materials with straws bearing mature seeds were collected from the areas where they grow with economic advantage(where they grow either naturally or planted in big quantities). The whole stalks above the ground weresampled and prepared for pulping.

2.2 Preparation of Materials

The collected samples were cut into small sizes of about 2-3 cm, screened to remove the fines, cleaned with distilled water to removed adhered soilparticles, and dried under shed. The dry plant materials werestored in dry cabin to avoid fungal attack.

2.3 Hydrolysis of the Raw Material

The dry materials with a known o.d. weightwerefirst soaked in water at room temperature for 24 hours ina solid/liquor ratio of 1:10 in order to reduce on the extractives. The liquid part was decanted off and the plant materials were transferred to hot water in the autoclave in solid/liquor ratio of 1:8 andheated at 100°Cfor 1 hour. Hydrolysis was doneto increase the permeability of the chemicals from the cooking liquor[15].

2.4 Pulping

The hydrolysed materials were cooked in a 15litre laboratory digester PL001 with a motor actuating the reactor with a pressure and temperature control. Two pulping methods (soda- anthraquinone (AQ) and Kraft pulping) were employed. The soda –AQ pulping was done at variedconditions of soda charges (10%-25%), temperature (100° – 160°C) at constant time duration of 1hour and 0.1% anthraquinone concentration. The Kraft pulping was done at variedconditions of sulphidity (10%-40%) and temperature (100° – 160°C) at sameduration of 1hour.The cooked materials were fiberized in a wet pulper at 1200rpm for20 minutes and the screenings separated by sieving through a screen of 1mm mesh size.

2.5 Pre-Bleaching

The isolated pulps were pre-bleached with a two-stepHP_E sequence. The hypochlorite stage involved subjecting the isolated pulp toa concentration charge of 3%, hypochlorite at 60°C and a consistency of 6%. The alkalised hydrogen peroxidestage was carried out at concentration charge6% hydrogen peroxidealkalized with 2.7% NaOH and 0.05% $MgSO_4$at a consistency of 6% at 80^oC.The kappa number of the pre-bleached pulp was measured using the standard Tappi method (T236 cm-85).

2.6 Taguchi Experimental design

A series of experiments were conducted to evaluate the effect of the cooking liquor charge and cooking temperature on the yield and Kappa number of the pulp produced. The configuration of orthogonal array L_{16} (2^4) required 16 experiments for each plant material pulped. The conditions/factors and their levels used in the experiments are defined in Table 2. Time of cooking as one of the other factors was taken constant at 60minutes since previous researches had indicated it as the optimum for most fibre materials and ranked least significant[16]. Taguchi Optimisation design which uses of the signal to noise (S/N) ratio was used in identification of best conditions for the high quality of a response. The varying parameters were taken alternatively as signal variable and noise variable. The S/N ratios for thesetypes of responseswere calculated using the equation (1) [17][12];

$$S/_N = -10\log\left[\frac{1}{n}\sum_{i=1}^{n} y_i^2\right] \qquad (1)$$

The greater the S/N ratio, the better the performance. The range of the S/N ratios (dB) was used to find the significance ofeachparameter in terms of ranking towards the value of the kappa number. The greater the Delta term (dB), the more significant the parameter is toward the response.

Table 2: Control factors and their Levels for Soda-AQ and Kraft pulping

Level	Control factors		
	Cooking Temp (T) /°C	Cooking Liquor charge (S)	
		Soda Charge for Soda-AQ pulping	Sulphidity (%) for Kraft pulping
1	100	10	10
2	120	15	20
3	140	20	30
4	160	25	40

3.0 RESULTS AND DISCUSSION

3.1 Soda-Anthraquinone pulping of *Cymbopogon Nardus* and *Paspalum notatum*.

Research resultsof the percentages of unscreened pulp yield, pre-bleached pulp yield, rejects and Kappa numberfor soda-AQ pulping of both fibrous plant materials are presented in Fig 1 and Fig 2. The results revealed that, the percentages of unscreened pulp yield, pre-bleached pulp yield, rejects and Kappa number all decreased with increase in both the cooking soda charge and cooking temperature for the two fibrous materials. The decrease in all four parameters shows increased level of lignin removal with increasing soda charge and cooking temperature during pulping process.Therefore residue lignindecreased as both cooking temperature and white liquor soda charge increased for both plant materials. Of the four pulping responses,Kappa number directly reflects the level of pulping or lignin removal and decreased more rapidly than others property as both soda charge and cooking temperature were increased. The Kappa number of the pre-bleached*Cymbopogon Nardus* soda pulp decreased from 108.0 to 82.2 at 100^oC (24% decrease) and from 76.2 to 24.4 (65% decrease) at 160^oC when the soda charge increased from 10% to 25%.And the Kappa number pre-bleached *Paspalum notatum* soda pulp decreased from 52.7 to 41.6 (21% decrease) at 100^oC and from 42.5to 24.4 (43% decrease) at 160^oC for the same variation of soda charge. This shows that the kappa number and hence the lignin content is much removed at high temperatures and alkali charge for both types of plant materials. When soda concentration was varied from 10% to 15% at 160^oC the kappa number of *Cymbopogon Nardus* pulp decreased by 36.8 units, from 15% to 20% by 6.6 units and 20% to 25% by 8.0 units. While the kappa number of *Paspalum notatum* decreased by 9.4, 5.9 and 2.4 units at the same respective soda charge variations. This implies most lignin removal takes place up to the soda charge of 15% and after which additional increase in alkali contraction removes just residual lignin. The graphs of Kappa numbers in Fig.1 and Fig.2 also exhibited great changes gradients at soda charge of 15% of cooking liquor for the four pulping temperatures implying that pulping is more effective at any charge higher than 15%. The lowest*Cymbopogon Nardus* soda pulp was achieved with the kappa number of 24.4and a pre-bleached yield of 42.72 % at soda concentration of cooking liquor of 25% and cooking temperature of 160°C. This observation did not differing much from that of Phragmites karka a wetland grass which produced a screened pulp yield of 45% with Kappa number of 18.5 at active alkali charge of 15%, a maximum cooking time of 2.0 hours and cooking temperature of 150°C[18]. Butit is known that at higher the concentration charge of the cooking liquor and cooking temperature, depolymerisation of cellulose fibres results[19]. Rejects for soda pulping of Cymbopogonnardus decreased to 0.17% at a cooking temperature of 160^{o}c and a cooking soda concentration of 25%. While that of *Paspalum notatum* decreased to zero even at 100^{o}C at 20% soda concentration. This implied *Paspalum notatum*requires less heating energy and is easy to pulp. The lowest kappa number of 24.4 for soda pulp of Paspalum notatum was achieved at soda charge of 25% and cooking temperature of 160°C and a pre-bleached yield of 31.10%

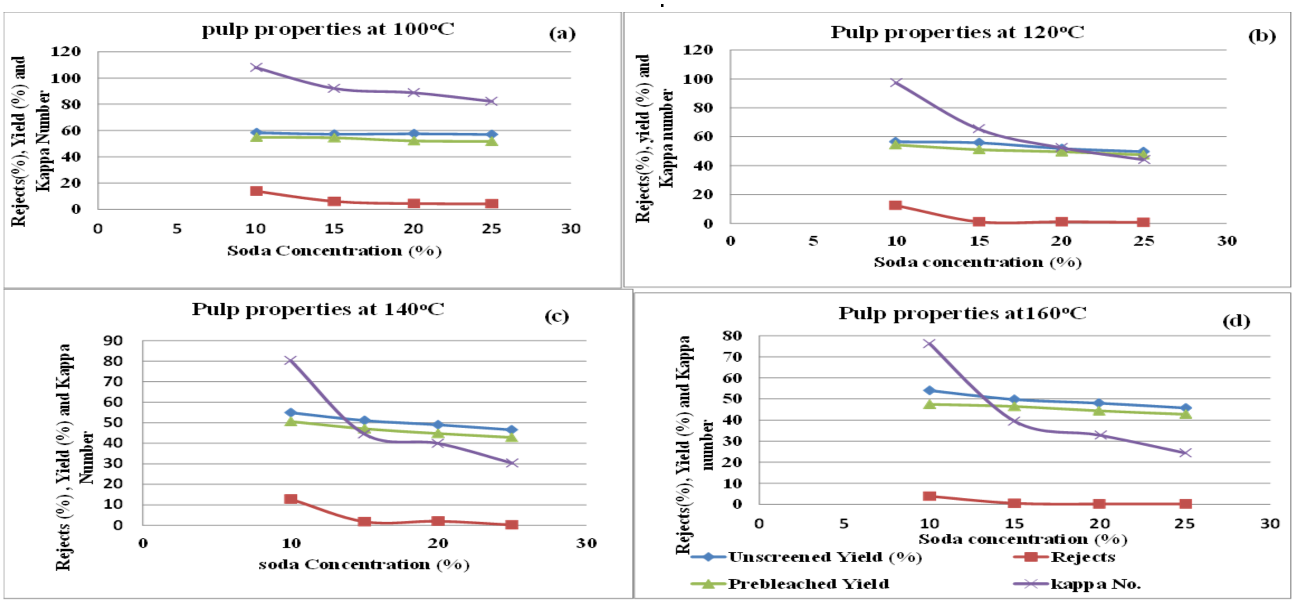

Fig. 1: Variation of *Cymbopogon Nardus* Soda pulp properties with varying soda charge at 100°C (a), 120°C (b), 140°C (c) and 160°C (d)

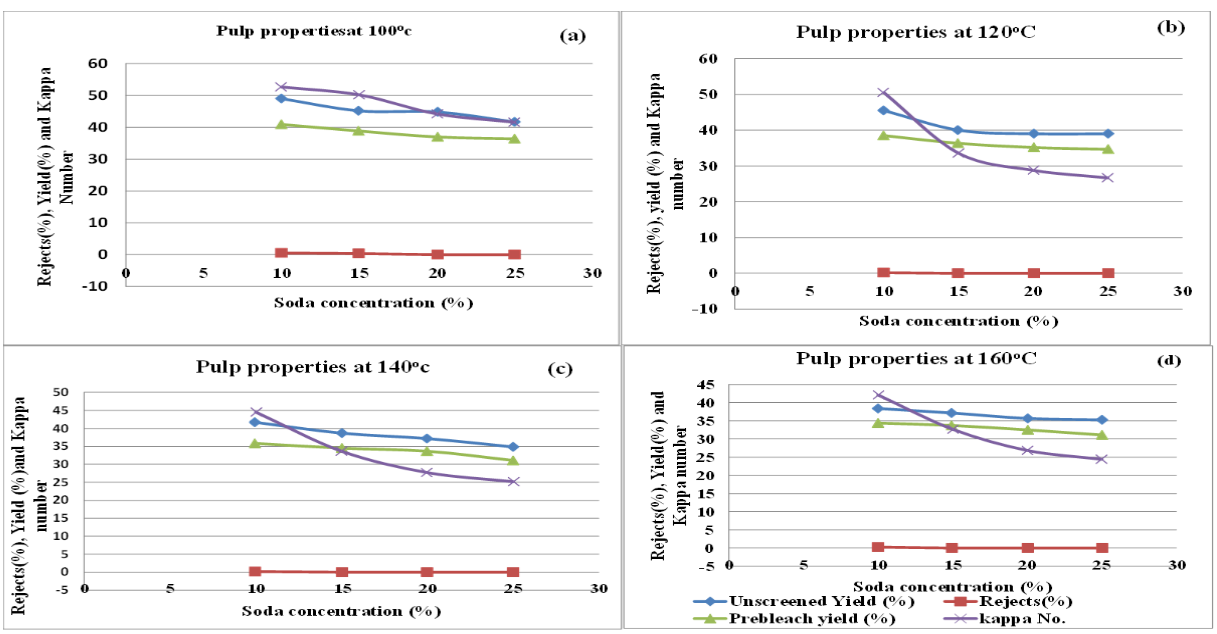

Figure 2: Variation of Paspalum notatum pulp properties with varying soda concentrations at 100°C (a), 120°C (b), 140°C (C) and 160°C (d).

3.1.1 Analysis of the S/N Ratios of *Cymbopogon Nardus* and *Paspalum notatum* Soda-AQ pulping

Kappa number was used asthe response in the evaluation of the pulping process, while the cooking temperature and cooking liquor concentration were taken alternatively as signal and noise variables. Since kappa number decreases with increased efficiency of lignin removal, this type of optimisation upholds the rule "the smaller the better". From Table3 it is observed that optimal pulping conditions for the two variables for the two plant specieswere at their highest S/N values at level 4 (T_4=160°C and S_4 = 25%). This is in close agreement with Jalal et al[20]observation that bleachable grades of Tobacco pulp were only produced using 25% alkali charge, 0.2 % AQ charge and cooking temperature of 165°C.The cooking temperature of *Cymbopogon Nardus*hadahigher dB term it isranked one, in order of significancetowards effect to the Kappa number value and hence towards the pulping effectiveness oftwo the fibrous plants. On the other hand the soda charge had the higher dB valuein pulping *Paspalum notatum* and therefore ranked one in its significance on kappa number value.

3.1.2 Regression Analysis of Soda pulping conditions for *Cymbopogon Nardus* and Paspalum notatum

The mathematical regression models were developed for theKappa number in terms of thecooking temperature and soda charge. The multivariable regression analysis of Stata, standard statistical software was used to derive mode equations. The regression model equations are very important because they can be used to estimate the quality of pulp at the optimised pulping conditions. This can optimise cost of chemical and energy requiredin pulping.The Kappa numbers of *Cymbopogon Nardus* soda pulp at any pulping conditions were found to be given by the model equation 2. The model has a coefficient of determination R^2 of 0.87 which implies the model equation fits the data within 87% confidence level.

$$Y_{KP} = 62.4 - 24.71X_T - 21.4X_S \text{ at } R^2 = 0.87,\ F>42.86,\ p<0.00001 \qquad (2)$$

The model equation 2 shows that the kappa number of*Cymbopogon Nardus* soda pulp decrease as both the cooking temperature and soda charge increase.X_T andX_S are the normalized values of the cooking temperatures and liquor charges respectively. The model equation 3 shows that the pre-bleached yield of *Cymbopogon Nardus* soda pulp which decreased with increasing cooking temperature and soda charge.The model equationfits the experimental data at 94% confidence level.

$$Y_{Pb} = 48.88 - 4.28X_T - 2.84X_S \text{ at } R^2 = 0.94\ F> 97.01\ p<0.0001 \qquad (3)$$

The change in temperature was found to be more significantlyaffecting the pre-bleached yield of pulp than cooking soda concentration The Kappa number and Pre-bleached yield of Paspalum notatum soda pulp at any pulping conditions are given by the model equation 4 and equation5 respectively. The model equation 4 has a coefficient of determination R^2 of 0.76which implies it fits the data with 76 % confidence level.

$$Y_{KP} = 36.21 - 5.86X_T - 9.16X_S \text{ at } R^2 = 0.76\ F>21.19\ p<0.0001 \qquad (4)$$

The model equation 4 shows that the kappa number of Paspalum notatum soda pulp decreases as the cooking temperature (X_T) and cooking soda charge (X_s) increases.

$$Y_{Pb} = 35.13 - 2.5\,X_T - 1.35X_S \text{ at } R^2 = 0.73\ F> 17.17\ P<0.0002 \qquad (5)$$

The coefficient of determination R^2 of equation 5 is0.73 which shows that the equation 5 fits experimental data at 73% confidence level.

Table 3: Response table of S/N ratio for kappa number of the *Cymbopogon Nardus* and *Paspalum notatum* soda pulp

Plant Materials	S/N ratio	Level					
		1	2	3	4	dB	Rank
Cymbopogon Nardus	**Temp (T)**	-39.39	-36.64	-34.37	-33.54⋆	5.85	1
	Soda charge	-39.22	-36.09	-35.21	-34.07⋆	5.15	2
Paspalum notatum	**Temp (T)**	-33.51	-31.16	-30.53	-30.16⋆	3.35	2†
	Soda charge	-34.33	-31.65	-30.28	-29.68⋆	4.65	1†

⋆ Highest S/N ratio Value, †special observation

3.2 Kraft pulping of *Cymbopogon Nardus* and *Paspalum notatum*.

Research results of the percentages of unscreened pulp yield, pre-bleached pulp yield, rejects and Kappa numberfor Kraft pulping of both fibrous plant materials are presented in Fig 3 and Fig 4. The results revealed that, the percentages of unscreened pulp yield, pre-bleached pulp yield and rejects, all slightly increased with increase in the sulphidity and decreased with the increase in cooking temperature for both *Cymbopogon Nardus* and paspalum notatum respectively. The increasein the unscreened yield and pre-bleached yield with increase insulphidity is probably due to the protective actionof hydrogen sulphide ions on cellulose fibre against depolymerisation by the alkali. At around the sulphidity of 30% the increase sealed off and the yield remained almost constant, studies at higher concentration values of sulphidity than 30 % do not influence much on the yield[21].This increase in the three parametersmay also be attributed to the selectivity nature hydrogen sulphide which removes lignin while leaving the carbohydrate/

hemicellulose intact. Increased sulphidity decreased in lignin in the pulp but increased the residual carbohydrate / hemicellulose hence on the unscreened yield, pre-bleached yield, and rejects. This is also in agreement with the fact that the pulp yield increases with increase in sulphidity until a yield plateau (constant value) is reached[22]. The kappa number of*Cymbopogon Nardus* soda pulp decreased from 100.0 to82.20at 100^{o}C and from35.60 to31.00at 160^{o}C when the sulphidity percentage was increased 10% to 30%.The lowest the kappa numbers for both kinds of materials were achieved at Sulphidity percentage of 30 % and at a cooking temperature of 160°C as shown in Fig. 3. For Paspalum notatum the kappa number decreased 48.7 to39.9 at 100^{o}C and from 29.83 to 25.90at 160^{o}C as sulphidity was increased from 10% to 30% as shown in fig 4. The decrease in kappa number with increase in sulphidity was still attributed to selectivity nature of hydrogen sulphide in lignin removal against carbohydrates.The lowest the kappa numbers for both kinds of materials were achieved at Sulphidity of 30 % and at a cooking temperature of 160°C as shown in Fig. 3 FromFig.3 and Fig 4 it is observed that the graphsof kappa numbers at different temperatures had turning points in betweenthe sulphidity of cooking liquid of20% to 30%, indicating that sufficient lignin removal occurred at sulphidity values between 20% and 30 % for both fibrous materials. Thelowest kappa number of 31.0 for *Cymbopogon Nardus* pulp was achieved at sulphidity of 30 % which implied the best Kraft pulping occurred at the sulphidity of 30% at the total alkali chargeof 20% and cooking temperature of 160°C with the pre-bleached yield of46.08%. The lowest Kappa number of 25.9 for *Paspalum notatum* was achieved at sulphidity of 30 % at the total alkali charge of 20% and cooking temperature of 160°C with a pre-bleached yield of 31.58%. Therefore like in wood mills in industries,Kraft pulping of grasses can be done at a sulphidity around 30% for the optimal yield.

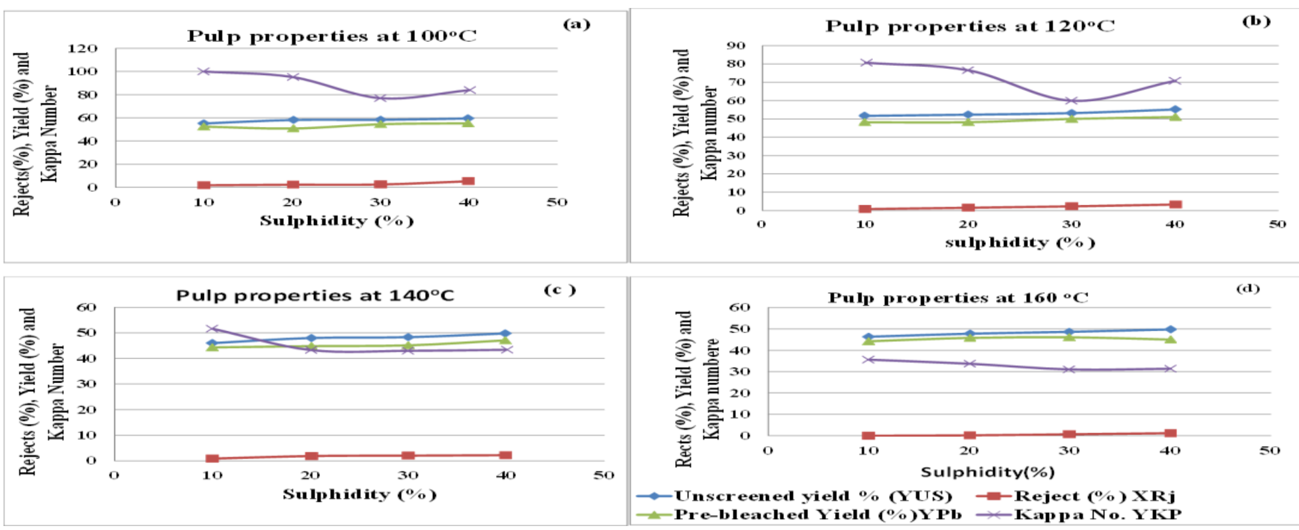

Fig. 3: Variation of *Cymbopogon Nardus*Kraft pulp properties with sulphidity at 100°C (a), 120°C (b), 140°C (c) and 160°C(d)

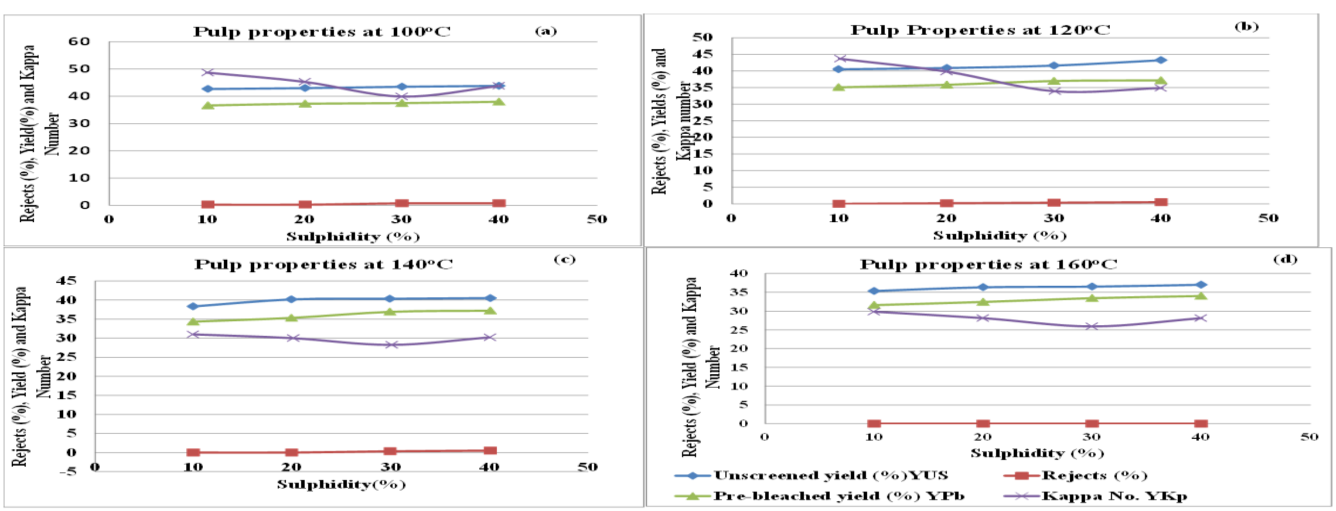

Fig 4: Variation of*Paspalum notatum*Kraft pulp properties with varied sulphidity for at 100°C (a), 120°C(b), 140°C (c) and 160°C (d).

3.2.1 Analysis of the S/N Ratios for Kraft pulping of *Cymbopogon Nardus* and *Paspalum notatum*

From the S/N ratio in Table 4 it is observed that the optimal pulping temperature for the two fibrous materials is at level 4 (T_4=160°C) and that of sulphidity is at level 3 (S_3 = 30%). And from Delta term dB, the cooking temperature is ranked number one, in order of significant towards the Kappa number of the extracted pulp and hence on the effectiveness of the pulping methodfor both plant materials.

3.2.2 Regression Analysis of Kraft pulping conditions for *Cymbopogon Nardus* and *Paspalum notatum*

The Kappa number of *Cymbopogon Nardus*Kraft pulp at any pulping conditions was found to be described by the model equation 6. The model has a coefficient of determination of R^2 of 0.95 which implies the model equation fits the experimental data at 95% confidence level.

$Y_{KP} = 60.13 - 29.83X_T - 5.19X_S$ at R^2 = 0.95, F>122.47, p<0.00001 (6)

X_T and X_S are the normalised Temperature and Sulphidity respectively. The model equation 6 shows that the kappa number of*Cymbopogon Nardus*soda pulp decreases as the cooking temperature (X_T) increases and increases as sulphiditypercentage (X_s) increases. The Pre-beached yield of *Cymbopogon Nardus* Kraft pulp at any pulping conditions was found to be given by the model equation 7.

$Y_{Pb} = 48.31 - 4.26X_T + 1.54 X_s$ R^2 = 0.91 F> 69 P<0.00001 (7)

The model has a coefficient of determination of R^2 of 0.91 which implies the model equation fits the data at 91% confidence level. The kappa number did not show a significant dependence on the combination of sulphidity and cooking temperature. The model equation 8 shows that the kappa number of Paspalum notatum soda pulp decreases as both the cooking temperature (X_T) and sulphidity percentage (X_S) increases.

$Y_{KP} = 35.08 - 8.63 X_T - 2.40X_S$ at R^2 = 0.88, F>48.13, p<0.00001 (8)

The pre-bleached yield of Kraft paspalum pulp is described by the model equation 9

$Y_{Pb} = 35.61 - 2.08 X_T + 1.13X_S$ at R^2 = 0.86, F> 40.50, p< 0.00001 (9)

According Rama et.al,[23], multiple linear regression analyses with coefficients of determination R^2greater than 0.90, indicate that models satisfactorily fit the experiment data. And also according to Neseliet al [12] that if the R^2 values are very close to 1indicates that the developed equations are good statistical models

.

Table 4: Response table S/N ratio for kappa number for the *Cymbopogon Nardus* and paspalum notatum Kraft pulp

Plant Materials	S/N ratio	Level					
		1	2	3	4	dB	Rank
Cymbopogon Nardus	**For Temp (T)**	-39.03	-37.19	-33.15	-30.36⋆	8.67	**1**
	For Sulphidity	-37.08	-36.20	-35.17⋆	-35.76	1.19	**2**
Paspalum notatum	**For Temp (T)**	-32.97	-31.66	-29.48	-28.98⋆	3.99	**1**
	For Sulphidity	-31.75	-30.81	-30.22⋆	-30.83	1.23	**2**

⋆Highest S/N ratio Value

3.3 Confirmation Test of models

The developed model equations were tested in comparison with experimental results at a pulping condition of 20% of the cooking liquor charge/sulphidity and cooking temperature of 160°C. The error percentages of all the estimated values of kappa numbers from model equations to the experimental values were all less than 10%indicating that model equations were in agreement with experimental data(Table 5).

4.0 CONCLUSION

From Findings, it can be concluded that the effectiveness of the pulping methods improves with increase in:

- Cooking temperature.
- Soda charge in case of soda pulping
- Sulphidity in case of Kraft pulping

According to Taguchi design model the optimal pulping conditions are 25%soda charge and30% sulphidity; at a cooking temperature of 160°C for soda pulping and Kraft pulping respectively. The multivariable regression model equations can be used to extrapolate experimental data. Basing on the kappa numbers at a given active alkali charges that the two methods and their optimalconditions did not significantly differfor the two fibrous plants. Although the magnitude of the yields and kappa numbers for the two grass species differed.

ACKNOWLEDGMENTS

The authors would like to extend their sincere thanks and acknowledgement to the Swedish International Development Agency (Sida) for financing this research work. Also special thanks Makerere University, Busitema University and Natural Chemotherapeutics Research Laboratory Ministry of Health, Uganda, for research facilitations offered.

Table 5: Values of Kappa number from experiments and regression model equations along with percentage errors

Method	Plant material	Cooking Liquor charge (S)	Cooking Temp °C (T)	Estimated Kappa number from Model equations	Experimental Kappa number	Error percentage
Soda-AQ pulping	Cymbopogon nardus	20	160	30.53	32.8	6.93
	Paspalum notatum	20	160	26.84	26.8	0.15
Kraft Pulping	*Cymbopogon Nardus*	20	160	31.40	31.34	0.19
	Paspalum notatum	20	160	27.27	28.10	2.96

References

[1] Research & Development Report 2013 The Swedish forest industries facts and figures 2013© 2014 Swedish Forest Industries Federation

[2] Amba Research, 2008,LatAm industry report on Pulp and paper August 2008, Amba Investment Services Ltd. © Amba Holdings Inc.

[3] Marketing Initiatives, 2007, Environmental leadership in the paper supply chain. The new paper fibre basket, Trend Report 2007 pp.9

[4] Dutt, D., Upadhyaya J.S., Malik R.S., and Tyagi C.H., 2005, Studies on pulp and papermaking characteristics of some indian non-woody fibrous raw materials: PartI" cellulose chem. Technol.39(1-2), pp 115-128

[5] Dutt, D., Upadhyaya J. S., and Tyagi C. H., 2010 "Studies on hibiscus cannabinus, hibiscus sabdariffa and cannabinussativa pulp to be a substitute for softwood pulp- Part1: As-Aq Delignification process" Bioresources 5 (4) pp. 2123-2136.

[6] Skerman P.,J. and Riveros F., 1990 Tropical grasses, Food and Agriculture organisation of the United Nations pp 96-240

[7] Duke J.A, 1983, Handbook of energy crops (unpublished).

[8] Paavilainen, L., 1996. Modern non-wood pulp mill-process, concepts and economic aspects, TAPPI Proceedings, NA 254 C. Nonwood Fiber Symposium, Atlanta, GA, USA, pp. 227–230

[9] Katri Saijonkari- Pahkala, 2001, Non-wood Plant as raw materials for pulp and paper, PhD Academic Dissertation Faculty of Agriculture and forestry, University of Helsinki 2001 Finland

[10] Kamoga O. L., Byaruhanga J.K., and Kirabira J. B., 2013a "Characterisation of Ugandan selected grasses and tree leaves for pulp extraction for paper industry., International journal of scientific and technology Resaerch Vol. 2 issue9, issn2277-8616

[11] Kamoga O. L., Byaruhanga J.K., and Kirabira J. B., 2013b "A review on pulp manufacture from Non-wood plants, International Journal of chemical Engineering and Applications Vol.4 No.3 pp144-148

[12] Neseli S., AsilturkI. and CelikL., 2012, "Determining the optimum process parameters for grinding operations using robust process, Journal of Mechanical science and technology 26(11) pp 3587 -3595 Springer publishers.

[13] Rosa J.L. Robin A., Silva M.B., Baldan C.A., Carlos and Peres M.P., 2009 "Electrode-position of copper on titanium wires: Taguchi experimental design approach". J. Material processing Technology 209 1181-1188

[14] Marcel P., 2009 JMP 8 Design of experiments Second Edition Chapter 9 , JMP SAS Institute Inc. SAS Campus Drive North Carolina pp179-190

[15] Ma, X.J., Huang , L. L., Chen Y. X., Cao, S. L. and Chen L H., 2011, "Preparation of bamboo dissolving pulp for textile production part1, Study on prehydrolysis of green bamboo for producing pulp for dissolving pulp. BioResuorces Vol. 6 pp 1428-1439

[16] Ma, X.J., Huang L. L., Chen Y. X., Cao S. L., Luo X. and Chen L H., 2012, "Preparation of dissolving bamboo pulp for textile production part2, Optimisation of pulping conditions of hydrolysed bamboo and its kinetics BioResuorces Vol. 7 ser2 pp 1866-1875

[17] Tagushi G., 1990, Introduction to quality engineering, Asian productivity Organisation Tokyo.

[18] Lalit K. Dharm D. and Amit B., (2013) "Delignification of Phragmites Karka a wetland Grass by soda process", BioResource Vol8 (3) pp 3426-3437

[19] Dharm D. Arvind K. S., Swarnima A. and Archana G. 2012 "Characterization of Dogs Tooth grass and its delignification by Soda pulping process" Journal of Science and Technology Vol.1 No.8 PP 434-447 IJST Publication UK.

[20] Jalal S., Morteza A. B.M., Zeinaly F., AhmadreZa S., and Tayebe S., 2011, "Tobacco residuals as promising lignocellulosic materials for pulp and paper industry. BioResources vol.6 No.4 pp4481-4493

[21] Gustafson, C., 2012, "Reducing Variation in Mill Control Variables by Evaluation of Differences inPulp- and Paper Properties of Two Pine Species," Dissertation Master of Science in Engineering Technology, Chemical Engineering Design, Luleå University of Technology, Department of Civil, Environmental and Natural Resources Engineering.

[22] Macleod M., 2007, "The top ten factors in Kraft pulp yield" Paperijapuu- Paper and Timber Vol.89 No.4 pp. 1-7.

[23] Rama R.S. and Padmanabhan, G., 2012 "Application of Taguchi method and ANOVA in optimization of process of parameters for metal removal rate in electrochemical machining of Al/5% SiC composites" International Journal of engineering Research and Application Vol.2 Issue 3 pp.192-197.