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Utilization of Sudanese Natural Resources for Manufacturing of Paper and Pulp

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Abstract*:* Paper is an important element of our daily life, it is used for writing, printing, cleaning, decoration and packaging. This research is concerned with the importance of paper industry and the relevance of different manufacturing approaches to the daily needs and the available raw materials. The main objective of this research is to investigate the suitability of the Neem (Azadirachtaindica A. Juss) wood for the manufacture of paper and pulp. Samples of the Neem wood were investigated in the laboratory and many tests were made during the manufacturing process to adjust the paper quality produced. Furthermore, several quality tests were carried out on the manufactured paper and compared with recognized standards. It was found that the paper manufactured from Neem wood is of good paper quality and made a good use of a locally available raw material.

Keywords: *Pulp, Paper industry, Neem (Azadirachtaindica A. Juss).*

1. INTRODUCTION

Paper is a thin material mainly used for writing, printing or packaging. It is produced by pressing together moist fibers, typically cellulose pulp derived from wood, rags or grasses, and drying them into flexible sheets. Paper is used today in almost every activity and on day to day bases. For this we should thank the Chinese from a couple of millennia ago, as they were the first to make and then perfect the art of making paper. With the Europeans traveling to China the spread of paper went global. Until the boost of technology seen today paper was used in everything that involved office work, it is still used today although computers are finding new applications every day [1].

Paper is used for writing and printing. Books, magazines and newspapers are printed on paper. Also paper used for money is often made in very special ways, to make it hard for people to print their own money. Paper can be used for cleaning, such as paper towels, facial tissues, or toilet paper. Pretty paper can be used as decoration. It can be pasted onto the walls of a room, this is called wallpaper. Paper can be used to wrap gifts, This is called wrapping paper or gift wrap. Some kinds of paper are strong and can be used in boxes and other packaging material. Sometimes several layers of paper are held together with glue, to make cardboard[2][3].

Sudan is considered as one of the most suitable Arab countries for pulp manufacturing [4][5]. The first factory was built in the southern part of Sudan,were it depended on papyrus, which is found in large quantities in the areas of dams; however, the factory was shutdown.There was another factory in Toker which produced pulp from cotton stems planted in Delta Toker, but it was also shut down due to the fact that it was second hand and old fashion [6].

]. According to a preliminary study made by the Arab Organization for Agricultural Development in January 1991, regarding the status of suitable raw materials for paper industries in the Arab world, Sudan was recognized as having the richest potential[3][7]. It has the adequate supply of the necessary raw materials for making paper, such as fibers and other ingredients.Pulp ingredients for paper industry in the Sudan includes[8][9][10]11]:

a) **Fibers:** There are many fibers that make good pulp for paper industry. Papyrus is one of them. It is found in large quantities in the south of the Sudan.

b) **Kinaf:** The main uses of kinaf fiber have been rope, twine, coarse cloth, and is also used for animal feed. It is grown successfully at Abu Nea'ma in the Blue Nile State.

c) **Cotton stems**: a large area of land is planted with cotton.

d) **Bagasse:** The quantity of sugar cane pressed yearly in Sudan isabout 6 million tons. The dry remnants can yield up to 27,000tons of white pulp.

e) **Wheat remnants**: The area planted with wheat is very large. Consequently, a large amount of pulp can be produced.

f) **Bamboo:** Sudan is rich with African bamboo[13]. It grows naturally in the south of Kassala, Nuba Mountains, Ad-Dair Mountain in Kordfan, Copper Ditch and Zalinje in Darfur, Angessana Mountains in Blue Nile.

g) **Wood:** forests cover 22% of the total area of the Sudan prior to the separation of South Sudan; about127,000,000 acres. These forests are natural and ever-renewableresources. Their annual production exceeds the local consumption. Therefore any surplus can be used in paper industry or in other woodworks[12].

Neem (Azadirachtaindica A. Juss) [9][10],is a fast-growing tree[30] that can reach a height of 15-20 m (about 50-65 feet), rarely to 35-40 m (115-131 feet). It is evergreen but in severe drought it may shed most or nearly all of its leaves. The branches are wide spread. The fairly dense crown is roundish or oval and may reach the diameter of 15-20 m in old, free-standing specimens. The trunk is relatively short, straight and may reach a diameter of 1.2 m (about 4 feet), as shown in Fig.1. The bark is hard, fissured or scaly, and whitish-grey to reddish-brown. The sapwood is greyish-white and the heartwood reddish when first exposed to the air becoming reddish-brown after exposure.

The root system consists of a strong taproot and well-developed lateral roots[9][14]. Currently there are few published tests and research on the possibility of utilizing Neem trees in Sudan for the manufacturing of pulp. It is also worth mentioning that there are no special forests presently grown in the Sudan yet.

2. MATERIALS AND METHODS

The first step for manufacturing pulp from Neem is cutting the logs into small pieces called chips (Fig.2.a) these chips have a thickness of around 1.5-2 mm and a length of approximately 2.54 cm. Sodium hydroxide was used as cooking liquor for preparing the pulp (soda process)[15][16]. Further tests for the raw materials and final products were investigated as per standard methods and were reported in details.

2.1 Experimental Procedure

Firstly, a moisture content test was conducted in the laboratory to compute the moisture in chips to be eliminated from the weight[17][18]. In this procedure, three samples from chips (Fig.2.b) were taken and weighed by sensitive balance (Mettler), and was then put into a furnace for 24 hours and weighed [19]. The moisture content (Y'_{H_2O}) for chips was 5%, and calculated [19] as follows:

$$Y'_{H_2O} = \frac{(S_{Before} - S_{After})}{S_{Before}} \quad (1)$$

Where S_{Before} , S_{After} are the weights of chips in (g) before and after drying respectively. In addition, sodium hydroxide was used as cooking liquor for preparing the pulp(soda process) [18]. The quantity of (NaOH) required to cook chip is calculated [18] as follows:

$$NaOH\,\% = \frac{15 * Equiv.Weight_{NAOH}}{Equiv.Weight_{NA_2O}} \quad (2)$$

The ratio of water used with NaOH to the oven dry chips was 1:4. The prepared chips and caustic soda solution were carried to the digester for cooking process to freeing the cellulose fibers from lignin by chemical reaction[20]. A mass of 1163 g from chips weighed and put into the digester (Fig.2.c) and tightly sealed, the temperature and pressure were adjusted at (170°C-10 bar) respectively. It was found that the cooking process took 139 minutes to reach the temperature above, the digester was left for 90 minutes after reaching a temperature of 170°C and then opened, and thereafter the fibers of wood were disengaged from lignin.

Fig.1: Neem tree and wood

The initial pulp (Fig.2.f) was screened from the black liquor (NaOH + lignin) (Fig.2.d) then it was washed by a hot water for several times to eliminate the residual lignin [21], the pulp was weighed then taken to the mixer (Fig.2.h). The mixing process allows for fibers to disengage from each other, a quantity of water was added to the pulp in the mixer. After the mixing process the pulp was taken to a screen [18] (Fig. 2.g) to remove knots, unreacted chips, the pulp then was tightly dried and left for 24 hours. Three samples of pulp were taken to calculate the moisture content. The moisture content for pulps was measured as 78.6% with a moisture content factor (M.C.F) of 21.4% for pulp samples.

Table 1. Moisture content of Chips: (2 gram)

Before drying	
vessel weight (gram)	chips weight (gram)
W_1 = 26.348	S_1 = 2.079
W_2 = 40.101	S_2 = 2.001
W_3 = 30.054	S_3 = 2.005
After drying	
Total weight (vessel + chips) (gram)	chips weight (gram)
W_1 = 28.322	S_1 = 1.974
W_2 = 42.003	S_2 = 1.902
W_3 = 31.956	S_3 = 1.902

Table 2. Moisture content of Pulp: (2 gram)

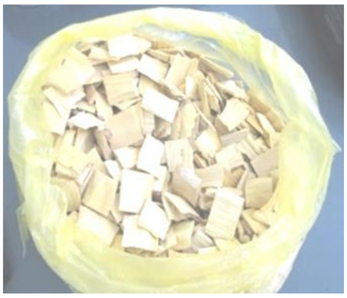
Before drying	
vessel weight (gram)	Pulp weight (gram)
W_1 = 46.058	S_1 = 2.042
W_2 = 45.254	S_2 = 2.013
W_3 = 40.102	S_3 = 2.017
After drying	
Total weight (vessel + pulp) (gram)	Pulp weight (gram)
W_1 = 46.459	S_1 = 0.401
W_2 = 45.658	S_2 = 0.404
W_3 = 40.496	S_3 = 0.484

The pulp and impurities resulting from screen were weighed for yield computation [22][18], the following equation was used:

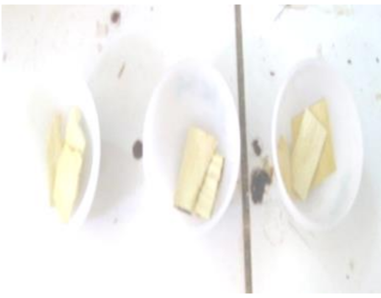
$$Screened\ Yield = \frac{oven\ dry\ weight\ of\ pulp}{oven\ dry\ weight\ of\ chips} \quad (3)$$

The reject ratio from the pulp was measured at 0.67%. The total yield for the final product is42.07 %.Inthe beating process the prepared pulp was dissolved into specified quantity of water and then moved to beater machine to improve the properties of paper. Beating the fibers makes the paper stronger, more uniform, denser, more opaque, and less porous. Bonding between fibers is also increased. After 30 minutes from the beginning of beating process, the beater was shut down to take 1000 ml of dissolved pulp. Thevolume was taken to the disintegrator to distribute the fibers properly, Fig.4,for 5 minutes.The volume then was completed to 5200 ml, 400 ml from this volume was measured and carried to paper manufacturing machineto make paper sheets, this step was repeated until the volume 5200 ml finished.

In the sheet forming machine, the volume of 400ml was added to the machine and completed by water. A screen is located at the bottom of the machine. When the arm of the machine is moved, the screen allows for water to pass through and the fiber is retained above the screen where the sheet was formed,(Fig.3). A heavy load was passed upon the paperand then picked upas shown in Fig.5.



(a) : The initial chips



(b) : The three samples of chips for moisture test

(c): Samples inside digester

(d): Pulp separated from black liquor

(e): The prepared chips

(f): Initial pulp from the digester

(g): S ject
From the pulp.

(h): Mixer rotates for 5 min.

Fig.2. Preparation of samples and production stages in lab

shown in Fig.5.It found that the sheet stuck on the paper, (Fig.6) which was left for a while until the sheet became dry and disengage from the paper,(Fig.7). The procedure was repeated after 15, and 30 minutes. The load was added to the beater in the above intervals to improve beating process.

Fig.3:Sheet forming on the bottom screen

Fig.4: Disintegrator

Fig.5: A heavy load was passed on the paper

Fig.6: The sheet stuck on the paper

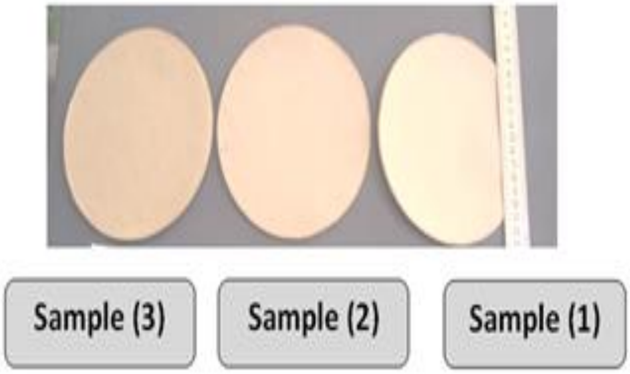


Fig.7: Three batches of paper sheets

3. RESULTS AND DISCUSSION

3.1 Freeness Test

This test was conducted to determine the quantity of water contained in the paper sheets [23].The (Schoper Reigler) device was used [12] for this purpose. 160 mL of dissolved pulp in digester was taken and completed to volume 1000 mL water, then put into the device which contains screen stopping the pulp and allows for water to pass[24]. The volume of water passed was contained in a measuring cylinder (V_{H_2O}), and the freeness was predicted according to the equation [23] below:

$$Freeness = \frac{\left(V_{H_2O} - 1000(ml)\right)}{10} \quad (4)$$

Before adding the load to the paper sheet the degree of freeness showed a value of22 °SR, 15 minutes later reached 29 °SR, and after 30 minutes reached a value of 40 °SR. It was observed that the freeness of paper sheet tends to decrease by refining and by increasing the intensity of fines in the fiber furnish.

3.2 Quality Tests

The manufactured paper sheets were taken for testing to investigate the properties. Five paper sheets were selected from each batch to perform these tests. Several tests were carried out in the laboratory as detailed below.

3.2.1 TensileTest

This test was conducted to recognize the capability of paper sheets to resist tensile forces[25].From each paper sheets batch, three pieces of a length of 15 cm and a width of 1.5cm were taken.8pieces from these were used for the tensile test using the Tensile tester,[26][27].It was observed that for sample sheets 1,2 and 3, the average tensile force reached 2.32, 2.92 and 3.9kN/m respectively which was found consistent with the recognized standard ofSudanese Standards and Metrology Organization (SSMO)[28], since the recognize standard for writing and printing paper are 3 kN/m.

3.2.2 BurstTest

This test was conducted to examine the capability of paper sheet to resist the penetration[29]. Two readings were taken for each sheet by burst device[31]. For bursting strength test, the average of measured reading was 1.0 kPa compared to Sudanese Standards [28] value of 0.9 kPa.

3.2.3 FoldingTest

This test was carried out to investigate the capability of paper to make double folds[32][33]. 7 pieces of each sample was taken toa foldingmachine, when the piece was fixed on the device [34], the cutter in device cuts the piece and the counter readthe average number of double folds of 0, 1, 2 for each sample. The measured numbers of double folds were consistent with Sudanese Standards[28].

3.3 Weight Computation

The three batches of paper sheets wereweighed by sensitive balance[25]. The tables below show the results for each five sheets for three different batches.

Table3. Actual and standard samples weight

Sample (1) g	Standard Sample (1) g	Sample (2) g	Standard Sample (2) g	Sample (3) g	Standard Sample (3) g
1.31	2.0764	1.20	1.9020	1.41	2.2349
1.45	2.2980	1.32	2.0922	1.44	2.2824
1.28	2.0288	1.35	2.1398	1.3	2.0610
1.28	2.0288	1.27	2.0130	1.45	2.2983
1.3	2.6050	1.33	2.1081	1.43	2.2666

The standard weight [25] of paper sheet (W_s) for each sample was predicted as follows:

$$W_s = \frac{A_s}{A_a} * W_a \quad (5)$$

Where A_s , A_a are the standard and actual area measured in the lab for each paper sheet in (cm^2) respectively while W_a is the actual weight of paper sheet in (g).Standard readings are given for paper sheet with an area of317 cm^2. The manufactured paper sheet in the lab has an area of 200 cm^2. As indicated the actual sample delivered acceptable deviations compared with standard weight.

3.4 Thickness Computation

Paper sheets were taken to measure their thickness [35][36], five random readings were taken from measuring scale for each sheet. The micrometer device was used[37]. Table (4) below shows the thickness results:

Table 4. Average of thickness for paper sheets

No	Sample (1) (mm)	Sample (2) (mm)	Sample (3) (mm)
1	0.178	0.128	0.149
	0.169	0.148	0.166
	0.187	0.148	0.150
	0.159	0.151	0.175
	0.172	0.152	0.159
Avg.	**0.173**	**0.145**	**0.159**
Stdv%	**1.040**	**0.988**	**1.098**
2	0.180	0.144	0.183
	0.210	0.159	0.160
	0.175	0.159	0.163
	0.152	0.171	0.174
	0.160	0.120	0.232
Avg.	**0.173**	**0.145**	**0.159**
Stdv%	**2.237**	**1.960**	**2.910**
3	0.172	0.130	0.165
	0.170	0.134	0.167
	0.152	0.140	0.186
	0.158	0.128	0.143
	0.159	0.135	0.168
Avg.	**0.173**	**0.145**	**0.159**
Stdv%	**0.850**	**0.450**	**1.530**
4	0.181	0.143	0.188
	0.170	0.160	0.163
	0.163	0.152	0.190
	0.165	0.171	0.123
	0.174	0.169	0.111
Avg.	**0.173**	**0.145**	**0.159**
Stdv%	**0.720**	**1.170**	**3.650**
5	0.160	0.174	0.104
	0.179	0.165	0.140
	0.182	0.155	0.124
	0.181	0.171	0.152
	0.169	0.158	0.169
Average	**0.173**	**0.145**	**0.159**
Stdv%	**0.950**	**0.810**	**2.500**
T. Avg.	**0.173**	**0.145**	**0.159**

The thickness of the paper produced was also compared against recognized standards. It was found that the average thickness (t_{avg}) of paper produced was 0.159 millimeter with standard deviation of less than 2.30%.The standard recognized thickness was performed between 0.07-0.18 millimeter[28]. According to thickness data, the density, specific volume (V_s)[38] and tensile index(T_{index})[39][40] of paper sheet were measured.

Table 5. Density and Tensile index data for different beating intervals.

Property	Sample (1)	Sample (2)	Sample (3)
Beating degree (°SR)	22.00	29.00	40.00
Beating time (min)	0	15	45
Spec. Volume (cm^3/g)	2.680	2.38	2.15
Density (g/cm^3)	0.373	0.42	0.47
Burst pressure (kPa)	0	1	1
Tensile-Index (Nm/g)	35.8	44.3	54.4

The paper sheet reached nearly 55 Nm/g tensile index. This indicates an improvement in the properties of produced paper with increased beating time. These relations [38] [39]were performed as follows:

$$V_s = \frac{t_{avg} * 31.7}{W_{avg}} \tag{6}$$

$$T_{index} = \frac{T_{avg} * 31.7}{W_{avg}} \tag{7}$$

It was observed that when the beating time was increased, the density, specific volume, and tensile index of paper also increase.

4. CONCLUSIONS

The Neem tree is one of the most common trees in the Sudan. It has the ability to grow in severe conditions and its usage as a raw material in the Sudan is relatively low. Due to these reasons this research aims to investigate the possibility of producing good quality paper from the Neem wood. Based on this experimental study, the following conclusions were drawn:

- Preparation of the Neem logs is considered the first step in the manufacturing process considered. Samples of Neem logs were taken and broken down into small pieces (chips). The following step is the cooking process, the purpose of this step is to free the fiber from the wood to make initial pulp. Several cooking liquors could be used in the cooking process such as sodium sulfate, sodium sulfite, or caustic soda. In this experiment caustic soda was used because it is the most convenient with the hard woods such as the Neem wood. The cooking process was carried out in the digester machine, in the factory many additives are added in this step to improve the properties of paper such as chlorine and sodium/calcium hypochlorite needed for bleaching to aid the production of white paper. This process was not carried out in the experiment due to the scarcity of the chlorine in the laboratory. The pulp was then taken to the turbo pulp machine to fritter the fibers from each other, prior to its feed to a screen machine where unreacted wood is separated from the pulp.

  - The next step in the manufacturing process is the beating process, this process makes the paper stronger, less porous, and the bonding between fibers is also increases. The last step in manufacturing process is carrying the dissolved pulp to the sheet forming machine to make the paper sheets.

- The thickness of the paper producedwas measured (0.159 mm) and compared with Sudanese Standards. It was found that the average thickness of paper produced is acceptable, consistent with Sudanese Standards data(0.07-0.18 mm). It can therefore be concluded that the paper manufactured form Neem wood is of reasonable quality and made a good use of locally available raw materials.
- The quality tests which were carried out in the laboratory wasfound to be consistent with the Sudanese Standards. For writing and printing paper the average measured reading of tensile strength was 3.7 kN/m, thus higher than the Sudanese Standards for writing and printing paper of 3 kN/m. Also for bursting strength test, the average of measured reading was 1.0 kPa compared to the Sudanese Standards of 0.9 kPa.

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