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Full Length Research Paper

Production of Paper Pulp Using Sisal Fiber Waste from Sisal Spinning Processes

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ABSTRACT

Disposal of large volumes of textile waste is an escalating problem for textile industries. Sisal spinning industry is the one of the textile industries releasing large volumes of textile waste in the landfills. The rising costs, and reduction of available space together with increasing stringent environmental measures are making burying and land filling of textile waste, a declining option. This study therefore explores recycling options where the potential of using sisal fiber waste produced during sisal spinning processes as raw materials for the production of paper pulp was investigated. Sampling was done at 21stCentury Holdings Limited allocated at Chang'ombe industrial street Dar es Salaam mainly dealer of sisal yarns production. Materials were prepared and cut into small pieces of about ½ inches to reduce the fiber into unit lengths so as to achieve pulping required performance. Pulping process was achieved through Soda pulping techniques with two different effective alkali charges (EA-20% and EA-24%) for 240 minutes under maximum temperature 140◦C, and liquor to fiber ratio 4:1by using Mathis Labomat dyeing Machine. The kappa number obtained was (25.5, 34.5) for material treated under EA 24% and EA 20% respectively, Percentage pulp yield were (47.1, 54.4) for EA 24% and EA20% pulp respectively. Freeness (630CFS, 555CSF) after refining at 4500 rpm. Finally, the resulting pulp was used for hand sheet making and the sheets were tested for their mechanical properties; Grammage (61.1, 61.1) g/m2, Tensile index (9.9, 22.3) Nm/g, Tear index (13.3, 17.4) Nm2/g, burst index (1.7, 3.7 and 1.6) kPa.m^2/g and Elongation at break (2.02, 2.22) % for EA24% pulp, EA20% pulp respectively. The findings shows that sisal fiber wastes have a promising potential for paper pulp production compared to other non-wood raw material.

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INTRODUCTION

Textile factory spinning and finishing processes commonly produces a range of wastes, including pre-consumer wastes which consist of all wastes generated during the processing of the fibers into yarns such as dusts, short fibers, tow (unspinnable fiber), yarns cutting from laboratory quality control tests and yarns that do not meet consumer or user requirements and therefore get disposed. However, the amount of wastes produced during spinning of sisal fibers depends on the quality of the raw materials and machinery settings. Generally, the generation of wastes during spinning processes cannot be neglected since there is no 100% efficiency spinning process (Ljokkoi R, 2000). Statistics show that about 10 tonnes of wastes are produced every month, which is equivalent to a loss of about Tshs 30 million of input materials in addition to Tshs 375,000 disposal costs per 10 tons truck, as reported by the production department at 21st Century Holdings Limited 2018.

In this regard, by-products produced from each production process are regarded as wastes and have no value to the factory.

Literature shows a number of benefits of recycling and re-use of textile wastes. While it is noted that waste disposal in landfills can harm the environment and human health, the requirement of landfill space is reduced when waste is re used. On the other hand, the cost for landfill disposal, which is continuously increasing is also reduced when waste is re used. More importantly, textile waste in landfill contributes to the formation of leachate, the liquid that is produced from the decomposition of waste within the landfill as it decomposes, which has the potential to contaminate ground water (Aggarwal, 2010). Incinerating textile waste in large quantities emits organic substances such as acidic gases and dust particles, which are all harmful to humans and animals (Aggarwal, 2010).

The best way to tackle the waste generated from these spinning industries, is to investigate the way to reuse the wastes coming from the spinning industries.

Commercial and potential methods for pulping non-wood raw materials

Pulping is a process of delignification, whereby the fibers in a raw material are separated (Saijonkari-Pahkala, 2001). Normally, in pulp and paper industries, pulping process is one of key processes. Fibers separation (pulping) could be carried out through chemical, semi-chemical, and mechanical (like thermo-mechanical) pulping processes (Sridach, 2010b). There are different processes suitable for pulping non-wood plants, but commercially, only a few of them are commonly used. Regularly employed methods include alkaline processes (such as Sulphate (Kraft), Caustic Soda (NaOH) methods, and oxygen alkali method), sulfite methods (such as neutral sulfite and alkaline sulfite pulping), Organ solvent pulping (Pulping with organic solvents such as alcohol solvents like methanol and ethanol, Organic acids solvent like formic acid, acetic acid, and formic acid + acetic acid, Ester organic solvent like ethyl acetate, Compound organic solvent like methanol+ acetic acid and ethyl acetate + ethanol + acetic acid, Phenol organic solvents like phenol, and Active organic solvents (Zhong Liu*, 2018).

In this project, sample of sisal fiber wastes were pulped using soda pulping liquor as it contributes to higher paper strength produced (including tearing and tensile strength) and also it produces pulp yield with better quality.

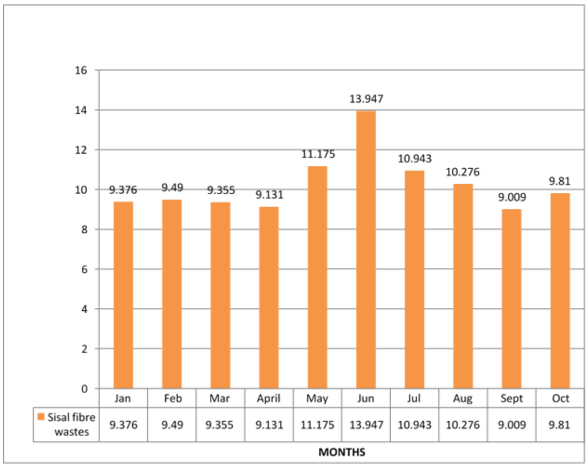

Figure 1: Amount of sisal fiber wastes in tons produced at 21stCentury Holdings Limited 2018

METHODS AND MATERIALS

Materials and Pre-processing

This study mainly used Sisal fiber wastes from spinning factory 21stCentury Holdings Company Limited, as a primary source of materials.

Short fiber Wastes and dusts were collected and cut into small pieces of about ½ inches to reduce the fiber into unit lengths. Pulp production was achieved by Soda pulping process with two different effective alkali charges of EA-20% and EA-24% for 240 minutes under maximum temperature 140◦C, and liquor to fiber ratio of 4:1(see Table 1 below)

Table 1: Pulping conditions during pulp production at liquor ratio 4:1

Effective alkali (EA%)	Temperature (˚C)	Time (Minutes)
20	140	240
24	140	240

PULP CHARACTERIZATION

A sample of short sisal fiber waste was characterized before cooking (pulping) and after cooking by using FTIR spectrum, washed screened pulp was evaluated its modification. The aim was to evaluate the effectiveness of alkali percentages on the material. Sample collection was obtained using 32 scans, in the range of 4000 to 400cm-1, at resolution of 4cm-1. Two different samples of oven dry sisal fiber and oven dry sisal fiber dust were evaluated and 4 different pulp samples treated at different conditions of EA 20% and EA24s% were evaluated. The peak at 1733.8 cm-1 was assigned to C=O unconjugated stretching of carboxylic acid or ester of the hemicelluloses and the peak at 1239.1 cm-1 was assigned to C–O stretching vibration of acyl group present in the lignin (Herrera-Franco and Valadez-González, 2005; Kim and Netravali, 2010). The broad peak in the range of 3300–3500 cm-1 and a peak at 1630 cm-1 were due to the characteristic's axial vibration of hydroxyl group of cellulose (preferably from 2, 3 and 6 carbon of glucose). The peak at around 1080 cm-1 was due to the associated hydrogen group (Mohan and Kenny, 2012). For the evaluation of all spectra was possible to verify that there was no disappearance of any of the major peaks but some modification was done. This indicates that the treatment applied does not alter the chemical structure of the fibers only sisal fiber residues was dissolved/reduced. In order to evaluate the effect of the treatment on mechanical properties of fiber pulp, tensile tests were performed after made a paper sheet.

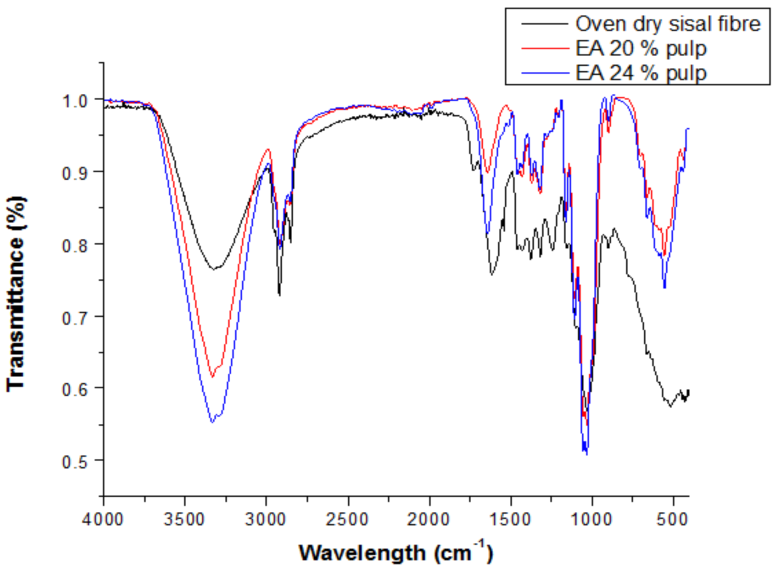

Figure 2: Fourier transform infrared (FTIR) spectrum for oven dry sisal fiber waste before treatment and treated pulp samples

PRODUCTION OF HANDMADE PAPER SHEET

Pulp suspension were dispersed inside clean water into the paper mould and agitated using agitator to achieve uniformity of pulp suspension. Water was then allowed to drain off downward through a sieve wire and the aligned fibers were remained on top of the sieve wire. Aligned fibers onto a sieve wire were removed by using a blotter paper and chrome plate and then pressed with a pressing machine for about 5 minutes. After pressing, the paper samples were then air dried for about 12 hours.

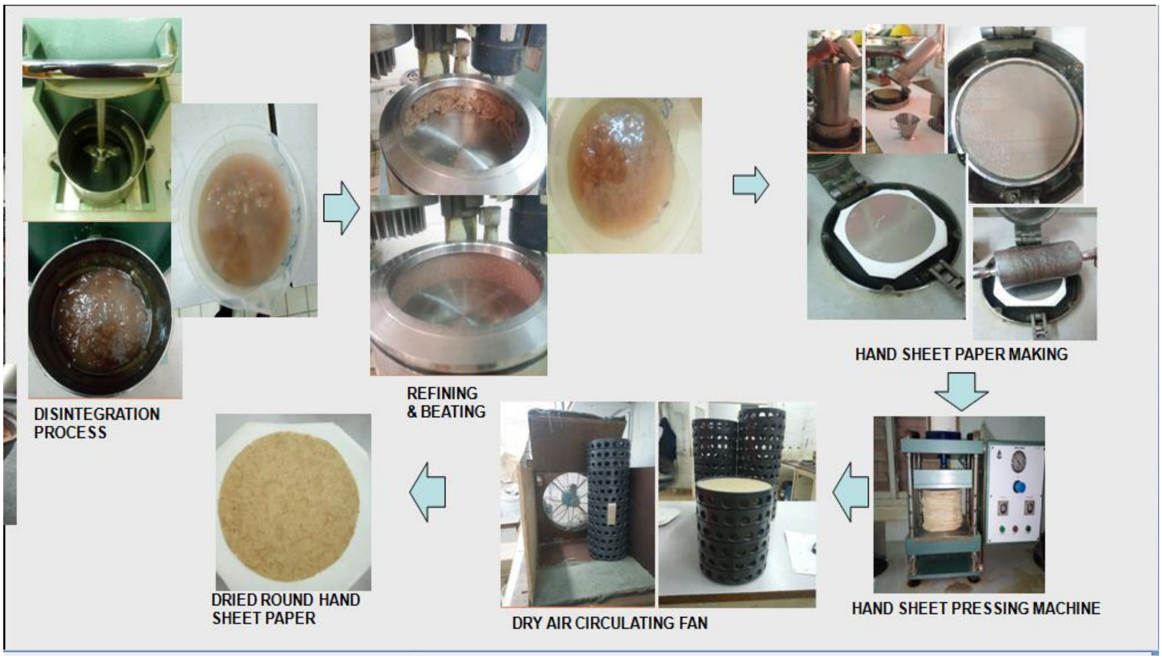

Figure 5: General procedures of hand paper sheet making using sisal fiber waste pulp 2019.

Paper characterization

Paper characterization was done using a Universal Testomeric Machine to determine the Grammage, tensile index, tear index, burst index and elongation at break (stretch). Paper characteristics were used to discuss the quality of pulp obtained for production of various paper products. Therefore, gathered data from the experimental tests were analyzed and compared with other paper pulp made from different non-wood materials and standard wood. In Table 1 shows all the important results obtained from this research project and experimental data analysis compared with various conducted research on the pulp yield and chemical compositions of some common non-wood fibers and hardwood and softwood reported by (Parham and Kaustinen, 1974).

Table 2: Results obtained and potential findings of sisal fiber waste after paper pulp production 2019.

Table 2: Results obtained and potential findings of sisal fiber waste after paper pulp production 2019

Item Description	**Unit**	**Short sisal fiber wastes**		**Sisal fiber dusts**	**Standard Wood paper**
		E.A 20%	**E.A 24%**	**E.A 24%**	
Sun dry raw material weight	Grams	185	150	150	
Oven dry raw material weight	Grams	171	138	142	

Effective alkali dose	%	20	24	24	
Lab digester – cooking temperature	Minutes	240	240	240	
Lab digester – cooking time at 140ºC	ºC	140	140	140	
Cooked and washed pulp oven fry weight	Grams	93	63	20	
Pulp yield	%	54.1	47.1	14.1	40 - 55
Kappa number of disintegrated pulps	number	34.5	25.5	27.1	
Pulp freeness after disintegration (4500 revolutions)	CSF	700	720	520	
Pulp freeness after refining (PFI MILL – 4500 revolutions)	CSF	555	630	**Not refined**	
Substance/Grammage	gr/m^2	61.1	61.1	57.4	
Burst Index	K.Pa.m^2	3.7	1.7	1.6	4+
Tear Index	Nm^2/kg	17.4	13.3	8.9	9+
Tensile Index	Nm/g	22.3	9.9	5.0	36+
Stretch (Elongation)	%	2.22	2.02	2.50	2+

RESULTS AND DISCUSSIONS

Sun dry raw materials 185 gram of short sisal fiber wastes equivalent to 171-gram oven dry weight treated under EA24% NaOH, another sun dry raw materials 150 gram of short sisal fiber wastes equivalent to 138 gram oven dry weight treated under EA20% NaOH and sisal fiber dusts sun dry materials 150 gram equivalent to 142 gram oven dry weight treated under 24%NaOH. After the treatment the potential use of the materials in pulp and paper products was analysed on the basis of potential percentage pulp yield and mechanical properties of the paper sheets. Therefore, the pulp yield calculated by using gravimetric method, the results was 54.4% pulp yield for the material treated under EA20% NaOH, 47.1% pulp yield for material treated under EA24%NaOH and 14.1% pulp yield obtained after treated sisal fiber dusts under 24%NaOH. From the results obtained, compared with the standard wood pulp yield 40 – 55 % this could show that, if sisal fiber waste collected and treated under EA20% NaOH and EA24% NaOH respectively about 54.4% and 47.1% pulp yield can be obtained and have potential use for pulp production for making various paper products such as paper boards, eggs trays, leather boards and filter papers and different composites materials. However, for the sisal fiber dusts the results shows pulp yield was 14.1% which follow below average standard therefore has no potential in pulp production. Mechanical properties of the paper which were tensile index, burst index, tearing index and Grammage/substance and elongation. In Table 2 of the results show the burst index and tensile index follows below average of standard wood properties this as the results of the high freeness value of the pulp obtained during stock preparation which lead to poor fiber to fiber bonding and the effects of low pulping temperature to high effective alkali dosage at long time interval of the treatment during pulp production.

CONCLUSIONS

The research paper clearly demonstrates that, sisal fibre waste at the correct fibre length can be used as a raw material for paper production. Significant pulp yield was obtained when sisal fibres of average ½ inch were used. Soda pulping with EA20% and EA24% was found to be significant method and produced pulp yield of 54.1% and 47.1% respectively.

A mechanical comparison of paper produced from sisal fibres had good relation with wood fibres in some areas but did deviate on some due to raw materials and process factors.

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