Thermal and chemical analysis of Sudanese biomass for energy and materials production

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Context and objectives

Sudan is one of the richest countries in Africa characterized by the presence of several biomass sources; the basic form of biomass comes mainly from agricultural and wood residues (Omer and Fadalla 2003). Biomass could contribute to the replacement of fossil fuels and reduction of emission of CO_2 according to the environmental regulations in Sudan and Europe. However in Sudan, so far their utilization is still at the experimental level and not very much has been scaled up to the industrial level (Omer 1998). Constraints for widespread use of these fibers include the limited consistency in the quality of fibers, their thermal instability and lack of availability of sufficient data on their properties. As important contributing factors to understand current and future application, potential, economical, ecological, legislative as well technological aspects need to be looked into (Fei et al. 2008), responding to the increasing awareness and concern among the world population toward new environmental regulations. Growing socioecological issues, high rate of depletion of petroleum and mineral resources have promoted an intensive use of biomass wastes. Biomass residues from agricultural wastes are exploring the potential of using cheaper, nontoxic, and renewable resources for the production of energy and composite materials (Ibrahim et al. 2012).

This project will initially examine opportunities for valorization of Sudanese biomass for energy and new biomaterial composites. This could be done by assessing the thermal, chemical, physical and mechanical properties of some natural fibers such as Cotton stacks, Bagasse and Kenaf in order to establish a model for their thermal decomposition and degradation (Jawaid et al. 2017). Establishing of such thermal study is of great importance as extensive knowledge on the thermal decomposition of these fibers is needed considering that in both applications the fibers will be processed at high temperatures (Asadullah. 2014).

Materials and Method

The Sudanese fibers that used in this study are: cotton stacks (4.5 kg), bagasse, the fibrous residue of the cane stalk from a sugar mill after crushing and extraction of the juice (7 Kg) and kenaf, warm-season annual fiber crop where the fibers are extracted from their stalks (2.6 kg). Cotton stalks and Kenaf are collected from Al-Gezira state, Central part of Sudan. Bagasse is provided by the White Nile sugar company.

Thermal analysis. The thermal degradation was performed by using a thermogravimetric instrument (TGA Q50 Instrument) in the Xylomat laboratory in Mont de Marsan, France. Bagasse, kenaf and cotton Stalks were used to study their thermal degradation. For this, 10 mg of sample powder of samples was weighed and put in the small pan for the instrument. The temperature program was from 30 to 600 °C at a heating rate of 10 °C /min. The measurement was conducted under air with a flux of 60 ml/min. Each test was done three times.

Chemical analysis. The chemical characterization of the bagasse, kenaf and cotton stalks including moisture content (105 °C after 24h00), ash (575 °C during 3h00), solubility in hot and cold water, extraction by NaOH (1 %), extraction by organic solvent (ethanol and hexane), cellulose (ethanol and nitric acid) and lignin (sulfuric acid 72 %), was done at the National center for research in Khartoum, Sudan, by using TAPPI standard methods.

Determination of the total phenolic content of bagasse, kenaf, and cotton stalks was done in Xylomat laboratories in France according to Folin-Ciocalteu method according (Aloui et al. 2004). A volume of 2.5 mL of Folin-Ciocalteu reagent was added to 1 mL of aqueous extract, diluted ten times and after 1 minute of incubation, 2 mL of sodium bicarbonate (75 g/L) were added. Then, mixtures were allowed to stand 5 min in a water bath at 50°C. After cooling, sample absorbance was compared with versus prepared water blank was and monitored with a Jenway 6300 spectrophotometer at 760 nm. A solution of gallic acid solution (100µg/mL) was used for calibration. The final results were expressed as % gallic acid equivalent (GAE) per g of dry weight (DW).

Results and Discussion:

Thermal analysis

The thermogravimetric analysis curves for bagasse, kenaf and cotton Stalks respectively were characterized by the same evolution of the mass loss versus temperature as shown in Fig. 1 to 3. The results showed help to understand the thermal behavior of fibers and their applications.

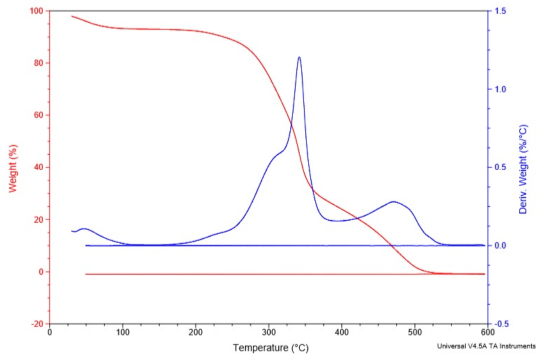

Fig .1: TG & DTG curves of Bagasse

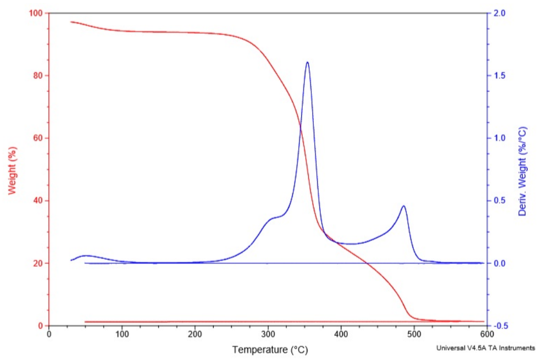

Fig. 2: TG & DTG curve of Kenaf

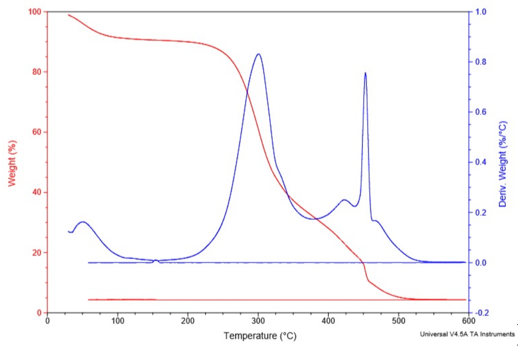

Fig. 3: TG & DTG curve of Cotton Stalks

The analysis of TG & DTG curves for the fibers shows that the kenaf fiber is more stable than bagasse and cotton stalks, while bagasse is more stable than cotton stalks.

Chemical analysis

The chemical characterization for the bagasse, kenaf and cotton stalks are shown in the table below:

No	Test	Bagasse	S.D	Kenaf	S.D	Cotton Stalks	S.D
1	M.C %	7.80	0.07	5.27	0.026	4.47	0.14
2	M.C.F	0.9220	0.00087	0.9472	0.00026	0.9552	0.0014
3	ASH%	8.07	0.054	2.54	0.014	5.36	0.033
4	Extraction by hot water %	14.15	0.123	4.64	0.026	15.51	0.24
5	Extraction by cold water %	11.96	0.038	2.75	0.013	11.33	0.23
6	Extraction by hot NaOH %	43.27	0.123	16.52	0.24	31.43	0.30
7	Cellulose %	50.70	0.27	56.42	0.017	40.94	0.045
8	Extraction by Ethanol%	9.95	0.016	10.11	0.029	9.47	0.022

9	Extraction by Ethanol + n. hexane %	0.190	0.022	0.034	0.0016	0.328	0.0016
10	Extraction by hot water after Ex %	7.98	0.037	6.76	0.043	7.95	0.029
11	Lignin %	21.62	0.016	9.97	0.0082	21.29	0.016
12	Total phenols (%)	1.451	0.0357	0.473	0.0095	3.270	0

The results of the total phenols of bagasse, kenaf, and cotton stalks showed that the fiber with the highest phenol concentration is cotton stalks followed by bagasse and finally kenaf.

The thermogravimetric analysis has shown the stability of fibers below 200 °C. All these results permit us to give a better understanding of the potential use of Sudanese fibers in the future. The chemical analysis for the bagasse has shown that the percentage of cellulose and lignin is 50.70 % and 21.62 % respectively, 42.42 % and 9.97 % for kenaf and 40.94 % and 21.29 % for cotton stalks. The results of the total phenols of bagasse, kenaf, and cotton stalks showed that the fiber with the highest phenol concentration is cotton stalks followed by bagasse and kenaf.

These results permit to enhance the uses of fibers and to understand their current and future application in order to provide the global market with new materials for innovative industrial applications.

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