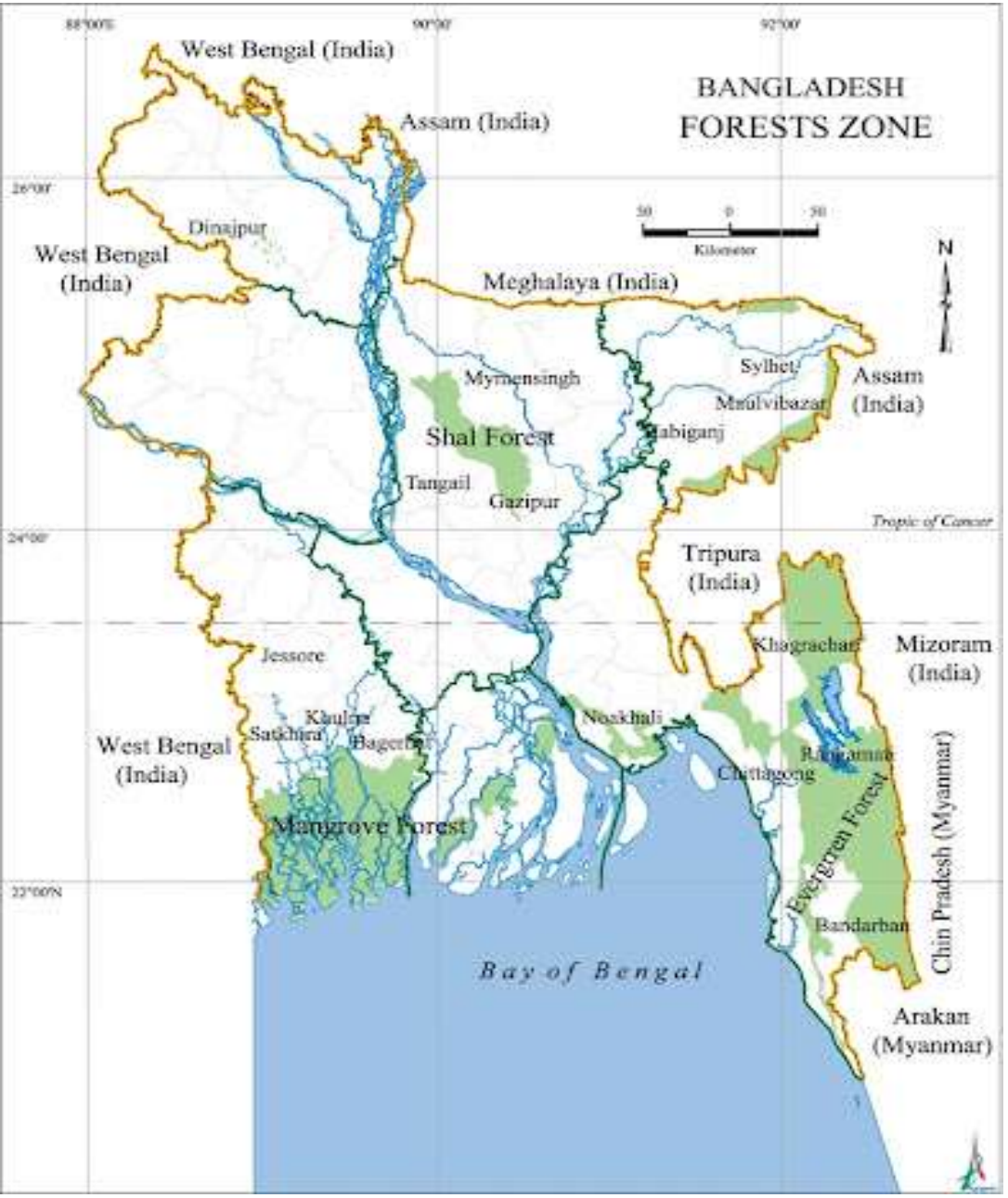
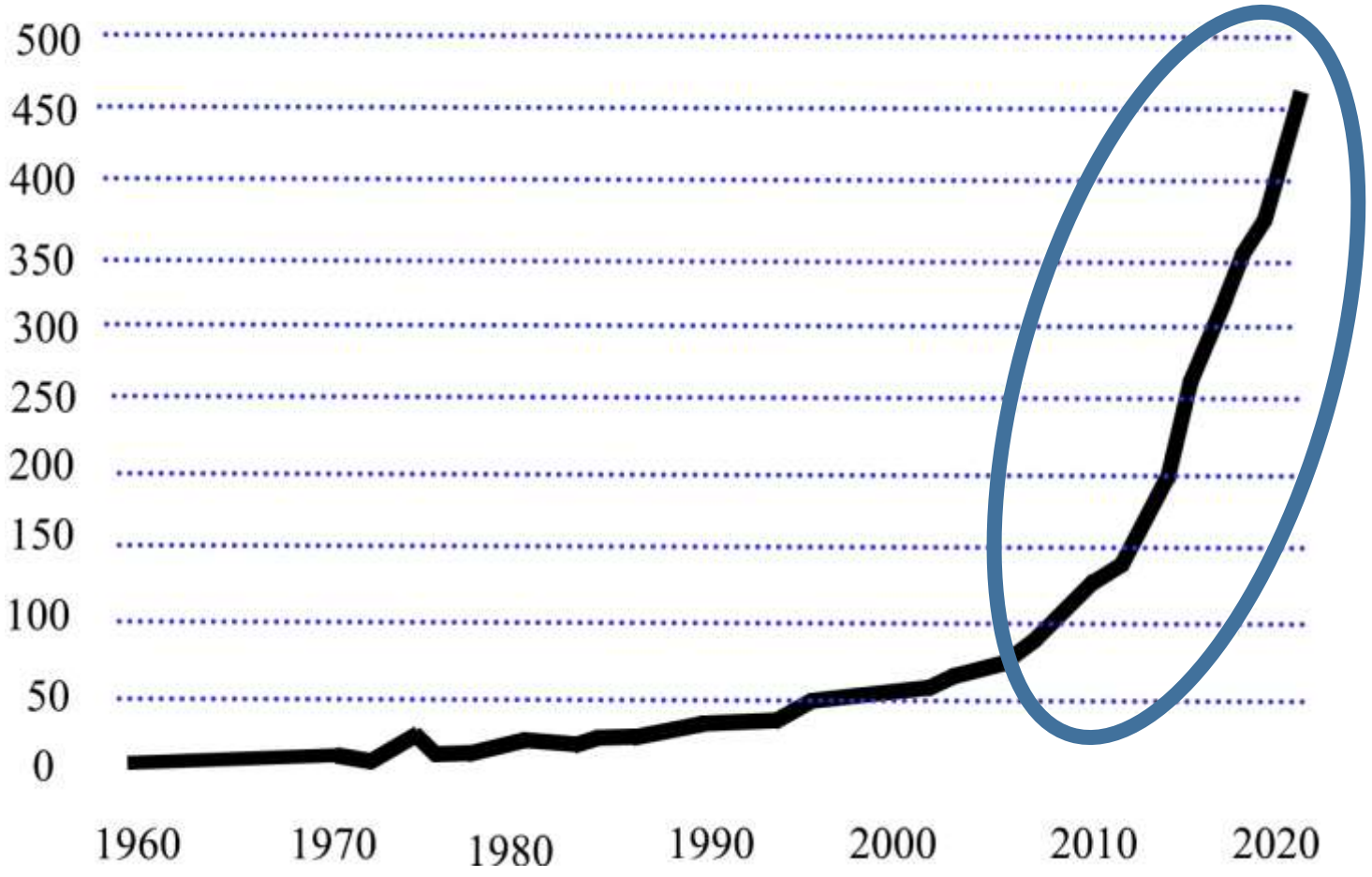
POTASSIUM HYDROXIDE PULPING OF RICE STRAW

M. Sarwar Jahan

Pulp and Paper Research Division, Bangladesh Council of Scientific and Industrial Research Laboratories, Dhaka, Dr. Qudrat-i-Khuda Road, Dhaka 1205, Bangladesh

Bangladesh





GDP growth in Bangladesh

https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=BD

Bangladesh case

- Bangladesh is a densely populated small country.
- Forest resources are very limited.
- Faces acute shortage of fibrous raw materials for pulp industry.
- Bangladesh is an agricultural country, generates a substantial amount of crops residue, which can be alternative raw materials.

Availability of agricultural wastes

Availability of some important crops and their wastes generated in 2023 in Bangladesh (FAOSTAT 2024)

Crops	Production in Bangladesh, MT	Waste generated, MT
Rice	57,189,193	85,783,790
Wheat	1,085,834	1,628,751
Maize	4,261,845	6,392,767
Jute	1,529,947	2,824,868*

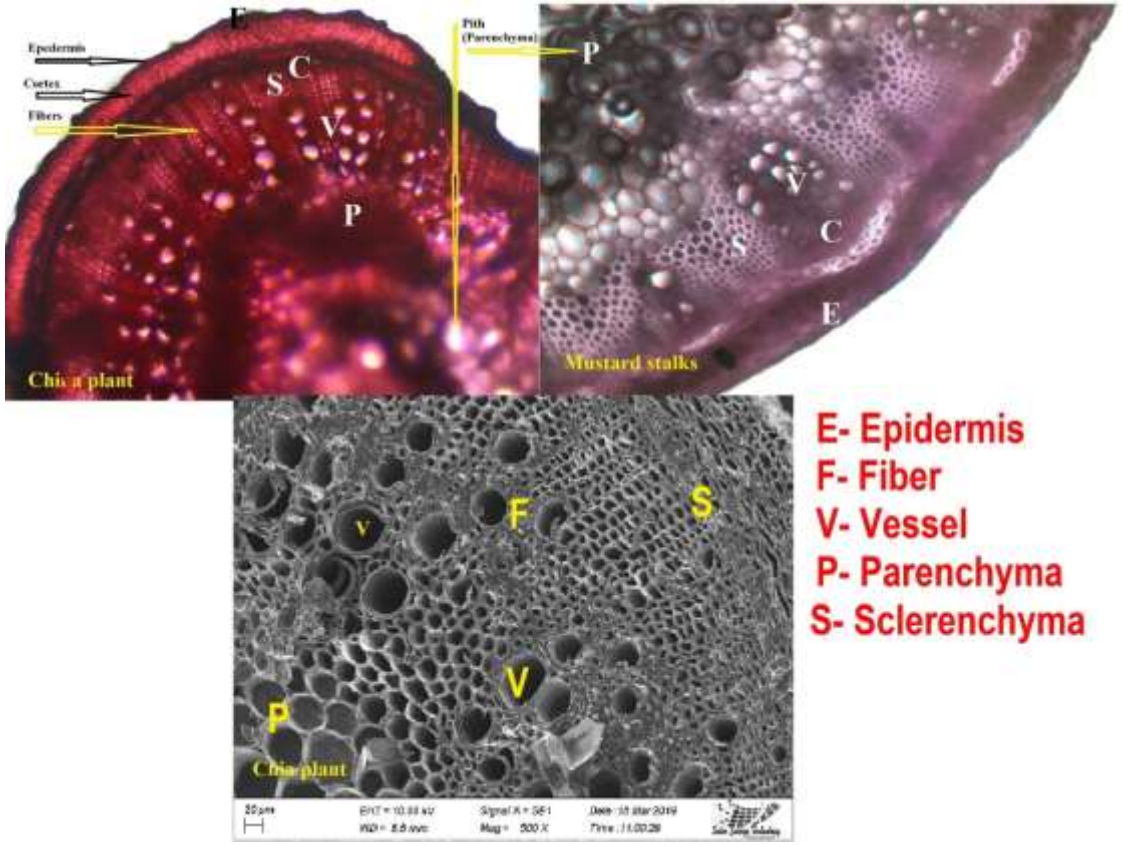
Advantages such as higher biomass yields, no competitions with edible crops or land, eco-friendly production, **their large commercial application is yet to occur**.

Chemical Characteristics of non-wood

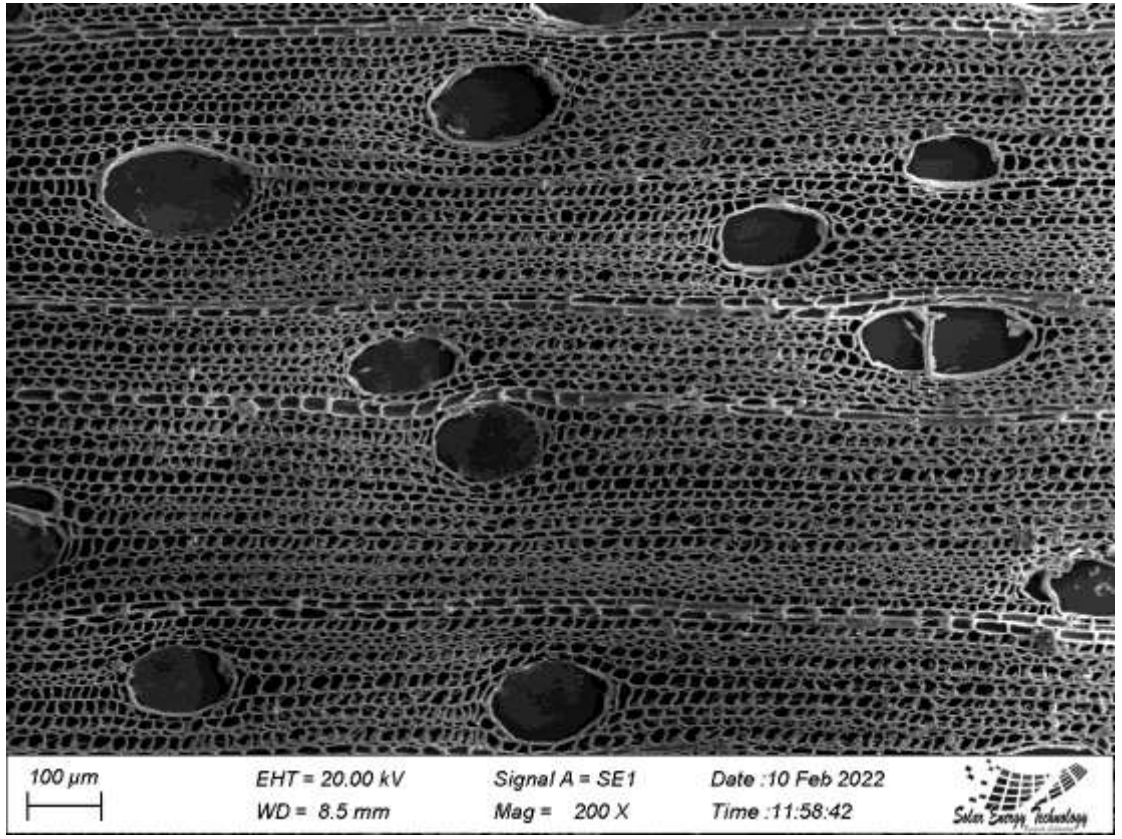
Crops	α-cellulose (%)	Lignin (%)	Pentosan (%)	Ash (%)
Rice	**38.5**	**12.7**	**19.1**	**17.2**
Wheat	**40.1**	**15.0**	**21.9**	**9.7**
Maize stalks	**46.5**	**14.0**	**27.6**	**4.5**
Bagasse	**44.2**	**17.9**	**23.9**	
Jute	**63.1**	**12.7**	**13.5**	**2.0**
Jute stick	**45.7**	**24.1**	**22.7**	**2.7**

Jahan, M. S., (2007). *BJSIR*, *42*(4), 425-434; Jahan et al. M.S. (2012). *Industrial Crops and Products*, *37*(1), 164-169; Jahan, M. S., (2016). *Bioresource technology*, *219*, 445-450.

Anatomical differences



E- Epidermis
F- Fiber
V- Vessel
P- Parenchyma
S- Sclerenchyma



Non-wood *vs* wood

Ferdous, T. et al. (2020). *Tappi J*, *19*, 511-524; Islam et al. (2023). *Tappi*, *22*(6), 411-421.

Limitation of agricultural wastes

- High silica content
- High fines content
- High content of pith
- Collection of raw material
- bulky

EU/USA Policy

- The share of biofuels in the fuel pool will be increased to 30% by 2030.
- Imports of petroleum products – including petrol, diesel, fuel oil, jet fuel, and kerosene – for domestic use will be decreased by 50% from 2005 levels by 2030.
- President Biden announced a goal to cut U.S. greenhouse gas emissions between 50 to 52 percent by 2030.
- Hon'ble Prime Minister Sheikh Hasina expressed hope in COP26 to have 40% of energy from renewable sources by 2041.

Biofuel Int. Nov 25, 2016; Science April 22, 2021

How to reduce greenhouse gas emission

Wood

Non-wood

- Use renewable resources
- Biomass

Integrated biorefinery concept

Chip

Gasification

Power
Mixed alcohols
Chemicals etc.

Chip

Hemicellulose extraction

Hemicellulose conversion

Ethanol
Polymers

Eenrgy Chemicals

Cooking liquor

Recovery boiler

Pulp

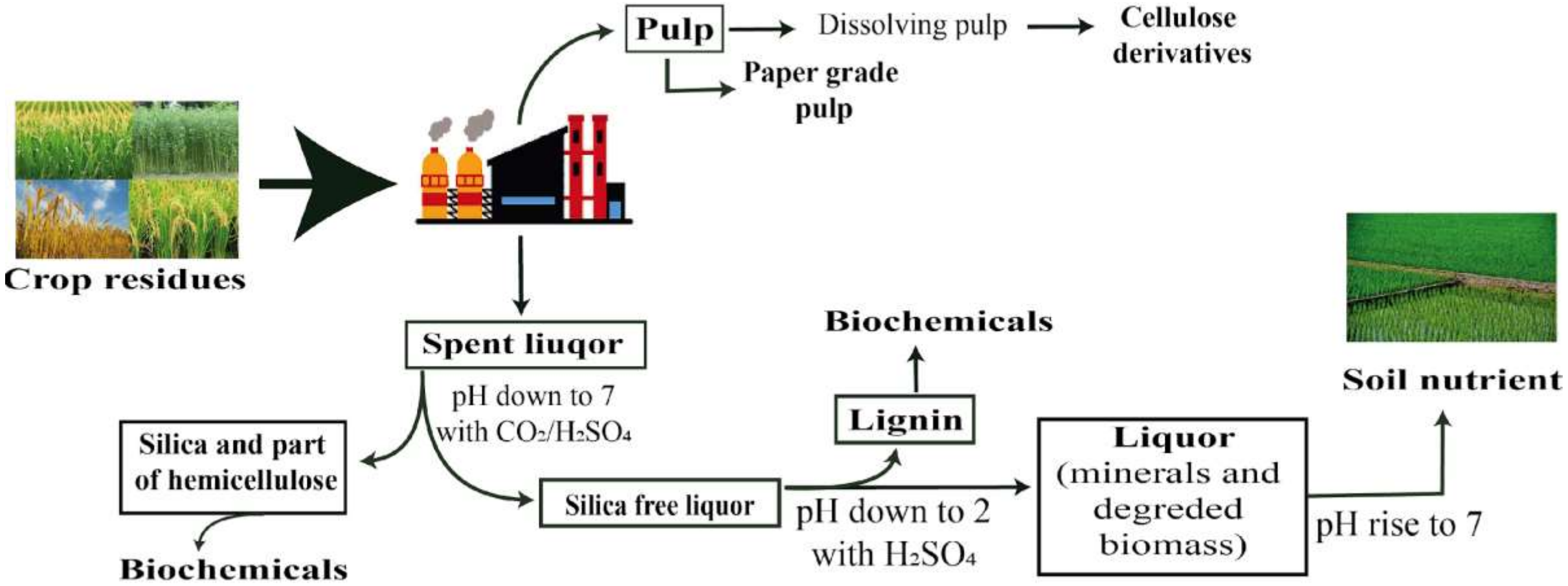
Paper

Lignin extraction

Lignin conversion

Biochemicals

KOH pulping



Jahan, M. S. et al., (2016). *J-FOR 6*(1), 46-53; Jahan, M. S. et al. (2016). *Bioresource technology*, *219*, 445-450.

Objectives

- Pulping of rice straw at atmospheric pressure or with weak potassium hydroxide (KOH) charge.
- Evaluation of papermaking properties of the produced pulps.
- Separation of dissolved lignin and silica.
- Use of KOH liquor in soil amendment.
- Target to use all fractions of biomass, so nothing would be wasted in the proposed process.

KOH pulping of rice straw at atmospheric pressure

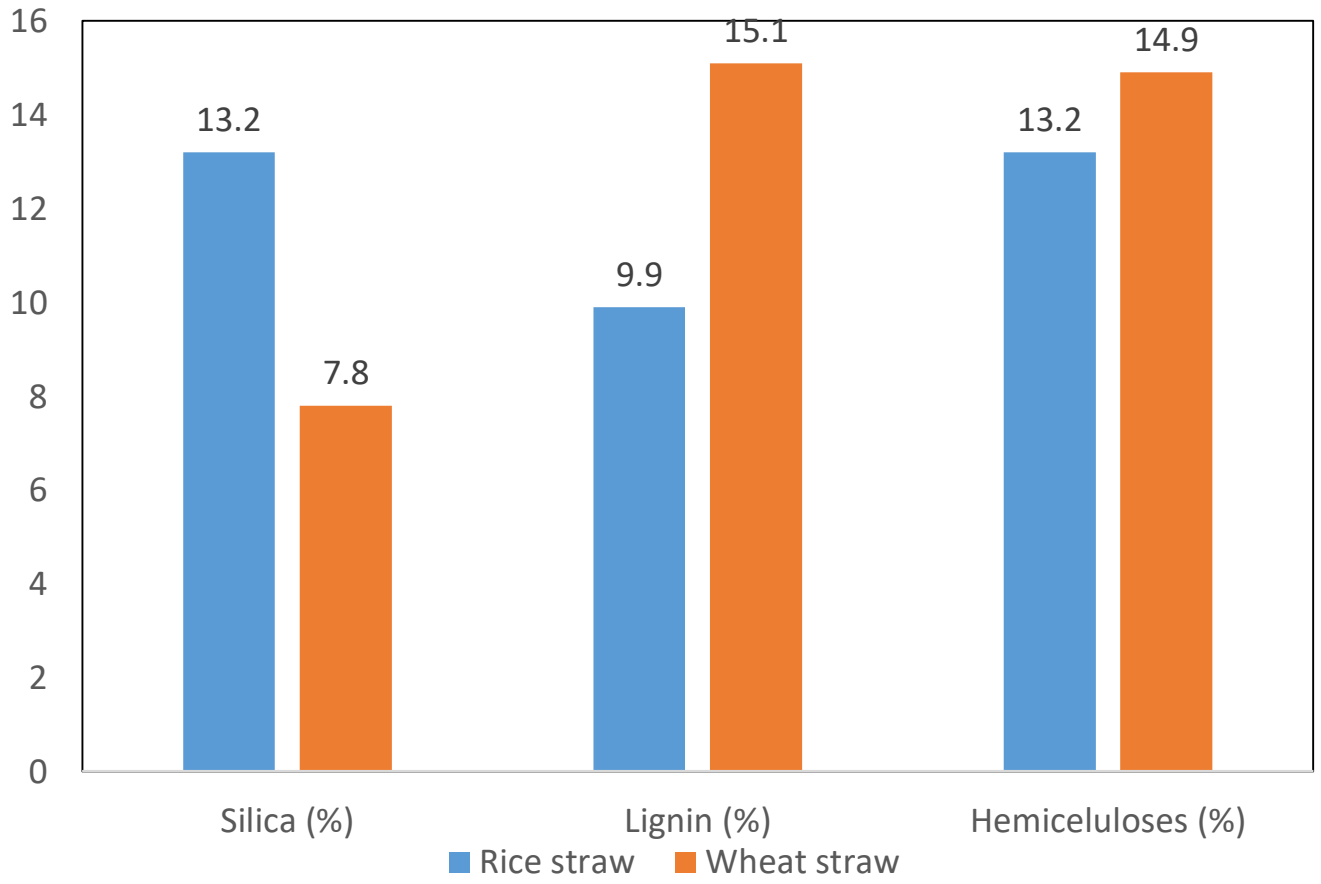
Raw material	Pulp yield (%) based on raw material	Kappa number
Rice straw	45.4	19.7
Wheat straw	52.8	20.8
Kan grass	48.9*	27.9
Bagasse	48.5	23.4

*180 min of cooking

Papermaking properties of crop residues pulps obtained from low temperature at 40 °SR

Raw material	Tear index ($mN \cdot m^2/g$)	Tensile Index ($N \cdot m/g$)	Burst Index ($kPa \cdot m^2/g$)
Rice straw	5.2	45.4	2.5
Wheat straw	7.7	52.2	2.7
Kan grass	9.0	58.3	3.0
Bagasse	6.3	63.5	4.2

Fractionation of KOH spent liquor at atmospheric pressure



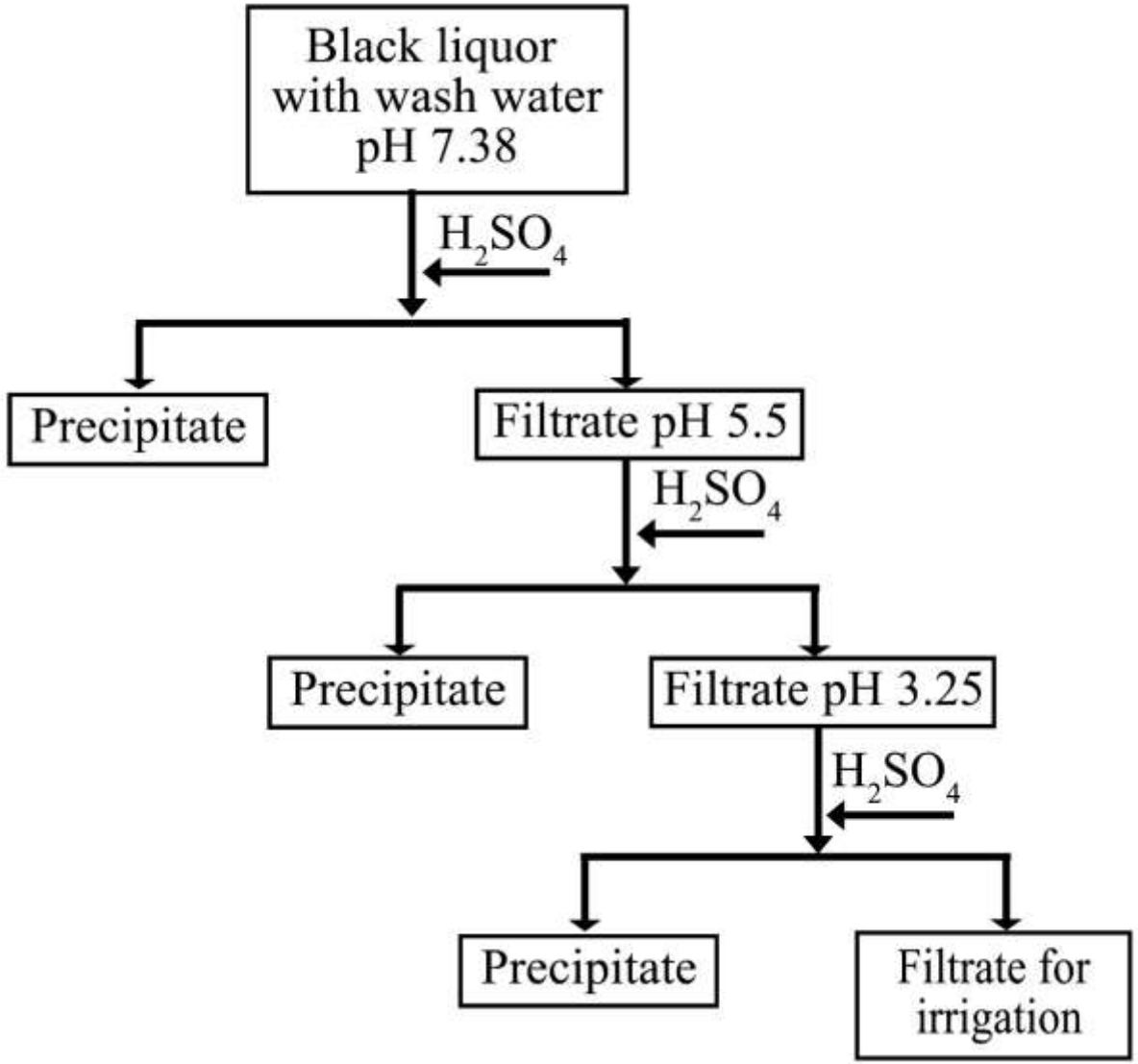
Weak potassium hydroxide pulping of rice straw

KOH charge (%)	Pulp yield (%)	Kappa number	Ash in pulp (%)
6	51.0	23.4	13.9
8	47.0	17.7	13.1
10	43.7	16.8	9.7

Papermaking properties of pulp produced from weak KOH

°SR	Tear index ($mN \cdot m^2/g$)	Tensile Index ($N \cdot m/g$)	Burst Index ($kPa \cdot m^2/g$)
31	4.62±0.23	35.1±1.87	2.0±0.19
36	6.95±0.19	47.16±1.43	2.3±0.21
39	6.84±0.21	47.21±1.23	2.63±0.15
41	6.02±0.24	47.39±2,83	2.69±0.06
47	4.84±0.19	49.08±1.95	2.76±0.22

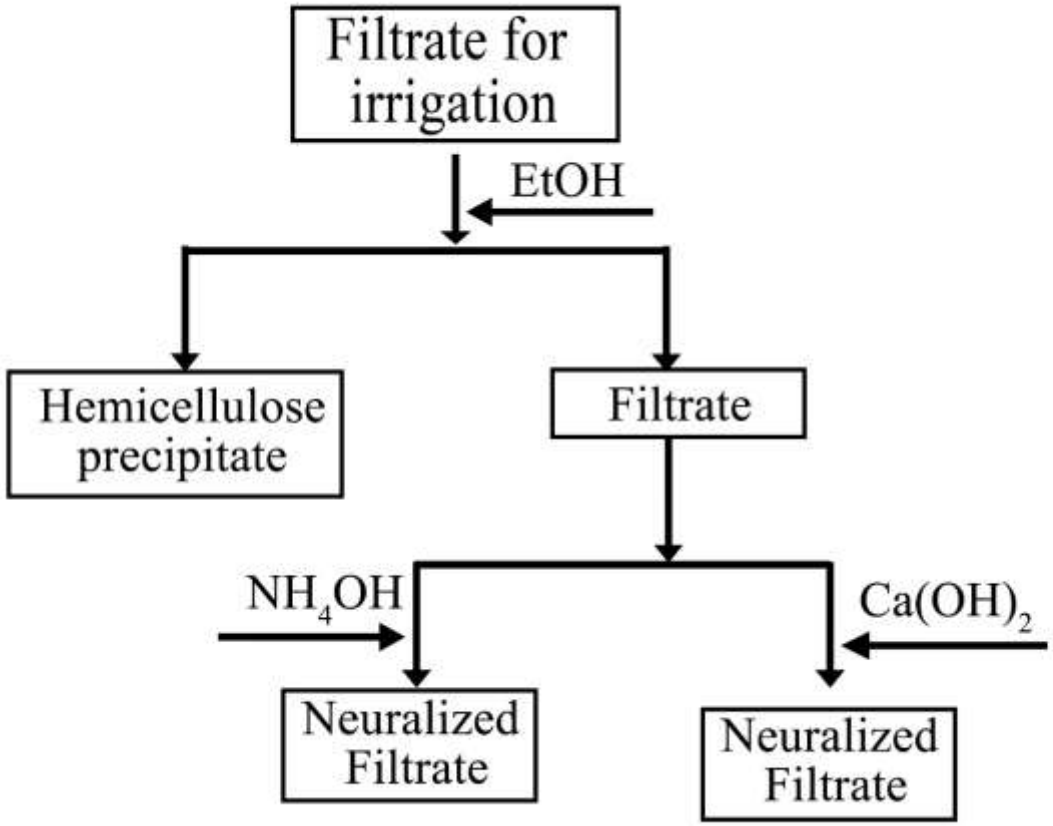
Lignin precipitation scheme

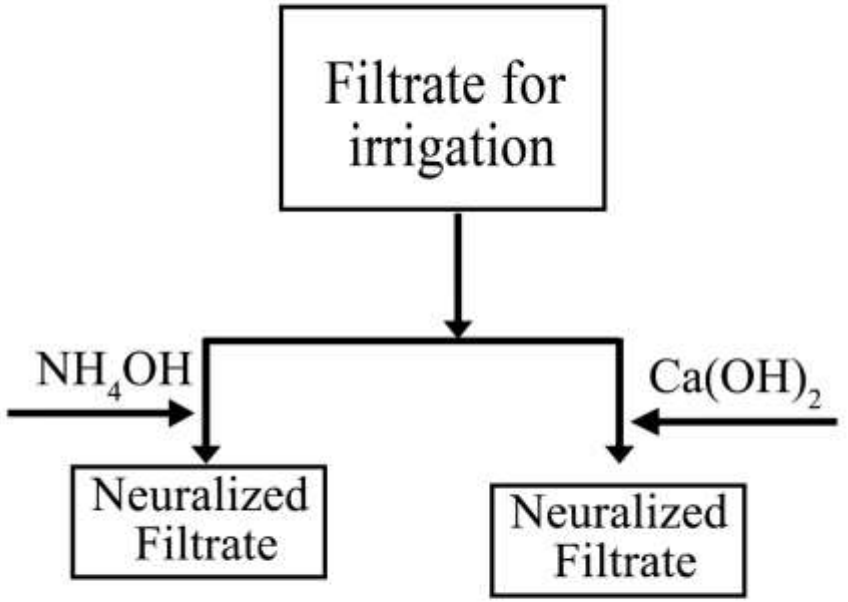


XRF results of ash of pulp, filtrate and lignin

Ash sample	K_2O, %	SiO_2, %	Fe_2O_3, %
Pulp	0.98	61.8	2.54
Pulping liquor at pH 7.38	80.4	1.85	1.69
Pulping liquor at pH 5.5	76.4	1.92	1.03
Pulping liquor at pH 3.25	56.4	1.51	0.77
Precipitated lignin at pH 7.38	6.7	25.4	0.44
Precipitated lignin at pH 5.5	10.5	35.3	8.19
Precipitated lignin at pH 3.25	65.2	1.3	2.21

Filtrate for irrigation





Conclusions

- Rice straw is easily defibrated by weak KOH charge or two stage KOH pulping at atmospheric conditions.
- The produced pulp yield in weak KOH pulping was higher (around 50%) than the two stage KOH pulping at atmospheric conditions.
- Most of the silica retained on the pulp fiber in weak KOH pulping, while silica dissolved in two stage KOH pulping.
- The papermaking properties of produced pulp with weak KOH at 40 °SR were slightly better than those of the pulp from strong KOH.
- From the dissolved biomass in the two stage atmospheric pulping, 13.2% silica, 9.9% lignin, and 13.2% hemicelluloses were separated, those can be used for biobased products.
- The liquor still contained a high amount of K_2O organics, which support to amend soil.

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Thank you