Environment Friendly Removal Of Silica From Wheat Straw And Saccharum Munja Using Urea

Sinha Akhouri Sanjay Kumar

Department of Chemical Technology, SLIET, Longowal, Sangrur, Punjab - 148106, INDIA.

ABSTRACT

This novel study is based on finding environment friendly economical process for treatment of agro residue based and grass raw materials for paper industries. The paper industries are facing pressure for reducing the consumption of forest based wood raw materials in paper making. ***Wheat straw and*** Saccharum Munja (Sarkanda) are two important established fibrous raw materials for paper industries. But higher percentage of ash and silica which is the main constituent of ash causes problems for chemical recovery and other process. The wheat straw and Saccharum Munja contains nearly 5-6% and 4-5% ash respectively. Nearly 75 % portion of ash is silica, which causes problem due to getting deposited on evaporator tubes in chemical recovery plant. The urea treatment (2% on OD raw material basis) for 30 minutes of time at 50 ^{0}C temperature provides 55% reduction of silica in Saccharum Munja. Whereas urea treatment (3.5 % on OD raw material basis) for 60 minutes of time at 50 ^{0}C temperature provides 60 % reduction of silica in wheat straw. This result is compared with NaOH treatment. The urea water can be easily used as fertilizer since it does not have any harmful chemical. This study will provide an innovative process for raw material treatment for silica removal from high silica containing raw materials at better economy.

Key Words: *Wheat Straw, Saccharum Munja, Silica, Urea, NaOH, Ash.*

Introduction

Proper utilization of the agro waste and industrial waste materials is the key of **s**ustainability of industrial growth on this planet. Scarcity of conventional wood based & other fibrous raw materials for pulp and paper industry is one of the most challenging tasks. Wheat straw is available in abundant quantity in India and other countries. Wheat production at world level has been 691 million tons in year 2011 as per Food Outlook Global market analysis of FAO (Food & Agriculture organization). USA has produced 60.1 million tons of wheat in 2011. Production of wheat in Asia is 337 million tons as recorded in 2011. India is producing 81.9 million tons of wheat where as other countries like China, Pakistan and Turkey are producing 117.6, 23.0 & 19.8 million tons respectively. Nearly 1.5 tons of wheat straw is produced per ton of wheat grains [1]. Under subtropical Indian conditions, a crop producing 4.6 tons of grains plus 6.9 tons of straw absorbed 128 Kg N, 46 Kg P_2O_5, 219 Kg K_2O, 27 Kg Ca, 19 Kg Mg, 22 Kg S, 1.8 Kg Fe, 0.5 Kg Zn, 0.5 Kg Mn & 0.15 Kg Cu. The proportion of nutrients absorbed that end up in the grains is 70 % in the case of N and P and 20-25 % in the case of K [2]. Nearly 36% of the paper production comes from the forest based raw material and the remaining from the non-conventional raw materials such as agro residues and waste paper [3]. Wheat straw is a fibrous lignocellulosic material which has higher content of silicon dioxide (SiO_2) in comparison of hard wood and softwood. Ash content on a dry weight basis ranges from 4 to 6%, varying according to the state of conservation. The use of organic solvents for fractionation of woody materials has been greatly expanded during the past few years. The huge amounts of residual plant biomass considered as "waste" can potentially be converted into various different value added products like natural fibers used for paper making, bio-fuels and chemicals [4]. Some technical approaches for handling the high silica content in raw materials like rice straw have been studied based on catalyzed acetic acid pulping which do not dissolve the silica so the silica remains with pulp only. And the pulp with inherent ash helps in getting higher opacity and other properties. This pulp can be used in specialty papers which require higher opacity and high ash percentages [5, 6, & 7]. The other approach is removal of silica from the raw material itself so that it will not be left for getting dissolved in black liquor while doing soda or kraft pulping. An experimental study of wheat straw has shown 7.6 % ash and 4.54 % silica. Hollocellulose is reported as 66.7 % [8]. Saccharum Munja, known as **munja** also is found in arid areas and along river banks in India. It belongs to the family Gramineae. Its white flowers are of ornamental value. Saccharum Munja commonly called as Sarkanda is available in large quantity in north India. It is 2-2.5 meters long and have diameter in the range of 1 to 1.5 cm for a fully grown plant. It is a good fibrous raw material for paper making. It has a good fibre length averaging 1.3 mm. Hollucellulose, klason lignin, pentosans and ash percentage in Saccharum Munja are 79.13, 22.03, 26.5 and 4.67 respectively.

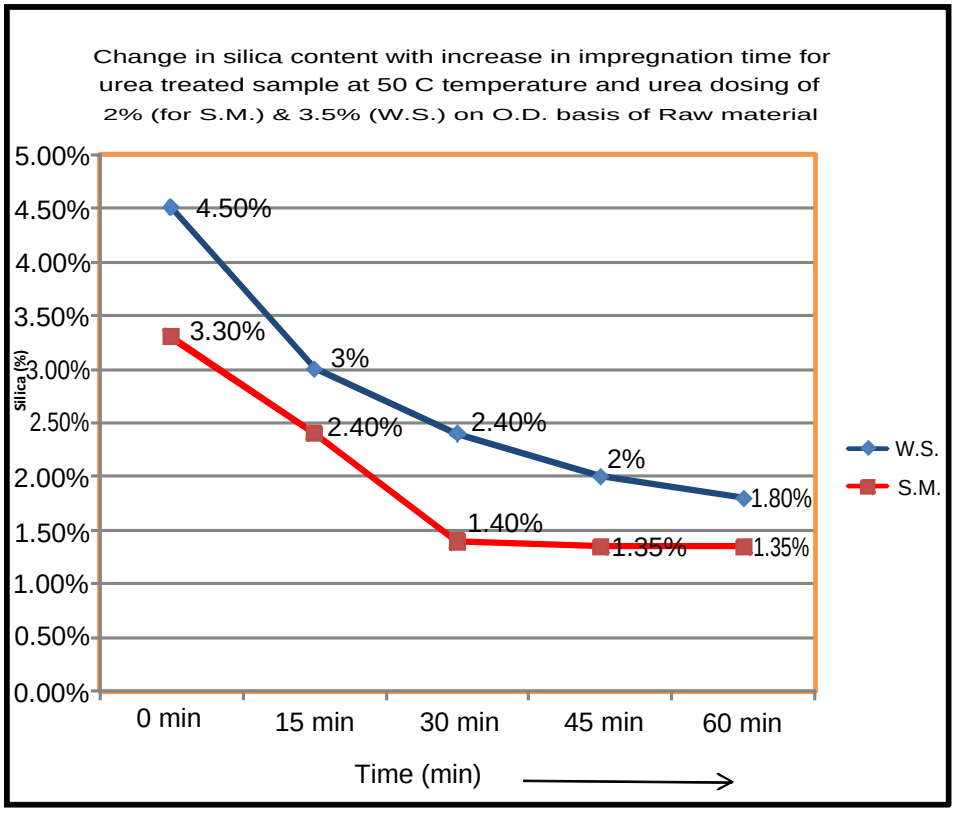
This provides good strength properties in paper which are comparable to bagasse and other non woody raw materials [9]. Urea treatment of middle season rice straw with high silica content has been studied for better digestibility in animal feed. Five percent and ten percent urea treatment have been studied along with 1.5 % NaOH treatment. Light microscope (LM) and scanning electron microscope (SEM) were used for investigation of the histology and study of images. The results indicated that silica was deposited in epidermis polymerized with cuticle waxes to become a barrier to rumen microbial attack. The cuticle wax layer seemed to be affected by urea treatment [10]. Silica is present in Sacchrum Munja & wheat straw in substantial quantity. When Sacchrum Munja & wheat straw is pulped, the silica is dissolved into the black liquor. If the black liquor is concentrated in a multiple-effect evaporation system, some of the silica precipitates and deposits onto the evaporator heating surfaces, rapidly decreasing their capacity. The presence of silica in black liquor can also cause high black liquor viscosity, which limits the solids concentration that can be achieved during evaporation. As a result, many mills do not concentrate and burn the liquor. The removal of silica is very much required for economical and environment friendly use of these raw materials. The urea treatment of raw material does not affect the fiber quality adversely. As the use of urea as an additive in kraft pulping of eucalyptus has been studied by other researchers. The impact on unbleached pulp properties, black liquor properties, refining energy requirement and physical strength properties of bleached were studied in details. They have shown increase of unbleached pulp viscosity by nearly 15% and improvement in black liquor properties due to decrease in viscosity by 30% [11]. So urea treatment will also be helpful in further pulping process.

Experimental: Experiments were carried on following combinations of reaction conditions

Sample	Reaction Temperature (°C)	Reaction Time (min.)				chemical charge					
						NaOH (%)			Urea (%)		
Sacchrum munja	50	15	30	45	60	2	3.5	5	2	3.5	5
Wheat straw	50	15	30	45	60	2	3.5	5	2	3.5	5

Table 1: Analysis of rice straw (raw material)

S.NO.	Analysis	Wheat Straw	Saccharum Munja
1.	1% NaOH Solubility	37.75 ± 2.51	38.75 ± 2.61
2.	Ash	5.9 ± 0.20	4.6 ± 0.22
3.	Silica	4.5 ± 0.15	3.30 ± 0.16
4.	Alcohol benzene solubility	4.5 ± 0.22	4.2 ± 0.24
5.	Klason lignin	16.24 ± 0.62	21.7 ± 0.69
6.	Holocellulose	65.35 ± 0.63	69.2 ± 0.67
7.	Hot water solubility	8.5 ± 0.41	9.2 ± 0.42
8.	Moisture content	11.51 ± 0.96	12.51 ± 0.91



Materials & Methods

Wheat straw and Saccharum Munja was collected from the near-by farming fields of Sangrur, Punjab. The raw materials were washed, cleaned and dried. It was cut into small size of 8-10 mm. Silica removal reaction of wheat straw and Saccharum Munja were carried out in small air tight jars at controlled temperature. Each experiment was carried out by taking 100 gm of oven dry raw materials. Different percentages of urea were tried for the study of effect on silica and ash removal from raw materials. The raw materials were also treated with NaOH for observing the effect on silica removal from wheat straw and Saccharum Munja. After completion of reaction for a given time for that batch, the mass was cooled and then filtered out. The responses were studied for time and temperature effect at different chemical dosing. Ash and acid insoluble ash (silica) contents of the rinsed samples were determined according to Tappi Methods 211 and 244 respectively. Effect of chemical treatment on Klason lignin and holocellulose has been noted.

Klason lignin and holocellulose are measured by TAPPI Std. T 222 and T-212 methods respectively. The proximate analysis of raw materials are also done as per TAPPI standard procedures.

Results & discussion

Proximate analysis of wheat straw and Saccharum Munja are shown in Table 1. It shows that ash and silica percent in wheat straw are 5.9 % and 4.5 % respectively, whereas Saccharum Munja has ash and silica percent 4.6 % and 3.3 % respectively. Klason lignin and holocellulose in wheat straw was 16.4% and 65.35% respectively. Whereas Klason lignin and holocellulose in Saccharum Munja are 21.7% and 69.20% respectively.

The reactions has shown the best efficiency for 2% urea treatment for Saccharum Munja and 3.5 % urea treatment for wheat straw at the given temperature of 50 ^{0}C . The effect of increase of time of reaction has been studied for both the raw materials. Reaction time of 30 minutes is sufficient for removal of silica from Saccharum Munja but increase of time provides better result for wheat straw.

The urea treatment of wheat straw also helps in reduction of lignin from 16.24 to 12.35% and holocellulose in nearly same as it changes from 65.35 to 63.95 %.

The urea treatment of Saccharum Munja provides reduction of lignin from 21.7 to 17.8% and holocellulose changes from 69.2 to 68.1 %.

The comparision of urea and NaOH has been done for effectiveness in silica removal from both the raw materials at 25 and 3.5% chemical dosing on O.D. raw material basis. The temperature and reaction time time has been same at 50 ^{0}C and 60 minutes respectively.

Analysis of Pulp quallity

The raw materials were cooked by soda pulping process in a lab indirect heating Digester using 12% NaOH on O.D. raw material basis at maximum temperature of 160°C, the ratio of liquor to O.D. raw Material 5.5: 1 (V/W), time to maximum temperature 120 min, and time at maximum temperature 30 min. After cooking pulps were washed thoroughly with water and screened with a lab vibratory screen.

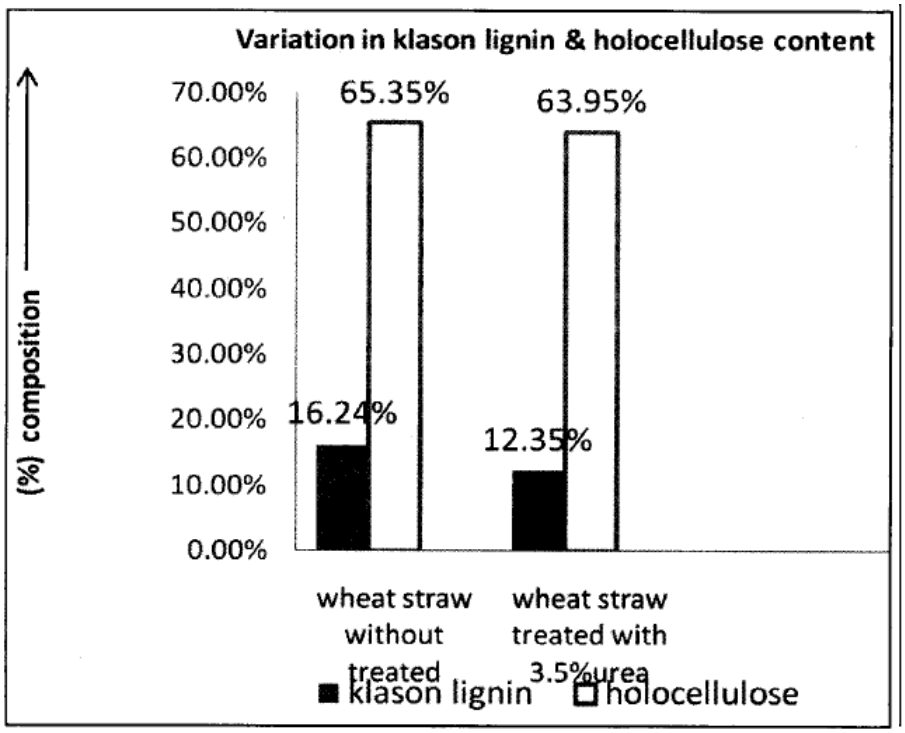
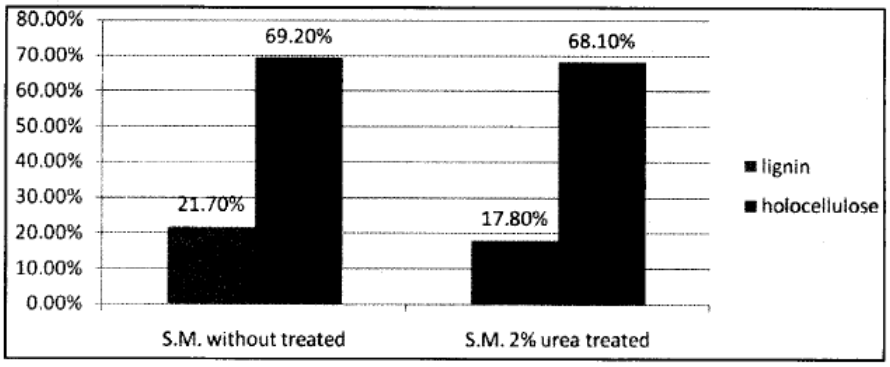
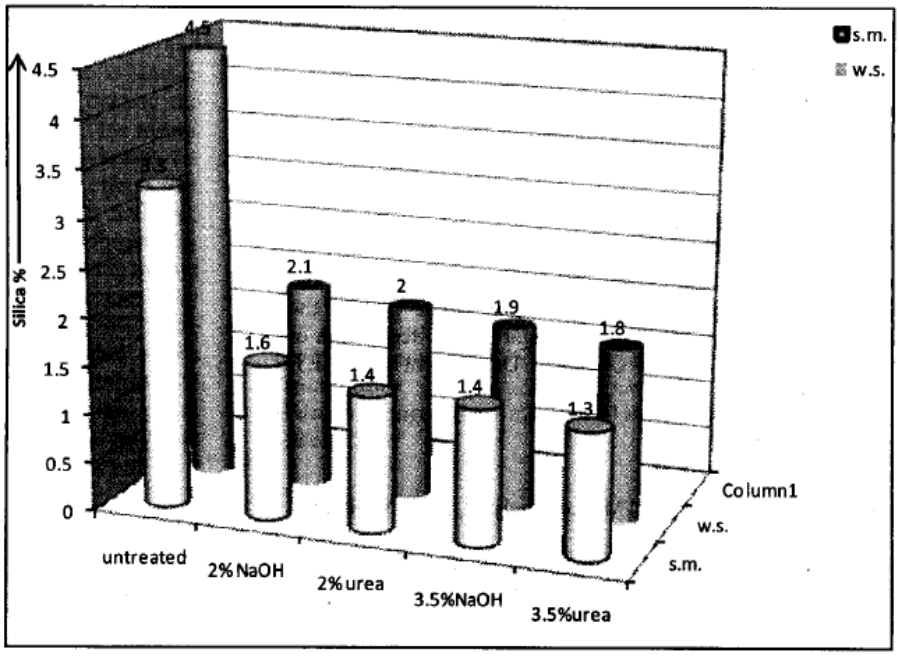


Figure2: Effects of urea treatment on klason lignin and holocellulose pecentage of wheat straw.





Average weight fiber length of wheat straw and Sacchrum Munja pulp, calculated by bauer Mcnett method are 0.86 mm and 0.92mm respectively. The brightness of unbleached paper of wheat straw and Sacchrum Munja pulp are 28 and 30 % ISO (measured at 457 nano meters) respectively . The pulp was beaten to 40 ^{0}SR. 100 gsm papers were made and tested for burst strength, tear strength and tensile strength. The burst index of wheat straw and Sacchrum Munja pulp sample paper are 0.53 to 0.61 kPa.m^2 /g and 0.62 -0.69 Kpa.m^2/g respectively. Tear index of wheat straw and Sacchrum
Munja based paper samples varied from 4.25 to 4.38 mN.m2 /g and 4.45 -4.7 mN.m^2/g respectively.

Tensile index values of wheat straw and Sacchrum Munja based paper samples varied in between 24.3 to 26.90 N.m /g and 25.2 to 28.90 N.m /g respectively. These are good for writing & printing grades of paper.

Conclusion

Agro residues and grasses like Saccahrum Munja have the great potential to eliminate the dependence on the forest raw materials for meeting the need of raw materials for pulp and paper industries. But presence of silica badly affects the economy and quality of working of paper industry. Therefore the removal of silica becomes essential. Hence chemical treatment of these raw materials with environmentally friendly and cheap chemicals is necessary to remove the silica. The wheat straw and Saccharum Munja have 5.9 and 4.6 percent ash respectively. The silica percentage in wheat straw and Saccharum Munja are 4.5 and 3.3 percent respectively. The Majority of silica can be removed by treatment of raw materials with urea. Sacchrum Munja can be effectively treated by 2% charge of urea on O.D. raw material basis at moderate temperature condition of 50 ^{0}C and 30 minutes of time. Whereas wheat straw treated with 3.5% urea solution gave best result at process condition of 50 ^{0}C temperature and 60 minutes of time .The results are comparable with NaOH treatment with similar process condition. When impregnation time is increased for wheat straw sample in urea solution then silica content decreased with time continuously. But for Saccahrum Munja it was nearly constant after 30 minutes of time of reaction. The Use of NaOH is costly as well as provides very high alkalinity of waste water and cannot find suitable use in agriculture. It is not suitable for discharge in nearby land or water bodies. Urea can be beneficial in removing silica from wheat straw & sacchrum munja due to lower cost and the effluent water can be used in agricultural fields as fertilizer.

Acknowledgement

The author is thankful to his students Mr. Ashok Mahara and Mr. Khim Singh for doing repetition of some part of the research results and Mr. Ramnik Aggarwal, Sr. technician of paper tech. laboratory of Chemical Department of SLIET, Longowal.

References

[1] Food Outlook Global Market Analysis, FAO, November, (2011), 2-4.
[2] Nutrient Management Guidelines for Some Major Field Crops, Food and Agriculture Organization, Chapter 8, pages 235-240.
[3] G. Chaturvedi, R.K. Jain, K. Singh, A.G. Kulkarni, Indian paper industry-Growth and prospects, IPPTA J. 18 (2006) 73-77.
[4] R.L. Howard, E. Abotsi, V. Jansen, E.L. Rensburg, S. Howard, Lignocellulose biotechnology: issues of bioconversion and enzyme production, African Journal of Biotechnology 2 (2003), 602-619.
[5] A.S.K. Sinha, Study of effects of process variables of rice straw delignification in catalyzed acetic acid medium at atmospheric pressure, IPPTA J. 20 (2008), 107-111.
[6] A.S.K Sinha, M. Singh, S.P. Singh, Study on use of non-magnetic fraction of pulverized coal fly ash as filler in specialty paper manufacturing, IPPTA, 22 (2010), 117-120.
[7] A.S.K Sinha, Effects of pulverized coal fly ash addition as wet end filler in paper making, TAPPI, 7 (2008), 3-7.
[8] U. K. Ghosh, Production of paper grade pulp by organic acid based pulping of wheat straw, IPPTA, Convention Issue (2006), 45-47.
[9] R. Bharati, S. Bharati, A. Sighal, A. Sinha, Light microscopic studies of Saccharum Munja (Sarkanda) for paper making, IPPTA Convention Issue (1994), 29-34.
[10] H. S. Shen, F. Sundstol, E. R. Eng, L. O. Elk, Studies on untreated and urea-treated rice straw from three cultivation seasons:3, Histological investigations by light & scanning electron microscopy, Animal Feed Science and Technology, 80 (1999), 151-159.
[11] P. Bajpai, S. Tripathi, N. Sharma, O. P. Mishr, P.K. Bajpai, Use of urea as additive in kraft pulping of eucalyptus, TAPPI EPE Conference, August 24-27, 2008, Portland, Oregon.