Development and Analysis of Low Cost Sheet Structure using Agricultural Waste

S. K. Patil, P. M. Pawar

Abstract— The basic moto of this idea is to generate haste from the waste. As pandharpur and many other districts in Maharashtra are rich in cultivation of wheat there is lot of agro waste residue of wheat straw. The farmers here burn this wheat straw making pollution and causing lot of environmental impact. So the idea is to develop fabrication materials and household materials using this wheat straw which is rich in cellulosic properties and eco friendly. So the cellulosic properties when extracted from this wheat straw forms a sticky and non degradable pulp, which helps to mould fabrication materials viz. interior panels etc, household materials viz, disposable food plate etc. These materials formed using Wheat straw pulp are tough durable and sound proof.

Keywords: moto, pandharpur, agro waste residue of wheat straw, environmental impact, fabrication materials, cellulosic properties and eco friendly.

I. INTRODUCTION

Pandharpur is agriculturally rich by the grace of river Bhima and its left and right bank canals, supported by Nira right bank canal. However, the industrial growth is very poor and is limited to sugar industries only. However, in the rural areas, the available resources are often under-utilized due to lack of knowledge and required technical support. Hence, technology penetration is the need of the hour. Waste and by-products of agro-food industries such as wheat straw can be used to produce environmental friendly and sustainable products. The current practice in most cases is to burn these materials. However, burning process adds little/no value and may cause some environmental impact. Wheat Straw is a lignocellulosic material. Currently over produced and underutilized, the use of these materials can accomplish two very important objectives (a) Reducing the existing dependence on environmentally hazardous products by offering sustainable products (b) Creating alternative sources of income to rural women. The average productivity of wheat in the re-gion is 1100 Kg. per hectare. There are only four tahsils which have a yield above 1500 Kg per hectare. These four tahsils are namely Karmala, Malshiras, Pandharpur and North Solapur. As wheat straw is an abundant by-product from wheat production, it can serve as best option for low cost raw material for generating constructional, household products. The generated constructional materials will possess the eco friendly properties and will serve as tough, durable and structurally sound material in any conditions.

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The following table shows properties of wheat straw:

Chemical composition of wheat straw (Ali *et al*., 1991; Patterson, 1995; Yasin *et al*., 2010) Components	Percentage (%)
Dry matter	89 to 94
Metabolizable energy mcal/lb	0.67
Crude protein	3.6
Acid detergent fibre	54
Cellulose	33.7 to 40
Hemicellulose	21 to 26
Lignin	11 to 22.9
Ash	7 to 9.9
Silica and silicates	4.5 to 5.5
Calcium	0.18
Phosphorus	0.05
Relative feed value	60

II. PHYSICAL AND CHEMICAL PRETREATMENT PROCESSES FOR LIGNOCELLULOSIC BIOMASS

Lignocellulose, the most abundant renewable biomass on earth, is composed mainly of cellulose, hemicellulose and lignin. Both the cellulose and hemicellulose fractions are polymers of sugars and thereby a potential source of fermentable sugars. Lignin can be used for the production of chemicals, combined heat and power or other purposes. After initial biomass processing, the production of fermentable sugars from biomass is usually ap-proached in two steps:

1. A pretreatment process in which the cellulose polymers are made accessible for further conver-sion. In this step hydrolysis of hemicellulose may occur, as well as separation of the lignin frac-tion, depending on the process applied.
2. Enzymatic cellulose hydrolysis to fermentable sugars using cellulase enzyme cocktails produced on location or acquired from enzyme manufacturers.

Obstacles in the existing pretreatment processes include insufficient separation of cellulose and lignin, formation of by-products that inhibit ethanol fermentation, high use of chemicals and/or energy, and considerable waste production. Research is focussed on converting biomass into its constituents in a market competitive and environmentally sustainable way. Different pretreatment technologies published in public literature are described in terms of the mecha-nisms involved, advantages and disadvantages, and economic assessment. Pretreatment technologies for lignocellulosic biomass include biological, mechanical, chemical methods and various combina-tions thereof. The choice of the optimum pretreatment process depends very much on the objective of the biomass pretreatment, its economic assessment and environmental impact. When fermentable sugars are produced, special attention must be paid to the formation of fermentation inhibitors. Especially the formation of phenolic compounds from lignin degradation should be pre-vented, as well as the formation of furfural and HMF from sugar degradation by keeping the process temperature and residence time as low and as short as possible. Only a small number of pretreatment methods has been reported as being potentially cost-effective thus far. These include steam explosion, liquid hot water, concentrated acid hydrolysis and dilute acid pretreatments. At the moment the production of ethanol from lignocellulose is growing rapidly and by looking at the industrial activities in this field more knowledge can be gained on the applied pretreat-ment methods. It is not possible to define the best pretreatment method as it depends on many factors such as type of lignocellulosic biomass and desired products. Pretreatments must improve the digestibility of lignocel-lulosic biomaterials, and each pretreatment has its own effect on the cellulose-, hemicellulose- and lig-nin fractions. Looking at industrial activities for the production of ethanol, acid-based pretreatment methods are preferred. In these processes lignin is left with the substrate and removed after the hy-drolysis of the (hemi)cellulose or even after distillation. Research topics for these processes include amongst others minimization of sugar loss, increase of solids concentration and higher ethanol concen-trations after fermentation. However, when lignin is removed from the biomass in an early stage of the process (i.e. after the pretreatment) it can be recovered as a co-product with potential high added value. Another advantage is that the enzymatic digestibility is strongly related to the lignin content, and that lignin removal greatly enhances enzymatic hydrolysis. In this case pretreatment methods that focus on lignin removal become more interesting.

III. ABOUT LIGNOCELLULOSIC MATERIALS

The major constituents of lignocellulose are cellulose, hemicellulose, and lignin, polymers that are closely associated with each other constituting the cellular complex of the vegetal biomass. Basically, cellulose forms a skeleton which is surrounded by hemicellulose and lignin.

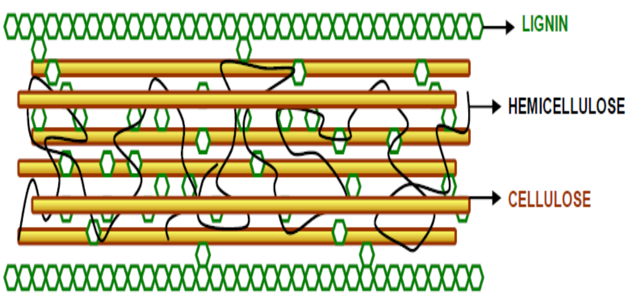


Fig. 1: Liginin, Hemicellilose and Cellilose Structure

Cellulose is a high molecular weight linear homopolymer of repeated units of cellobiose (two anhydrous glucose rings joined via a β-1,4 glycosidic linkage). Hemicellulose is a linear and branched heterogeneous polymer typically made up of five different sugars - Larabinose, D-galactose, D-glucose, D-mannose, and D-xylose - as well as other components such as acetic, glucuronic,and ferulic acids. Lignin is a very complex molecule constructed of phenylpropane units linked in a large three-dimensional structure.

IV. TESTS FOR DETERMINATION OF LIGNIN AND CELLULOSE PERCENTAGE IN WHEAT STRAW

A. Determination of Lignin Percentage:

The wheat straw was chopped into small pieces for the process of hydrolysis. Chopped straw (1gm) was then kept for hydrolysis with 1.25% H_2SO_4 for two hours. Then the straw was kept for further process of 72% H_2SO_4 hydrolysis for four hours. The residues was filtered and washed with distilled water to remove sulphuric acid and oven dried at 105°C for constant weight.

Photo 1: Determination of Liginin percentage,

The lignin was expressed by using the following equation (Milagres 1994)

$$Liginin\ (\%) = \frac{Liginin\ Weight\ (W2)}{Straw\ Weight\ (W1)} * 100$$

Where,

W_1 = weight of dry wheat straw = 1g

W_2 = weight of wheat straw after oven drying = 0.175g

So, Lignin percentage was found to be **17.5%** in wheat straw.

B. Determination of Cellulose Percentage:

Cellulose content in wheat straw samples was estimated by the method as described by Gopal and Ranjhan (1980). 1 g of oven dried wheat straw sample was taken in round bottom digestion flask. 15 ml of 80% acetic acid and 1.5 ml of conc. HNO3 was added to the flask and refluxed for 20 min. After refluxing the material was filtered through Whatman filter paper #1 and washed with hot water. After washing the digested material was oven dried at 105°C overnight and weighed then incinerated at 550°C for 5 hrs in a muffle furnace and weighed again. The percentage of cellulose on dry matter basis was calculated using the following eqaution:

$$Cellulose\ (\%)\ Dry\ Matter\ Basis = \frac{W1 - W2}{W} * 100$$

Where,

W1 = weight of digested material = 0.80 g

W2 = weight of ash = 0.415 g

W = weight of dry wheat straw = 1 g

So, Cellulose percentage was found to be **38.5%** in wheat straw.

V. CONSTRUCTION OF FABRICATION MATERIALS

1. The main constituent for constructing the panel is Wheat straw pulp.
2. The water is taken in a bucket as per amount of wheat straw to be boiled in it. Then appropriate amount of NaOH is added in this water and it is boiled until the water reaches its boiling point.
3. Then wheat straw is placed in boiling water and is boiled for about 1 hr.

Fig. 2: Straw in Boiling Water

4. After 1 hr straw is defibrillated in the water i.e, all fibres gets separated in the solution.

Photo 3: Fiber Separation in Solution

5. Then to impart the adhesive property to the pulp water soluble PVA is added into the water.

Photo 4: Polyvinyl Alcohol (PVA)

6. Then all the water is screened through the net and the bulk material is grinded to fine form using conventional mixer or by tamping.

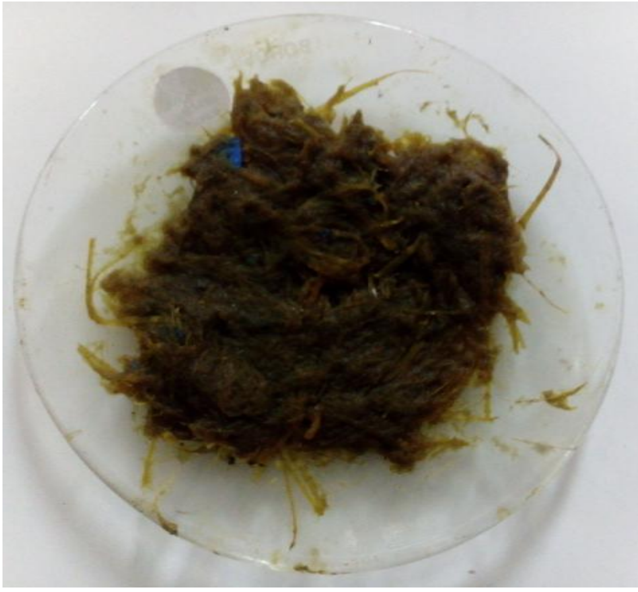


Photo 5: Grinded Bulk Material

7. The obtained pulp is applied on the bamboo panel of different sizes reinforced with gunny bags.

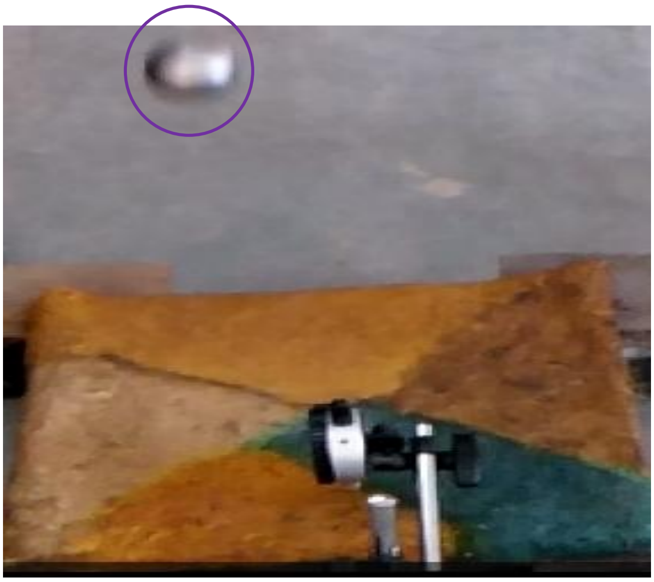
Photo 6: Preparation of Bamboo Panel

8. The panel is then sundried for 48 hrs after which it acquires maximum strength.

VI. DETERMINATION OF IMPACT STRENGTH FOR WHEAT STRAW PANEL

The test is conducted as per standard procedure for impact resistance by Plywood as per IS:1734-1983

1. The wheat straw panel of size 20cm x 20cm is taken for the test.
2. The panel is then rested on all for corners (simply supported).
3. The Steel ball of size 5cm in diameter and weight 450gm is taken for the test procedure as per IS standards.
4. The ball is then dropped on the panel at five different places from 100cm and the maximum deflection is recorded using dial gauges of 0.01mm least count.
5. The Maximum deflection is then checked for cracks and distortion.
6. The same procedure was then followed for plywood and then obtained results were compared.



7. RESULT: There is No development of Crack on wheat straw Sheet Structure at the point of maximum deflection. The Sheets are Impact Resistant & more Flexible as compared to Plywood.

VII. CONCLUSIONS

A new environmentally friendly technology for turning agricultural residues like straw into quality value-added composite products using conventional Polyvinyl alcohol resins has been developed and currently being scaled-up within the framework of an funded project. The implementation of the new technology will result in waste materials (agriwaste) being efficiently utilised as a sustainable resource for the industrial manufacture of commodity products like wheat straw structure reducing the amounts of agricultural wastes and eliminating the pollution occasioned by the burning of such residues.

REFERENCES

1. Adeeb, Z. (2004): Glycerol delignification of poplar wood chips in aqueous medium. Energy Educa-tion Science and Technology 13/2, pp. 81-88.
2. Alvira, P., E. Tomas-Pejo, et al. (2009): Pretreatment technologies for an efficient bioethanol produc-tion process based on enzymatic hydrolysis: A review. Bioresource Technology Article in press.
3. Bacovsky, D. (2009): 2nd Generation Biofuels - State of the art. IEA Bioenergy Task 39, from http://biofuels.abc-energy.at, http://www.a3ps.at
4. Biosulfurol (2010): http://biosulfurol-energy.com
5. Black, S.K., B.R. Hames & M.D. Myers (1994): Method of separating lignocellulosic material into lignin, cellulose and dissolved sugars: Anon., patent number US 5730837.
6. BlueFire Ethanol (2010): http://bluefireethanol.com
7. Cardona, C.A. and O.J. Sanchez (2007): Fuel ethanol production: Process design trends and integra-tion opportunities. Bioresource Technology 98(12): 2415-2457.
8. Eggeman, T. and R.T. Elander (2005): Process and economic analysis of pretreatment technologies. Bioresource Technology 96(18 SPEC. ISS.): 2019-2025.
9. Faulon, J., G.A. Carlson, et al. (1994): A three-dimensional model for lignocellulose from gymno-spermous wood. Organic Geochemistry 21: 1169-1179.
10. Garcia-Aparicio, M.P., I. Ballesteros, et al. (2006): Effect of inhibitors released during steam-explosion pretreatment of barley straw on enzymatic hydrolysis. Applied Biochemistry and Biotechnology 129(1-3): 278-288.
11. Guo, Z., J.G. Huddleston, R.D. Rogers & G.C. April (2003): Reaction Parameter Effects on Metal-Salt-Catalyzed Aqueous Biphasic Pulping Systems. Industrial and Engineering Chemistry Re-search 42/2, pp. 248-253.
12. Harris, A.T., S. Riddlestone, et al. (2008): Towards zero emission pulp and paper production: the BioRegional MiniMill. Journal of Cleaner Production 16(18): 1971-1979.
13. Hasegawa, I., K. Tabata, O. Okuma, & K. Mae, (2004): New pretreatment methods combining a hot water treatment and water/acetone extraction for thermo-chemical conversion of biomass. Energy & Fuels 18/3, pp. 755-760.
14. Hendriks, A.T.W.M. and G. Zeeman (2008): Pretreatments to enhance the digestibility of lignocellu-losic biomass. Bioresource Technology 100(1): 10-18.
15. Jayawardhana, K. and G.P. Van Walsum (2004): Modeling of carbonic acid pretreatment process us-ing ASPEN-Plus. Applied biochemistry and biotechnology 113-116: 1087-1102.
16. Jorgensen, H., J.B. Kristensen, et al. (2007): Enzymatic conversion of lignocellulose into fermentable sugars: Challenges and opportunities. Biofuels Bioprod Bioref.
17. Karunanithy, C., K. Muthukumarappan, et al. (2008): Influence of high shear bioreactor parameters on carbohydrate release from different biomasses. American Society of Agricultural and Bio-logical Engineers Annual International Meeting 2008.
18. Kim, K.H. and J. Hong (2001): Supercritical CO2 pretreatment of lignocellulose enhances enzymatic cellulose hydrolysis. Bioresource Technology 77(2): 139-144.
19. Kishimoto, T. & Y. Sano (2001): Delignification mechanism during high-boiling solvent pulping. Part I., Holzforschung 55, pp. 611-616.

20. Kootstra, A.M.J., H.H. Beeftink, E.L. Scott, J.P.M. Sanders (2009): Comparison of dilute mineral and organic acid pretreatment for enzymatic hydrolysis of wheat straw. Biochemical Engineering Journal 46 (2). - p. 126 - 131.
21. Linde, M., E.L. Jakobsson, et al. (2008): Steam pretreatment of dilute H2SO4-impregnated wheat straw and SSF with low yeast and enzyme loadings for bioethanol production. Biomass and Bioenergy 32(4): 326-332.
22. Mussatto, S.I. and I.C. Roberto (2004): Alternatives for detoxification of diluted-acid lignocellulosic hydrolyzates for use in fermentative processes: A review. Bioresource Technology 93(1): 1-10.
23. Muurinen, E. (2000) Organosolv pulping, ISBN 951-42-5661-1.
24. Nada, A.-A.M.A., A.A. Ibrahem, Y. Fahmy & H.E. Abo-Yousef (1999): Peroxyacetic acid pulp-ing of bagasse and characterization of the lignin and pulp. Journal of Scientific & Indus-trial Re-search 58/620, 628.
25. Oliverio, J.L., A.G.P. Hilst (2004): DHR - Revolutionary process for producing alcohol from sugar cane bagasse. International Sugar Journal 106/1263.
26. Papatheofanous, M.G., E. Billa, D.P. Koullas, B. Monties, & E.G. Koukios (1995): Two-stage acid-catalyzed fractionation of lignocellulosic biomass in aqueous ethanol systems at low tempera-tures. Bioresource Technology 54/3, pp. 305-310.
27. Pasquini, D., M.T.B. Pimenta, L.H. Ferreira & A.A.D.S. Curvelo (2005): Extraction of lignin from sugar cane bagasse and Pinus taeda wood chips using ethanol-water mixtures and carbon di-oxide at high pressures. Journal of Supercritical Fluids 36, pp. 31-39.
28. Rantwijk van (2003): Biocatalytic transformations in ionic liquids. Trends in Biotechnology, 21(3), 131-138.
29. Riddlestone, S., P. Hartwell, et al. (2007a): BioRegional MiniMill technology -report on UK demon-stration mill. Presented at TAPPI 2006, pulping and environmental conference." Kami,Parupu Gijutsu Taimusu/Japanese Journal of Paper Technology 50(6): 11-17.
30. Riddlestone, S., P. Hartwell, et al. (2007b): BioRegional MiniMill Technology report on UK demon-stration mill. Paper Technology 48(1): 25-32.
31. Ruiz, E., C. Cara, et al. (2008): Evaluation of steam explosion pre-treatment for enzymatic hydrolysis of sunflower stalks. Enzyme and Microbial Technology 42(2): 160-166.
32. Saha, B.C. and M.A. Cotta (2006): Ethanol production from alkaline peroxide pretreated enzymati-cally saccharified wheat straw. Biotechnology Progress 22(2): 449-453.
33. Saha, B.C. and M.A. Cotta (2007): Enzymatic hydrolysis and fermentation of lime pretreated wheat straw to ethanol. Journal of Chemical Technology and Biotechnology 82(10): 913-919.
34. Sánchez, O.J., C.A. Cardona (2008): Trends in biotechnological production of fuel ethanol from dif-ferent feedstocks", BIoresource Technololgy 99, 5270-5295.
35. Sun, F. & H. Chen (2007): Evaluation of enzymatic hydrolysis of wheat straw pretreated by atmos-pheric glycerol autocatalysis. Journal of chemical technology and biotechnology 82, pp. 1039-1044.
36. Sun, X.F., F. Xu, et al. (2004): Characteristics of degraded lignins obtained from steam exploded wheat straw. Polymer Degradation and Stability 86(2): 245-256.
37. Taherzadeh, M.J. and K. Karimi (2008): Pretreatment of lignocellulosic wastes to improve ethanol and biogas production: A review. International Journal of Molecular Sciences 9(9): 1621-1651.
38. Tengerdy, R.P. and G. Szakacs (2003): Bioconversion of lignocellulose in solid substrate fermenta-tion. Biochemical Engineering Journal 13(2-3): 169-179.
39. Teymouri, F., L. Laureano-Perez, et al. (2005): Optimization of the ammonia fiber explosion (AFEX) treatment parameters for enzymatic hydrolysis of corn stover. Bioresource Technology 96(18 SPEC. ISS.): 2014-2018.
40. Thermowoodhandbook (2003): Helsinki, Finland, Finnish Thermowood Association.
41. Zhang, Y.-H.P., S.Y. Ding, J.R. Mielenz, J.-B. Cui, R.T. Elander, M. Laser, M.E. Himmel & J.R. McMillan (2007): Fractionating recalcitrant lignocellulose at modest reaction conditions. Biotechnology and Bioengineering 97/2, pp. 214-223.
42. Zhao, X., K. Cheng & D. Liu (2009): Organosolv pretreatment of lignocellulosic biomass for enzy-matic hydrolysis. Applied Biochemistry and Biotechnology 82, pp. 815-827.
43. Zhao, Y., Y. Wang, et al. (2008): Enhanced enzymatic hydrolysis of spruce by alkaline pretreatment at low temperature. Biotechnology and Bioengineering 99(6): 1320-1328.
44. Zhu, S., Y. Wu, et al. (2006): Production of ethanol from microwave-assisted alkali pretreated wheat straw. Process Biochemistry 41(4): 869-873.
45. Zimbardi, F., E. Viola, et al. (2007): Acid impregnation and steam explosion of corn stover in batch processes. Industrial Crops and Products 26(2): 195-206.

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