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EVALUATION OF PHYSICOCHEMICAL PROPERTIES OF VIOLET TREE (*Securidaca longepedunculata*) ROOT POWDER

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ABSTRACT
The evaluation of physicochemical properties of modified and unmodified Violet Tree Root Powder (UVTRP/MVTRP) were examined on, ash content, moisture content, volatile content, fixed carbon, and bulk density. Others include porosity, specific gravity, swelling ability and anti-swelling efficiency. The values for unmodified and modified VTRP biomass compared, were ash content 9.60 ±0.03 % - 7.30 ±0.25 %, moisture content 17.14 ±1.24 % - 8.95 ±1.00 %, volatile content 32.70 ±0.20 % - 40.50 ±1.45 %, fixed carbon 57.70 ±3.26 % - 52.20 ±2.25 % and bulk density 23.30 ±0.28 g/cm^3 – 27.85 ±0.01 g/cm^3. The value for porosity was 67.80 ±0.01 % - 83.30 ±2.34%, specific gravity 0.6909 ±1.50 – 0.9906 ±1.25, swelling ability 86.70 ±1.36 % - 33.50 ±1.50 % accordingly, while the anti-swelling efficiency modified VTRP gave 61.36 ±2.44 %. The improved physicochemical values were indications of a better behavior of the modified VTRP for various application.
Keywords: Evaluation, Physicochemical, Modified VTRP, Unmodified VTRP, Biomass

INTRODUCTION

Securidaca longepedunculata Fresen (Polygalaceae), commonly known as violet tree in English, Ipeta in Yoruba, uwar magunguna' in Hausa and 'eze ogwu' in Igbo; is highly regarded as a medicinal and magical tree. The Mbula people of Adamawa State, Northeastern Nigeria commonly identified it as "Ngun Ngban", known among the people for its mysterious cleansing believe (Donatus, 2014). It occurs in the Northwest and Limpopo provinces of South Africa and Mozambique and widely distributed in tropical Africa. It is available between April and August each year **(**Ojewale, 2008). Violet Plant is scientifically identified as *Securidaca longependunculata* from the family polygalaceae. It is a common small tree or shrub in Sudanese and Guinean savannah country. In moist areas it is found on ironstone and rocks while in dry areas it is found on riverbanks (Arbonnier, 2004). Traditionally, the plant was used in the treatment of inflammations, abortion, ulcers, infertility, tuberculosis, venereal diseases, and toothache **(**Schmidt *et al.,* 2002). Secondary metabolites such as tannins, phlobatanins, saponins, alkaloids, flavonoids and cardiac glycosides have been reported from the root powder **(**Schmidt *et al.,* 2002). Biomass is defined as the biological degradable fraction of products, waste and residues from agriculture (including animal and vegetable materials), forestry and the biological degradable fraction of industrial and household waste (FAO, 1997). Physicochemical is the combination of physical and chemical properties of a substance that may influence its efficiency and applications. In order to achieve optimum result in utilization of biomass of interest in applicable areas, they can be treated to modify the substance morphology. Chemical modifications of wood with anhydride reagents have been the subject of research for many decades (Hill *et al.*, 2000; Rowell *et al.*, 1987 and Rowell, 1992). Application of agro-industrial residues in industries, on the other hand, provides alternative substrate and also helps in solving pollution problems, which their disposal may otherwise cause (Sun *et al.*, 2004). It is one of the most significant reactions to the derivatization or modification of cellulose and its allied lignocelluloses (Bogan *et al.*, 1979; Pizzi *et al.*, 1994). Acetylation one of the method of chemical modifications, has been the most widely used and successful method of chemical modification; and is a single place effect that replaces a hydroxyl group with an acetyl group. Acetyl associations are more hydrophobic than hydroxyl collections, consequently, substituting any of the hydroxyl groups reduces the hydrophilic character of the cell wall polymers (Xu and Sun, 2003; Rowell, 1992). The acetyl accumulation is also more significant than the hydroxyl group, therefore, the materials undergo permanent expansion (Karr and Sun, 2002). In common, acetylation points to an enhanced content of acetyl organizations in wood material, to almost 20% weight related to 1-2 % weight for unmodified wood. The opening of new acetyl groups in wood polymers effects within a specific level of bulking of the wood cells walls. This reduced capacity to attract water molecules and drives to profoundly improve the dimensional stability of acetylated wood material (Brelid and Simonson, 1999).

Modification with acetic anhydride can exchange the hydroxyl groups of cell wall polymers with acetyl groups on the biomass product; meanwhile develops the characteristics of those polymers so that all become hydrophobic. Those modified absorbents have the properties of low cost, high capacity, and quick oil uptake and are easy to desorb by a simple squeezing method (Sun and Sun, 2002). The modified violet tree root powder by acetylation, has been reported by Barminas *et al.,*(2015). The work showed enhanced VTRP biomass spectrum modified with absorption band of C=O carbonyl ester stretching 1745cm^{-1}. The C–O stretching 1354–1359 cm^{-1} bond in acetyl group –O(C=O)–CH_3. Interestingly, the study also showed the absence of absorption bands O-H bonds at 3400 cm^{-1}to 3600 cm^{-1} at free state or 2500 cm^{-1} to 3300 cm^{-1} in overlap spectrum of acid used. It is, in this view that this study evaluates the physicochemical properties of the sampled biomass, unmodified and modified violet tree root powder. The evaluation will be for application of the sample biomass as plan in further sorption experiment.

MATERIALS AND METHODS

Sample collection and preparation

The plant, violet tree (*Securidaca longepedunculata*) root was sourced from Girei town of Adamawa State-Nigeria. The plant root was dug from the ground of about 2-3 cm depth using a hoe. The plants were identified by a Botanist at the Department of Biological Sciences and confirmed in the plant taxonomy registry of the Modibbo Adama University of Technology, Yola-Nigeria. Afterward, it was cut into pieces and crushed to powder form using pestle and mortar. The ground powder was sieved using improvised mesh into the fine powder of violet tree root powder particles and kept in a clean plastic container with tight cover labeled (VTRP).

Physicochemical properties of Violet Tree Root Powder (VTRP)

Moisture content: The moisture content determination was done according to the method of Rengaraj *et al*. (2000), by thermal drying of 1 g of sample VTRP at 105 ℃ for four h. The method was repeated in triplicate to obtain a mean value.

Moisture (%) = (loss in weight on drying / initial sample weight) × 100.

Ash content: This was done as adopted by Aloko and Adebayo (2007). A weight of 1g of the dry sample of VTRP was placed in a pre-weighed porcelain crucible and assigned into a preheated muffle furnace set at a temperature of about 600 ℃ and heated for 1 hour after which the crucible and its content were transferred to a desiccator, allowed to cool and weighed. The measurements were done using electric balance in grams, and repeated in triplicate for mean values. The formula below was used to calculate the value for ash content:

W_3 = weight of density bottle + dry VTRP + water

A_C (%) = W_a – W_O/ W_O× 100; where Ac = Ash content; W_a = Weight of ash after cooling; W_o = Weight of dry biomass

Volatile content: The method of Fapetu (2000) was adopted where 1g of the sorbent VTRP was heated at 300 ℃ for 10 mins in a partially closed porcelain crucible placed in a muffle furnace. The crucible and its content were retrieved and cooled in a desiccator. The method was repeated in triplicate to obtain a mean value. The difference in weight recorded and the volatile content (VC) was determined:

V_c (%) = (w_o - w_a) / w_o× 100; Where V_c = volatile content of sample VTRP; W_a = weight of sample VTRP after cooling; W_o = original weight of dry sample VTRP.

Fixed carbon: The fixed carbon content was determined as adopted by Fapetu (2000) from the formula below: The method was repeated in triplicate to obtain the mean value.

F_c(%) = 100 – (V_c + A_c) where F_c = fixed carbon;V_c = volatile content VTRP; A_c = ash content of VTRP respectively.

Bulk density: This was determined using the method described by Ekpete and Horsfall (2011). VTRP sample of (10 g) was oven dried to constant weight at 105 ℃ for 1 hour and reweighed. 1g VTRP held into a 10 ml measuring cylinder, and a little water added. The bulk density was determined by the expression below:

Bulk density = mass of wet sample / volume

The method was repeated in triplicate to obtain a mean value.

Porosity: The method adopted was by Ekpete and Horsfall (2011). The volume of void (Vv) taken from the total volume of the measuring cylinder used given by ($V_T = \pi r^2 h$) and also the volume of the solid (VTRP) which was calculated using 1 g, (V_S=M_S/G_S P_W). The method was repeated in triplicate to obtain a mean value.

Where r = radius of measuring cylinder ; H = height of the measuring cylinder; M=mass of the measuring cylinder; G_S = specific gravity of VTRP calculated; P_W= density of water; V_S= volume of solid; V_T = total volume of cylinder; The volume of void (V_V):V_V = V_T– V_S

Thus, porosity calculated = V_V / V_T

Specific gravity: The method of Ekpete and Horsfall (2011) was adopted. The relative density bottle was cleaned, dried and weighed empty and 10 g of VTRP sample was carefully put into the bottle and weighed. Then water was added to fill the bottle, corked and re-weighed. Finally, the content was cleared of VTRP sample, filled with water alone and weighed. That was done in triplicate to obtain a mean value for the specific gravity (s.g) using the formula:

s.g = (W_2 – W_1) / (W_3 – W_2);

Where: W_1 = weight of density bottle; W_2 = weight of density bottle + dry VTRP sample;

All measurement were done in grams and repeated in triplicate for mean values.

Swelling and Anti-swelling stability: The swellability was determined as adopted by Termiz *et al.,*(2006) and using sets of 1 g VTRP each placed in a separate 10 ml measuring cylinders, then 3 cm^3 of distilled water added. The water was replaced daily for 3 days, this was modified to optimize the material's dimensional stability. The samples weighed, and the water absorption (S= swellability) anti-swelling efficiency (ASE) values calculated for the control and modified materials according to the equations below after each water replacement in line with procedures adopted.

$S\ (\%) = [(V_{wet} - V_{dry})/V_{dry}] \times 100$

$ASE = [(So-S)/So] \times 100$

Where S (%) swellability percentage; W_{wet} = weight of wet sample; W_{dry} = weight of dry sample; M_o= mass of bottle;V_o=volume of bottle.

Where W2 = wet weight of the sample after soaking in water; W1 = oven dry weight; So = volumetric swelling of untreated samples and S = volumetric swelling of treated samples

RESULTS AND DISCUSSION

Table 31: Physicochemical properties of VTRP

Properties	UVTRP	MVTRP
Ash content (%)	9.60 ± 0.03	7.30 ±0.25
Moisture content (%)	17.14 ±1.24	8.95 ±1.00
Volatile content (%)	32.70 ±0.20	40.50 ±1.45
Bulk density (g/cm^3)	23.30 ±0.28	27.85 ±0.01
Fixed carbon (%)	57.70±3.26	52.20 ±2.25
Specific gravity	0.9966 ±1.50	0.6909 ±1.25
Porosity (%)	67.80 ±0.01	83.30 ±2.34
Swellingability (%)	86.70 ±1.36	33.50 ±1.50
Anti-swelling efficiency (%)	-----	61.36 ±2.44

The values below were from the evaluated physicochemical parameters of VTRP studied.

UVTRP – unmodified violet tree root powder, MVTRP – modified violet tree root powder

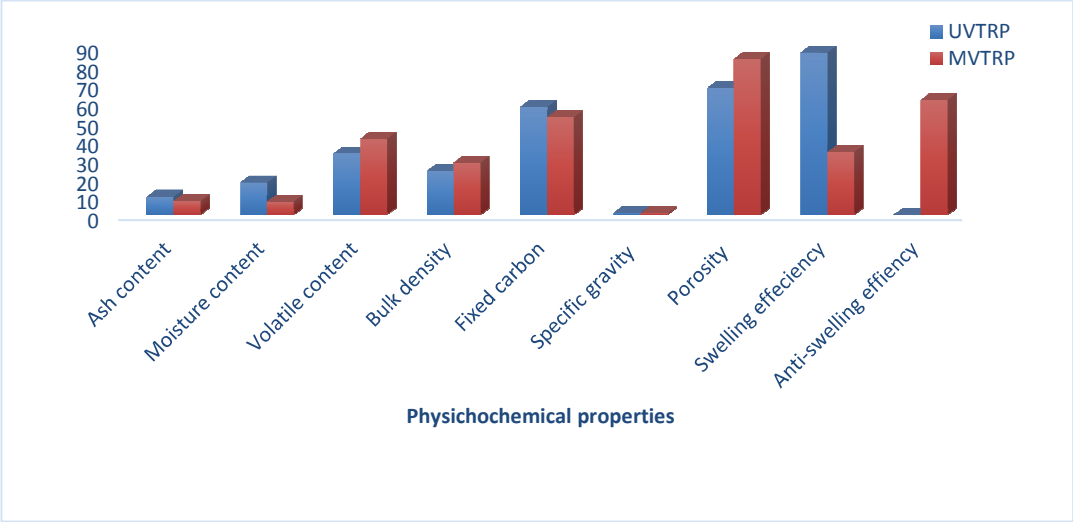

Figure1: A graph of the physicochemical properties of unmodified and modified VTRP.

The results of the physical properties of UVTRP and MVTRP showed that during the sequence of modification, the ash content which is a reflection of the inorganic composition of the VTRP samples decreased from 9.60 %±0.03- 7.30 %±0.25 in unmodified to modified VTRP. Some biomass studied, have been reported to have ash content in sugarcane bagasse 2.44%, wood chips 0.28 %, switch grass 8.77%, rice husk 29.53% coffee husk 7.7% (Braga *et al.,* 2013; Braz and Crnkovic 2014; Brandao *et al.,* 2010; Adekugbe 2012; Mansaray and Ghaly 1997). In general, the ash content of fibrous raw materials has been reported to be between 1 % - 20 % according to Ruben and Bokelman (1987).The result studied also showed a reduction in the moisture content from 17.14 % ±1.24 - 8.95 % ±1.00. The moisture content of fibrous materials determined its operational efficiency. Since fibrous materials are made of hemicellulose, cellulose and lignin as their major constituents, which has hydroxyl groups mainly attached naturally exhibit hydrophilicity (Shurong *et al.,* 2016).

However, modification of such components and the subsequent substitution of their functional group by using solvent of interest could result to morphological changes and the material chemistry. Thus, the low moisture content of the modified VTRP, suggests a low moisture uptake and more hydrophobic nature of the modified VTRP. The moisture content of wheat straw (4.3-9.5) % and sugarcane stalk 8.3% were reported by (Patel and Gami, 2012; Braz and Crnkovic, 2014) showed the moisture contents of rice husk, sugarcane bagasse, coffee husk and pin sawdust to be 8.19%, 6.95%, 8.44% and 6.90% respectively. The moisture content is an influencing factor which directly reduces the overall energy content of biomass and hence reduces its thermal activity (Patel and Gami, 2012). Any biomass with moisture retention value less than (<10%)is a feasible material for combustion (Braga *et al* 2013). The volatile matter in this study increased from 32.70 % ±0.02 VTRP to 40.50% ± 1.45 of MVTRP. Braga *et al.,* (2013), on the characteristics and comparative pyrolysis of elephant grass and rice husk reported that, the elephant grass showed to be more suitable for production of bio-oil due to its higher percentage of volatile content and less ash content, hence less energy to break the bonds of hemicellulose and cellulose than the rice husk in the thermal conversion process. However, Barminas *et al*., (2015) indicated efficient acetylation as the study reported absence of hydroxyl group in the modified VTRP derived from the use of cetyltrimethylammonium bromide (CTAB) as a catalyst. Similarly exceptional advantage is attributed to the removal of hydroxyl component of hemicelluloses and lignin of the cellulose (Hill *et al.,* 2000).The porosity value increased with 67.80% ±0.01 – 83.30% ±2.34 respectively of the unmodified to modify sample biomass. The increased porosity of the modified biomass is an indication that, the expected modified VTRP will be a promising sorbent with high sorption capacity due to the introduced acetyl group present that are larger than the substituted hydroxyl group (Rowell, 2006).

The determined bulk density, fixed carbon and specific gravity gave reductions from 23.30 g/cm^3 0.28±to 27.85g/cm^3 ±0.01; 57.70%±3.26to 52.20% ±2.25;but the specific gravity showed very low value of0.9966 ±1.50 g/cm^3 – 0.6909 ±2.20 g/cm^3, with such values less than the density of water can suggest a better sorption capacity in aquatic environment. It was observed that the immediate parameters exhibit decreased from unmodified to modified VTRP respectively, except fort for the bulk density which indicated increased in modified VTRP of 27.85 g/cm^3 ±0.01.The low value of specific gravity is an indication of efficient buoyancy expected upon application of MVTRP as a sorbent, since it is less denser than water. In addition, the fixed carbon and ash content of the biomass material also showed reduced chars of carbon content from unmodified VTRP to modified. The swelling ability also reduced from 86.70 ±0.36 % to 33.50 ±1.50 % which is indicative of reduced water holding ability due to modification of VTRP fiber. The anti-swelling efficiency of the modified VTRP indicated 61.36% ±2.44 is a significant improvement of the modified biomass sample. Xiaohu *et al*., (2013) reported, that swelling changes caused by increased biomass porosities showed significant increase on the efficiency of the biomass morphology. The improved efficiency is as a result of the penetration of modifying chemical into the cell wall of VTRP to the reactive chemical sites that became hydrophobic with decreased swelling ability (Barminas *et al.,* 2015).Biomass substrates experience modification when treated with different chemicals. The dimensional stability of biomass and other lignocellulosic materials are modified upon treatment of the natural hydroxyl groups and other oxygen containing groups of the polymer cell wall (Pandey *et al.,* 2009; Deka *et al.,* 2003; Rowell, 1975). This study is in tandem with Nwankwere et al., (2011) that established decrease in thermal stability with increased dimensional stability of treated rice husk.

CONCLUSION

In this study, the proximate analyses of unmodified VTRP and modified VTRP were investigated. The characterization revealed significant properties in ash content, moisture content, bulk density, specific gravity, fixed carbon, volatile content, porosity, swelling ability and anti-swelling efficiency of the VTRP biomass samples respectively. The study showed improved physicochemical properties of the modified biomass that will be of good industrial applications in multiple ways, especially the intended sorbent application for spill oil remediation. This study further recommends investigations into the thermal stability of the biomass and syntheses of its lignocellulose for possible identification.

REFERENCES

Adekugbe A., (2012), Determination of heating value of five economic tree residues as fuel for biomass heating system, *Nature & Science,* vol. 10(10), pp26-29.

Aloko D.F and Adebayo G.A (2007). Production and characterisation of activated carbon from agricultural waste (Rice-husk and corn-cob). *Journal of Engineering and Applied Sciences* 2 (2): 440-444.

Arbonnier, M.(2004) Trees, Shrubs, and Lianas of West African Dry Zone, *Cfra Margrat Publishers,* GMBH, Netherland, Pp 435.

American Standard for Testing and Material (ASTM) (1998). D 4007-81: standard test method for water and sediment in crude oil by the centrifuge method. Annual book of American society for testing and material standard (ASTM) committee on standards, West Conshohocken PA.

Barminas J.T., Maitera, O.N., Donatus, R.B., Tadzabia, K., and Tukki O.H (2015). Acetylation of Violet Tree (Securidaca longepedunculata) Root Powder. *International Journal of Scientific and Engineering Research,* 6 (9) 958-965.

Bogan, R.T., Kuo C.M and Brewer R.J. (1979). In Encyclopedia of Chemical Technology, Vol. 5, 3RD Ed., H.F Mark, D.F Othmer, C.G.Overberger and G.T Seaborg, Eds., *Willey Interscience,* New York Pp 703-756.

Braga R. M., Melo D. M. A Aquino F. M., Freitas J. C. O., Melo M. A. F., Barros J. M. F and Fontes M. S. B (2013). Characterization and comparative study of pyrolysis kinetics of the rice husk and the elephant grass, *Journal of Thermal Analysis and Calorimetry,* 115, 2, 1915 - 1920.

Brandão, P.C., Souza, T.C., Ferreira, C.A., Hori, C.E and Romanielo, L.L (2010). Removal of Petroleum hydrocarbons from aqueous solution using sugarcane bagasse as adsorbent. *JournalHazardous Mater.,* 175, 1106-1112.

Braz, Carlos Eduardo Mendes, and Paula Cristina Garcia Manoel Crnkovic (2014).Physical and chemical characterization of biomass samples for application in pyrolysis process*. Chemical Engineering Transactions* 523-528.

Brelid, P.L and Simonson, R. (1999). Acetylation of solid wood using microwave heating, part II: Werkst. 57: 383-389

Dara, S.S. (1991). Experiments and calculation in engineering chemistry. *S.Chand and Co. Ltd New Delhi,* 189-191.

Deka, M., Das, P and Saikia, C.N (2003).Studies on dimensional stability, thermal degradation and termite resistance properties of bamboo (*Bambusa tulda Roxb.)* treated with thermosetting resins. *J. Bamboo Rattan*. 2:29-41

Donatus, R.B (2014). Application of Violet Tree Root Powder (*Securidaca longepedunculata*) As a Natural Sorbent in Oil Spill Treatment. Being a Master Degree Thesis Submitted to the Department of Chemistry, Modibbo Adama University of Technology, Yola-Nigeria.

Ekpete O.A and Horsfall M.JNR (2011). Preparation and characterization of activated carbon derived from fluted pumpkin stem waste (*Telfairia occidentalis hook F*). *Research Journal of Chemical Science*.1(3): 10-17

FAO (1997) Regional wood energy development programme in asia (RWEDP) Report No.39,Availableathttp://wgbis.ces.iisc.ernet.in/energy/HC270799/RWEDP/acrobat/rm39.pdf.

Fapetu, O.P. (2000). Production of carbon from biomass for industrial and metallurgical processes. *Nigeria Journal of Engineering Management* 1: 34-37

Forest Products Laboratory. 1999. Wood handbook—Wood as an engineering material. Gen. Tech. Rep. FPL–GTR–113. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 463

Hill, C.A.S., Cetin N.S & Ozmen Z (2000). Potential catalyst for the acetylation of wood.*Holzforschu*ng (54). 269-272

Hon. David N.S, Lie-Gui Tang, & Yu-Qin Zhu (1996). An investigation in solution acetylation of cellulose by microscopic techniques. Solution Acetylation of Cellulose John Willey and Sons, Incorporation. 1953-1960.

Karr, G.S and Sun, X.Z., (2000). Straw board from vapour phase acetylation of wheat straw. *Ind Crops Prod.* 11: 31-41.

Mansaray, K.G. and Ghaly, A.E (1997), Physical and thermochemical properties of rice husk, *Energy Sources,* Vol.19, pp989-1004.

Nwankwere, E.T., Omolaoye J.A., Nwadiogbu J.O., and Nale B.Y (2011). Thermal and dimensional stability of NBS catalyzed acetylated rice husks. *Der chemica sinica* 2(1) : 189-195.

Odusemi, J.A., Asekunowo, A.K., Popoola, O.E., Adetoro, A.T.,and Tadagbe, B. (2016). Phytoconstituents, Proximate and mineral leaves of Securidaca longepedunculata. *International Journal of Science and Society*, YABATECH Vol 4, No 2, 54-58.

Ojewale, J.A (2008). Analgesic Anti-inflammatory and Hypoglycemic Effects of *Securidaca longepedunculata*(Polygalaceae)Root Bark Aqueous Extract. *Inflamma Pharmacology*, 16(4): 174-181.

Pandey, K.K., Jayashree, and Nagaveni H.C (2009). Study of dimensional stability, decay resistance and light stability of phenylisothiocyanate modified rubberwood. *BioResource*, 4:257-267

Patel B. and Gami B., (2012), Biomass characterization and its uses as solid fuel for Combustion.*Iranica journal of energy & environment,* 3 (2), 123-128.

Pizzi,A.P., Stephanou, A., Boonstra, M.J.,and Pendlebury A.J (1994). Anew concept on the chemical modification of wood by organic anhydrides.*Holzforschung*48,91-94.

Radetic, R.M. Jocic, M. Jovanic, D Petrovic.P and Thomas Z. (2003). Recycled wool-based non-woven material as oil sorbent. *Environ. Sci. Technol*, 37(5), 1008-1012.

Rengaraj S., Seun-Hyeon M., and Sivabalm S. (2000). Agricultural solid waste for the removal of organics: Adsorption of phenol from water and waste water by palm seed coat activated carbon. *Waste Management.* 22 543-548

Ronewicz K., Kluska j., Heda L., and Kardaś D. (2017). Chemical and Physical Properties of Pine Wood during Pyrolysis, *Drvna Industrija*, 68 (1) 29-36

Rowell, R.M., (1975). Reaction of Alkylene Oxides with Wood, Volume 2. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, USA., 116-124

Rowell, R.M. (1992). Opportunities for lignocellulosic materials and composites. *AGS Sympser* 476 12: 12-27

Rowell, R.M. Esenther G.R, Nicholas, D.D. & Nilsson, T. (1987). Biological resistance of southern pine and aspen flake boards made from acetylated flakes J.*Wood chem. Technol.* 7, 427-440.

Ruben, G.C. and Bokelman G.H. (1987). Triple-stranded left-hand twisted cellulose microfibril. *Carbohydrate Research*, 160, 434-443.

Schmidt, E., Lotter M. & McClelland W.(2002). Trees and Shrubs of Mpumalanga and Kruger National publication Park. Jakana Haughton, Johannesburg. 46-49

Shurong Wang, Bin Ru, Haizhou Gongxin Dai, Yurong Wang, Zhongyang Luo (2016). Kinetic study on pyrolysis of biomass components : A critical Review. *Current Organic Chemistry*, 20 (23). 2489-2513.

Sun, R.C and Sun, X.F (2002). Structural and Thermal characterization of acetylated rice, wheat, rye and barley straws and poplar wood fiber, *Ind. crops prod.*16, 225-235.

Sun, X.F. Sun, R.C. Sun, J.X. and Zhu Q. K. (2004). Effect of tertiary amine catalyst on the acetylation of wheat straw for the production of oil sorption-active materials.*Comptes Rendus Chimie*7(2).125-134.

Temiz A., Terziev N., Jacobsen B., and Ekenes M.(2006). Weathering, water absorption and durability of Silicon acetylated and heat treated wood. *Journal of Polymer Science*, 102 (5) 4506-4513

Xiaohu Ju, Courtnee Grego, Xiao Zhang (2013). Specific effects of fiber size and fiber swelling on biomass substrate area and enzymatic digestibility.*BioResource Technology*, 144, 232-239.

Xu, F. & Sun, R.C. (2003). The chemically modified cereal straw as efficient sorbents in oil spill cleans up. *J Cell Sci. Technol* 11, 51-56

Zhang Y, Ghaly A.E., Li B. (2012). Availability and physical properties of residue from major agricultural crops for energy conversion through thermochemical processes, *American Journal ofAgricultural and Biological Science,* 2012, 7 (3), 312-321.