2002 BELTWIDE COTTON CONFERENCES, ATLANTA, GA – JANUARY 8-12

COTTON/BAGASSE/KENAF NONWOVEN FOR HORTICULTURAL END-USE

Y. Chen and O. Chiparus
School of Human Ecology, Louisiana State University Agricultural Center
Baton Rouge, LA
X. Cui, T.A. Calamari and F. Screen
USDA Southern Regional Research Center
New Orleans, LA

Abstract

Bagasse is mass residual from the sugar refining industry. Disposal of this byproduct becomes critical for both agricultural profitability and environmental protection. This research studied an approach to converting bagasse into a biodegradable nonwoven material. A chemical method was used to extract bagasse fiber. The extracted fiber was cleaned and mixed with kenaf and cotton fibers with a ratio of 50:20:30. The fiber blend was carded and needle-punched to form nonwoven structure. The nonwoven fabric was padded by starch paste and dried in an oven. This further bonding procedure helped increase nonwoven strength significantly. Application for horticulture container was studied. SEM analysis and tensile testers were used for evaluation of bonding structure, mechanical properties, and biodegradability.

Introduction

Sugarcane is an important agricultural crop in the southern U.S., with a total crop value of $901.9 million in 1999 [www.usda.gov/mass/pubs/reports.htm]. Florida is the largest U.S., sugarcane producer followed by Louisiana (Table I). The cane stalk consists of an inner pith that contains most of the sucrose and an outer rind with lignocellulosic fibers. Cane processing crushes the entire stalk to extract the sucrose from which refined sugar is produced. Large quantities of the bagasse, containing both crushed rind and pith fibers, remain after sugar extraction. Disposal of this byproduct from the sugar industry is so far still inefficient. For instance, approximately 85% of the bagasse produced in Louisiana is currently used in-house as fuel in mill processes and for other low value applications such as mulch and inexpensive ceiling tiles. The remaining 15% is waste that is allowed to decay or is landfilled [Paturau 1989]. Therefore, finding better ways of bagasse use becomes an important research interest.

Converting bagasse into value-added and biodegradable agrotextiles provides a prospective solution for bagasse use. It will benefit both the environmental protection by reducing bagasse disposal and economic enhancement for the sugarcane industry as cane producers compete in a freer global market. With rapid development of technical textiles, agrotextiles become an important cluster, one of 12 subgroups of technical textiles categorized by the German exhibition company Messe Frankfurt [Smith 2000]. According to Messe Frankfurt, agrotextiles primarily include fabrics used in agriculture, horticulture and landscaping, forestry, animal husbandry, fences, etc. Its market size is about 3.8% of the whole technical textile market in North America [Smith 2000]. It is anticipated that production values of agrotextiles could reach $663 million in 2005 [Smith 2000].

Use of nonwoven for planting pots was reported recently [World Textile Publications Ltd. 2001]. This nonwoven is made of a special polyester filament by spunbond technique. A hot-press procedure is used to fabricate containers with desired shapes and air-permeable and water-releasing features. In the present work, application of cotton/bagasse/kenaf nonwoven for making planting pots is studied. A major research objective is to evaluate feasibility of this natural fiber nonwoven in the planting packaging. Comparing to the spunbond polyester planting pots, the cotton/bagasse/kenaf planting pot is not only air- and liquid-permeable, but also biodegradable. This end-use performance will appeal to the horticultural industry.

Experiment

To form the cotton/bagasse/kenaf planting pot, a series of chemical and mechanical process is needed, including bagasse fiber extraction, web formation and bonding, starch paste padding, and evaluation of mechanical property and biodegradability. Figure 1 is a flow chart illustrating the experiment used in this study.

Materials

Bagasse fiber, kenaf fiber, and low-melting-point polyester bonding fiber (PET) were used in the fabrication of bagasse fiber composite. Waste bagasse was obtained from a local sugarcane mill. Cotton (Maxxa) was provided by USDA Southern Regional Research Center. Kenaf was purchased from a company in Mississippi. Weight blending ratio of bagasse/kenaf/cotton is 50/20/30.

Extraction of Bagasse Fiber

Waste bagasse was pre-cleaned by manually sifting. The selected bagasse was boiled for one hour in a solution of NaOH with concentration of 3N. Liquid ratio (weight/volume) was 1:20. Extracted bagasse fiber was washed thoroughly by running water for several minutes. The bagasse fiber was dried in a Blue M Electric Company Oven at a temperature of 275°F for 45 minutes.

Processing Procedures

The bagasse fiber and kenaf fiber were cleaned using a Cleaning McPhearson Machine at the USDA Southern Regional Research Center in New Orleans. The percentages of weight losses during the cleaning process were 35% for kenaf fibers and 82% for bagasse fibers. Bagasse and kenaf fibers were opened and mixed using a Rando-Webber machine to loosen up fiber bundles, further remove impurities, and blend the different fibers uniformly.

Cotton fiber was blended manually with bagasse and kenaf and fed into a F015D Universal Laboratory Carding Machine to obtain fiber web. During the carding, the fiber blend was further opened and individual fibers were combed to be relatively parallel. To enhance web uniformity, the fiber blend was carded twice. A Morisson Benkshire needle-punching machine was used for mechanically bonding the cotton/bagasse/kenaf web. It ran at a feeding speed of 5.4 feet/min and punching rate of 228 strokes/min. The fiber web was significantly compacted after needle-punching.

The needle-punched web was further wet-bonded using starch paste. Corn Protein Isolate (CPI) starch (EnerGenetics, Inc.) was used for this application. Starch liquid with 5% solids was prepared and heated to the boiling point for gelatinization to form a paste. The starch paste was applied to the nonwoven by a padding machine (Birch Brother Inc.), as shown in Figure 2. The padded nonwoven was then dried in an oven (Blue M Electric Company) for 20 minutes at 257°F. Weight of the dry pasted nonwoven was 186 g/m^2.

Planting pots were made manually with two shapes, cylinder and circular truncated cone (Figures 3 and 4). The cylinder pot was used for durability test and circular truncated cone pot was buried in a large plastic pot for evaluation of biodegradability (Figure 5). Four nonwoven strip specimens (1.5×5 in) with total weight of 3.320 g also were buried in garden for the biodegradation evaluation.

Performance Evaluation

The paste bonding structure of the cotton/bagasse/kenaf nonwoven was studied using SEM technique. Tensile strength of the starched nonwoven was measured using an Instron 4301 tensile tester in reference to the ASTM 5035-95 for fabric break strength (strip method) [ASTM 1998]. Bending properties were tested using a QTest tensile tester with a special bending attachment [Chen 2001]. Time to dissolve the nonwoven in soil was recorded as a measure for its biodegradability. How long the nonwoven pot could sustain weather and routine watering in plant seeding also was recorded for assessing the nonwoven durability.

Results and Discussion

Paste Bonding Structure

After the nonwoven is padded, the starch paste forms a layer of film on the nonwoven surface. This makes a film-like adhesive bonding structure within the nonwoven plane (2 dimensional structure), as illustrated in Figures 6 and 7. In the cross-section plane, however, the adhesive bonding is more like point bonding (Figures 8 and 9). It also can be seen that the adhesive bonding occurs intensively in two surface layers of the fabric. The neutral layer of the fabric has significantly lower fiber density because of lack of paste adhesion. This results in a “hollow” structure in the middle of the nonwoven that helps enhance air permeability.

Processability

During the nonwoven fabrication, carding is a key step for making web. Because of high stiffness and short fiber length of bagasse fiber, carding pure bagasse fiber is difficult to form web. Blending cotton with bagasse is greatly helpful for web formation on the carding machine. In this case, cotton fiber works as a carrier fiber to nest bagasse fiber in carding. The kenaf fiber is used as an additive fiber for increasing nonwoven strength.

Mechanical Properties and Biodegradability

Table II shows tested results of tensile and bending properties of the starched bagasse nonwoven. The tensile strength is critical to determine end-use performance and durability of the planting pot products. The bending properties can be used for evaluating the nonwoven stiffness that are determined by starch add-on and starch liquid solid. Therefore, these instrumental data are useful for quality control purpose. In this study, the starched nonwoven is not stiff enough for the pot formation. The bending rigidity needs to be increased.

After 2 months the cylinder pot used for planting a flower is still in good shape (Figure 10). This indicates that the cotton/bagasse/kenaf nonwoven can sustain weather and routine watering and can meet durability requirement in the production of horticultural products (seedling and retailing). The circular-truncated-cone plot that was buried in a large plastic pot dismantled within 50 days. The starched nonwoven strip specimens [Figure 11] buried directly in garden flowerbed was "dissolved" within only 23 days. Figure 12 shows the sample residual found in the bury field. The residual weighs 0.348 g, reaching a total weight loss of 89.5%. This is an indication of good biodegradability for the cotton/bagasse/kenaf nonwoven. Gardeners can put the flowerpots directly in flowerbeds without taking off the nonwoven pots.

Summary and Further Work

The present study shows a possibility of making biodegradable plant pots using the cotton/bagasse/kenaf nonwoven. The flowerpots made of this nonwoven can be put in garden field or other larger containers and will be biodegraded within 23 to 50 days. Compared to plastic flowerpots now commercially used in the horticultural market, the biodegradable flowerpots are not only convenient for gardeners, but also beneficial for environment improvement. This research is still in an initial stage. Further research work will include study on one-step molding procedure for flowerpot making, evaluation of air/liquid permeability of the nonwoven, and characterization of biodegradability in terms of different types of soil, including control of moisture and pH value.

References

ASTM. 1998. "Annual Book of ASTM Standards, Vol. 07.02." American Society for Testing and Materials. Philadelphia, PA.

Chen, Y. 2001. New Instrument for Measuring Mechanical Properties of Industrial Fabrics, Proceedings of IFAI Expo 2001 Textile Technology Forum. The Textile Institute and Industrial Fabrics Association International. October 2001, Nashville, TN.

Paturau, J. M. 1989. Bio-Products of the Sugar Cane Industry, 3rd Ed. Elsevier, Amsterdam.

Smith, W. C. 2000. Industrial Textiles in North America – Putting it in Perspective. Techtextil North America Symposium, Section 101. March 2000. Atlanta, GA.

World Textile Publications Ltd. 2001. It's a Wrap, *Nowoven Report International*. February 2001, 33-35, 60.

Table 1. U.S. Sugarcane Production (10^3 tons).

State	1998	1999	2000
FL	17,925	16,100	16,871
HI	2,798	2,960	2,726
LA	12,920	15,206	15,000
TX	1,064	1,033	1,749
US Total	34,707	35,299	36,346

Table 2. Tensile and Bending Properties.

Tensile			**Bending**	
Breaking Load (lb)	**Breaking Extension (in)**	**Modulus (psi)**	**Bending Rigidity (Gm·cm^2/cm)**	**Bending Hysteresis (Gm·cm/cm)**
5.852	0.625	209.04	0.1802	1.4750

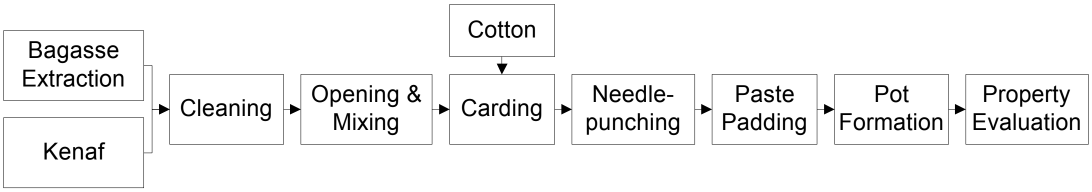

Figure 1. Experiment Flow Chart.

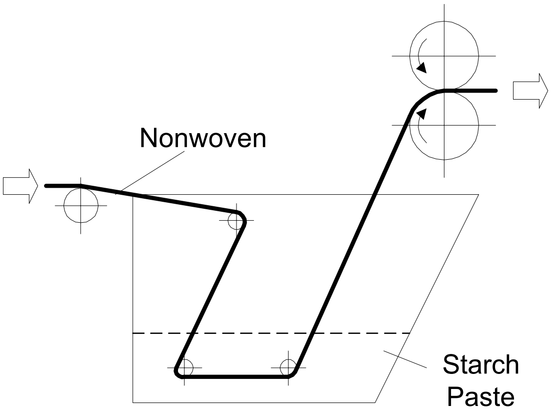

Figure 2. Padding Procedure.

Figure 3. Planting Pot (Cylinder Shape).

Figure 4. Planting Pot (Circular Truncated Cone).

Figure 5. Implantation.

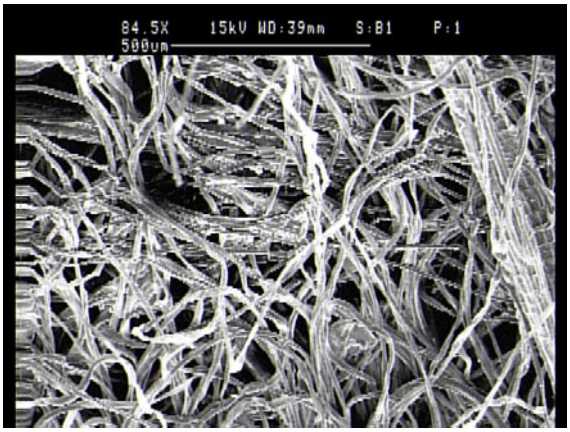

Figure 6. Starched Bagasse Nonwoven Surface.

Figure 7. Starched Bagasse Nonwoven Surface (Zoom-in).

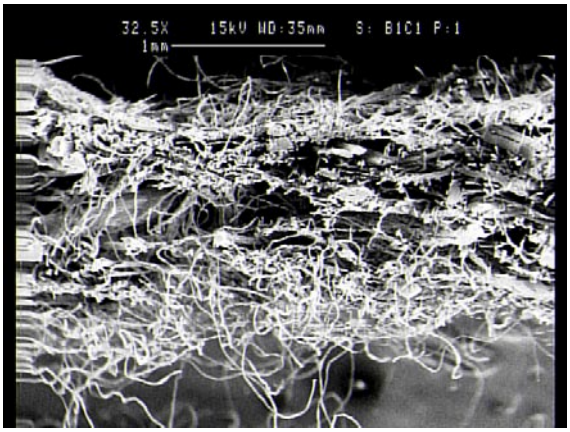

Figure 8. Starched Bagasse Nonwoven Cross-Section.

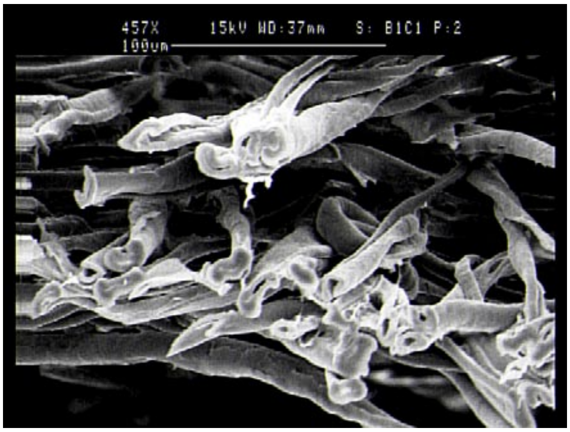

Figure 9. Starched Bagasse Nonwoven Cross-Section (Zoom-in).

Figure 10. Nonwoven Pot after 100 Days.

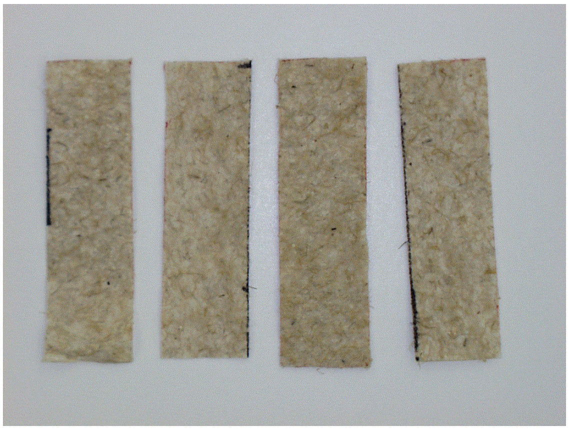

Figure 11. Nonwoven Samples for Burying.

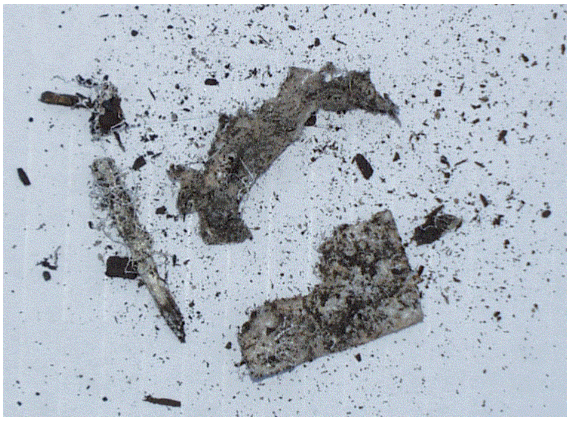

Figure 12. Sample Residual after Burying for 23 days.