

UTILIZATION OF AN INVASIVE SPECIES (*Spartina alternifolia*) IN THE MOLDED PULP INDUSTRY

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ABSTRACT

*As the world's forest resources become increasingly scarce, there is a serious shortage of fiber raw materials for the pulp industry. As a result, non-wood fibers are becoming more and more widely used as raw materials in this industry. In addition, non-wood fibers may be obtained from increasing supplies of biological wastes, and rapidly spreading invasive plants, such as monocotyledonous grasses. A good management practice for many invasive plants with huge biomass potential is to maximize use of them, in order to reach a position of balance, with regard to the control of the species. As an example, this paper discusses the utilization potential of *Spartina alternifolia*, a grass species, which has invaded large areas of coastal regions of Eastern China. Our present studies show that *Spartina's* fiber composition includes: cellulose 35.9%, hemicelluloses 27.2%, lignin 15.9% and ash 9.98%. The length of *Spartina* fibers is shorter and narrower than bamboo fibers, which, to a certain extent, makes it hard for its stems to be developed into chemical pulp. However, for this wild grass, a thermo-mechanical pulping (TMP) process was found to be easier to develop and mix with chemical pulps to manufacture molded pulp products. With new innovations in the world-wide packaging industry, molded pulp products (MPP) may be used in larger quantities and in a broader range of fields. Our present study aims to make TMP fibers from *Spartina* composites with other chemical pulps to produce MPP. Utilization of wild grasses, such as *Spartina*, has the following advantages: 1) It provides a new use for biomass of invasive species, which are considered problematic in many situations; 2) The species, with its large potential for biomass production, provides the opportunity to store CO₂ and biomass on a large scale; 3) Such biomass provides new industrial raw materials for replacing wood fiber-based chemical pulps and petroleum-derived plastics; 4) The technology allows a reduction of pollution, which could arise from wood fiber-based chemical pulping processes; and 5) The materials derived from these species allows new innovations, including the creation of new products with improved characteristics, such as hardness and strength.*

Key words: Invasive grass, *Spartina alterniflora*, Utilization of weeds, pulp molding products, mechanical pulp.

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INTRODUCTION

Spartina alterniflora and related grass species are native to certain coastal areas and have been introduced to many new coastal countries. Their seeds are dispersed primarily by water and they can also be spread long distances by floatation of, pieces of stems. As an invasive species, *Spartina* spp. have adapted well and spread rapidly in intertidal flats of many regions in China (Sally et al. 2001). In 2004, *S. alterniflora* infestations in salt marsh areas in Jiangsu Province reached a total of about 150 km². As herbaceous plants, they can reach heights of 1.5 to 2.1 meters in salty and wet coastal areas. There are 14 to 17 species in the genus *Spartina* (Curtis and Strong, 1997). Biogeographical patterns suggest that the genus *Spartina* originates from the Atlantic and Gulf Coasts of North America. Most species are native to America, while only *S. maritima* is native to Europe. *Spartina* species are highly invasive, as demonstrated by their successful introduction in many locations around the world (Loebl et al., 2006).

This extensive invasion and replacement of native wetland vegetation has resulted in the loss of habitat for aquatic species such as salmon and oysters, resulting in economic losses to those who rely on these species. In China, *Spartina* species have been shown to have significant negative impacts on native coastal ecosystems. Many native species, including plants, endangered birds and human food mollusks, are threatened by *Spartina* invasions (Kaparaju and Felby, 2010). *Spartina* can out-compete almost all native plants, including *Phragmites australis* and *Scirpus mariqueter*, that originally dominated the coastal wetlands and even invaded fish ponds and young mangrove swamps (Squiers and Cordeiro, 2004).

Molded pulp products (MPP) have undergone increasing usage for many kinds of packaging, such as industrial and food packaging. With new technical developments, MPP have become increasingly popular in a variety of manufacturing industries for their advantages in environmental compatibility, biodegradability, low production costs, recyclability, and safe methods of production. The traditional raw material for making pulp is wood fiber; however, with the increasing reduction of available traditional wood fiber sources, increasing attention has been given to non-wood fiber sources. At the present time, conventional MPP are made from diverse materials, including newspapers, waste cardboard, and cartons.

The present study was aimed at developing an industrial system to utilize the large biomass of *Spartina*, an invasive species, in the molded pulp industry, based on its fiber characteristics. An analysis of its fresh fiber characteristics provides a basis for initial utilization, and ultimately, permits the use of its large biomass in the manufacture of larger packaging containers with improved strength

properties. It is suggested that industrial utilization of such novel materials is an important management tool for those invasive plants with large biomass. This would allow for a balanced approach to invasive species management, within the "growth-collection-reduction" model for invasive species.

MATERIALS AND METHODS

Samples

Samples were harvested in October from the upper intertidal area of a muddy salt marsh located in Dafeng Port on the eastern coast of Jiangsu Province, China. The stems of *S. alterniflora* were firstly cut into 1-2 cm pieces (Fig. 1.). These pieces were then sieved, and samples from the 40–60 mesh fractions were selected in order to determine their chemical composition, and for further use.



Figure 1. Stem sample of *Spartina* Fiber Chemical Analysis.

Stem samples of *S. alterniflora* were characterized chemically in accordance with the applicable national standard methods (GBs) for different components, including lignin (GB/T10337-1989), hot water solubles (GB/T2677.4-1993), 1% NaOH solubles, ethanol/benzene extractables (GB/T2677.6-1994) and ash (GB/T2677.3-1993). The holocellulose, cellulose, hemicellulose, and lignin contents of the material were determined using an Ankom Fiber Analyzer (Ankom Corp. USA), with up to 24 samples treated individually enclosed in

filter bags. Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF) and Acid Detergent Lignin (ADL) contents were determined at the same time, and the percentages of cellulose, hemicelluloses, and lignin then calculated. Fiber length was determined biometrically, using an optical microscope, after micro-cooking the raw material with 10 % soda at 80°C for 1 hr and staining the fibers with 1% safranin, according to Rodríguez *et al.* (2010).

Molded Pulp Production

Fruit trays were selected as molded pulp products, which were made from pulps, which consisted of various mixtures of recycled newspaper pulp, bamboo pulp, corrugated cardboard box pulp and thermo mechanical pulp (TMP) from *Spartina* fibers, respectively. The properties of these molded pulp products are shown in Table-1.

Table-1. Properties of fruit trays prepared from different pulp fiber sources.

Sample Name	Fiber source	Average quantity (g)	Average thickness (mm)
A	Bamboo pulp	68.5	0.865
B	Bamboo & TMP (30%wt)	76.55	0.877
C	Bamboo & TMP (40%wt)	69.36	0.753
D	Newspaper pulp	66.5	0.85
E	Newspaper & TMP(40%wt)	68.5	0.803
F	Corrugated box pulp	81.8	0.83

Fruit Tray

Manufacturing Process

There were three main steps in the manufacture of molded pulp products. Firstly, the addition of a volume of water in the pulp pool was followed by the addition of a pre-weighed amount of composite TMP/chemical pulp. The raw materials in the pulp pool were then dissolved for 20-30 minutes using a Hydropulper. The pulp consistency in the pulp pool was approximately 2%. Normally, in this preparation step, the chemical agents were added into the pulp pool to impart special properties. Secondly, a metal mold for the fruit trays of the MPP machine was submerged in the pulp slurry, which was prepared in previous process, and then the slurry was pulled into the mold by vacuum to form the shape of the MPP fruit trays. After this step, the MPP was ejected out of the mold. The fruit tray products were then deposited on a conveyer that moves through a drying oven (Cao and Zhang, 2006). Lastly, the products were dried and then used for further analysis.

Testing of Fruit Trays

Tensile strength tests were undertaken on product samples using a horizontal paperboard tensile tester (WZL-B type horizontal paperboard tensile tester, Hangzhou, China), with ISO 1924.2-1994 as the methodology used in this test (Hoffmann, 2000; Kibirikštis, 2006). Puncture resistance tests were carried out with a board puncture strength tester (Huawei Company, Hangzhou, China) following the ISO 3036 standard method. Board determination of puncture resistance was the methodology for these tests. Air permeability testing was performed with a ZQA-1000 type air permeability monitor (Huawei Company, Hangzhou, China), using methodology with GB458-89 (Gallstedta and Hedenqvistb, 2006). The compression study was divided into two different parts: test of compression resistance of different types of fruit trays, and determination of the cushioning properties. For both parts, a compression tester (DYSY-1 Type compression tester) was utilized (Hornsby *et al.*, 1997).

RESULTS

Different types of molded pulp products can be made. Two such examples are fruit trays and wheel hub containers, which were both made from *Spartina* fiber raw materials and chemical pulps (Fig. 2.), which allows these pulp-based products to achieve high impact strength. These and other pulp products which are green and environmentally safe products made from plant/weed fibers and bamboo pulp as raw material, have potential for wide use in industry and agriculture, The present study is focused on the fruit trays.

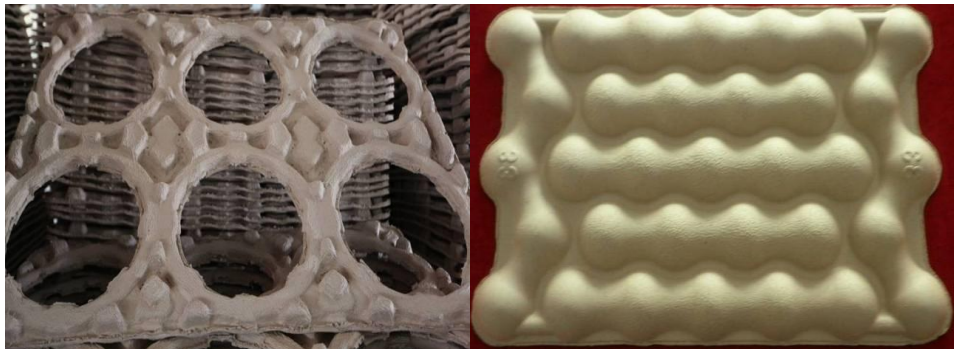


Figure 2. Wheel hub container (left) and fruit tray (right) made of mixed pulps.

Composition of *Spartina* Stem Tissue

The average values of each parameter determined in the chemical characterization of *S. alterniflora* stem tissue are given in

Table-2. A comparison of these values with those previously obtained for other agricultural residues, alternative non-wood plants or agricultural residues is also provided in Table-2. The holocellulose content for *S. alterniflora* stem tissue was higher than that of other agricultural residues, except wheat straw, while the cellulose content was lower than the values of the other materials. The hemicellulose content was higher than the values for rice straw, *Phragmites* and Sorghum stalks. The hemicellulose/cellulose ratio of *S. alterniflora* is suitable for the production of pulp, to increase the fiber's plasticity and flexibility. The lignin content was similar to Sorghum stalks, but lower than those of *Phragmites*, rice straw and wheat straw. Therefore, *S. alterniflora* provides an effective raw material for making mechanical pulp, since it contains 70.1% holocellulose, 35.9% cellulose and 15.9% lignin.

Spartina Fiber Properties

Fiber and cell photomicrographs of *S. alterniflora* fibers are shown in Fig. 3 for fibers and cells released after mechanical processing. The fiber size distribution plot (Fig. 4) indicates that the majority of the fibers are distributed in the 0.50-0.60 mm length range.

Table-2. Chemical Characterization of Various Alternative Raw Materials.

Material	Holocellulose (%)	Celullose (%)	Hemicellulose (%)	Ligin (%)
<i>S. alterniflora</i>	70.1	35.9	34.2	15.9
Wheat straw	76.2	39.7	36.5	17.3
Rice straw	60.7	41.2	19.5	21.9
<i>Phragmites</i>	64.2	39.8	24.4	23.7
Sorghum stalks	65.9	41.5	24.4	15.6

Mechanical Properties of the Molded Pulp Products

Compression resistance is one of the most important physical properties in the packaging industry. Accordingly, the compression resistance properties of the MPP obtained in this study were examined. The relationship between time and applied pressure was obtained for six types of fruit trays, under 120 mm/min uniform loading pressure, within 1 minute. The results (Fig. 5.) indicate that the type B sample (30% TMP/bamboo pulp from Table-1) exhibits the best compression resistance performance amongst the tested samples. Type C, which

was made of 40 wt% TMP/bamboo pulp, exhibited the worst compression resistance overall. From these results, it can be concluded that, when using TMP from *Spartina* mixed with bamboo pulp as a composite pulp to produce fruit trays, the *Spartina* fibers performed an important role in these composite fiber materials. When the weight percentage of *Spartina* fiber was less than 30%, the *Spartina* fibers can play an effective supporting role in TMP/bamboo pulp raw materials. However, if the weight ratio of TMP fiber increased to 40%, the compression resistance was less than that of the sample using 100wt% bamboo pulp.

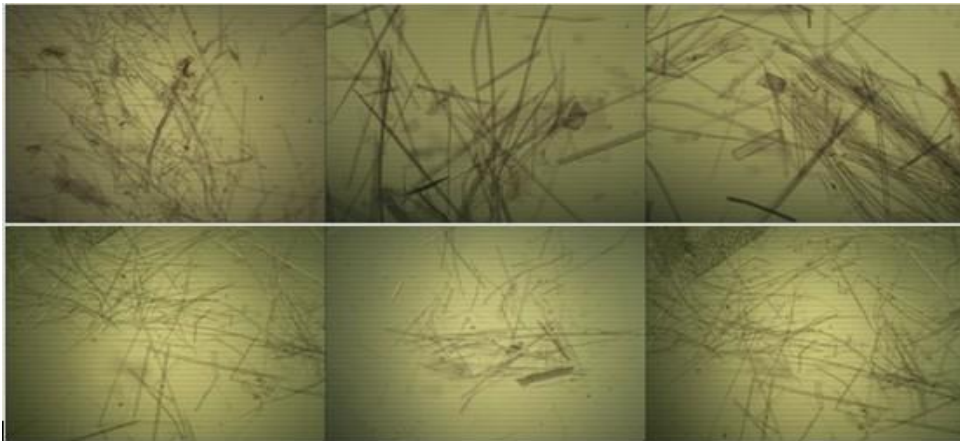


Figure 3. Fiber types of *S. alterniflora* by light microscopy.

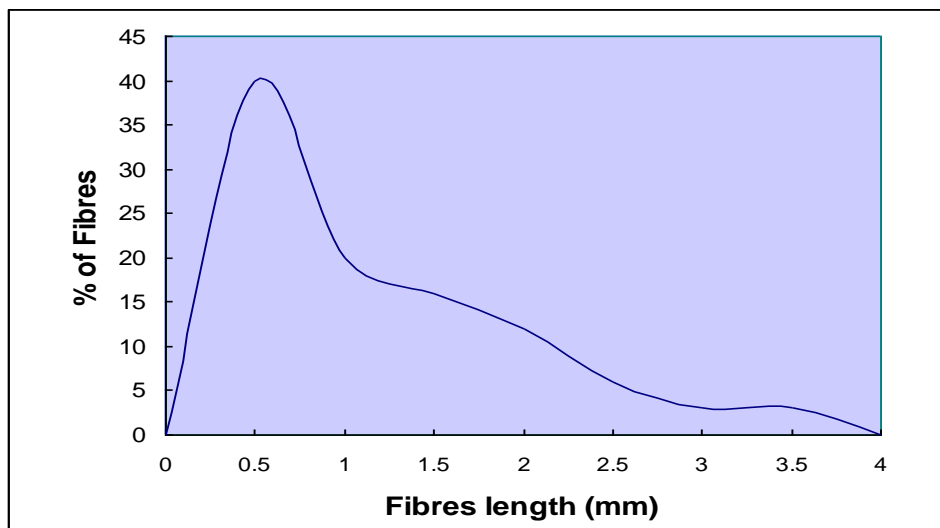


Figure 4. Distribution plot of *S. alterniflora* fiber size.

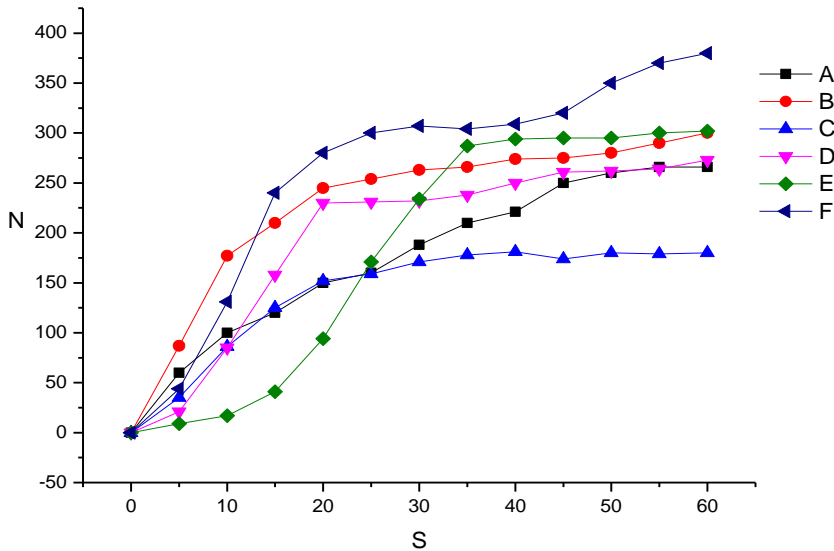


Figure 5. The resistance of compression properties of 6 types of fruit trays (Left). (A, B, C, D, E, F as shown in Table-1 above).

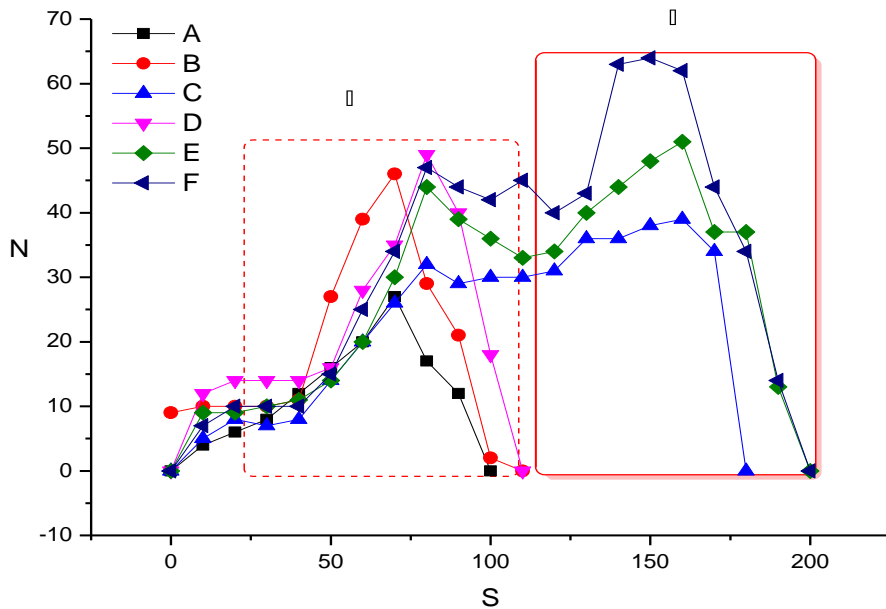


Figure 6. The cushioning properties of cushion structure in six types of fruit trays (Right). (A, B, C, D, E, F as shown in Table-1 above).

Cushioning Properties of Molded Pulp Products

One of the important characteristics of fruit trays is the resistance to vertical load, or cushioning. For instance, by stacking packed fruit trays for storage, there are cumulative vertical forces acting downwards on the trays. Good cushioning properties of fruit trays mean that they can achieve good loading capacity, thereby effectively reducing potential damage to the contained fruits. In this study, the resulting cushioning properties of fruit trays prepared from different pulp mixtures are shown in Fig. 6.

As observed in Fig. 6, the pressure loading of fruit trays of type A, B, and D increased with compression times in the range from 0-75seconds. However, for compression times from 75-100 seconds, the cushioning characteristics of these same 3 sample types decreased rapidly. These observations may due to the presence of different deformation processes in the materials, including elastic deformation to plastic deformation transitions. From these observations, it may be concluded that, types C, E, and F have better overall cushioning performance than the types A, B, and D.

CONCLUSIONS

Based on the chemical and biometric studies of *S. alterniflora* and the corresponding molded pulp products, it is concluded that pulp molding provides an effective means of utilization of invasive species consisting of non-wood fibers. Mechanical pulping of *S. alterniflora*, mixed with chemical pulp, can make useful molded pulp products with good mechanical properties. Based on the yield values obtained, nearly one half of the raw material can be efficiently converted into pulp for molding. This provides a good way to turn *S. alterniflora* into a useful raw material, while also finding a new balance between control and utilization of this invasive plant species. When two kinds of fibers are mixed as composite fiber materials, the TMP fibers can increase the hardness of the composite fiber, and the chemical pulp can increase the extension properties of the composite pulp. In conclusion, the present work represents the first reported utilization of *Spartina* spp. in the molded pulp industry. Using this weed as an industrial raw material to make packaging products provides a basis for further utilization of other straw and weed plants in the future.

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