Nonwood Fibres & Moulded Products

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Moulded products manufactured in North America and Europe are typically made from virgin woodpulp and/or recycled fibre pulp. With high woodpulp costs and declining wastepaper quality, producers are looking for alternative pulp sources.

In recent years, moulded tableware produced from nonwood fibre raw materials such as sugarcane bagasse, wheat straw and bamboo has entered North American and European markets, primarily from Asia. Some North American producers are importing nonwood pulps for domestic moulded product production, and a few are actively investigating and installing nonwood pulping lines.

This paper provides an introduction to the challenges and opportunities for nonwood fibre pulping for moulded products.

Introduction

Virgin woodpulp prices dropped in the 2008 to 2009 period but have since recovered to relatively high prices seen in the early 2000s.

At the same time, wastepaper recycling has increased substantially. By 2011, 70.4% of all paper grades were recovered in the EU [1]. There were 12 countries that recycled less than 60% but 13 that recycled more than 70%. In 2012, 65% of all paper grades were recovered in the USA including 70% of the newspaper/mechanical grades and 91% of old corrugated boxboard [2]. At the same time, 70% of all grades were recovered in the UK [3]. The UK also had the distinction that, of the 4.4 million tonnes of new paper and board produced, 86.5% of the furnish was recycled fibre.

Wastepaper grades that tend to be the least recycled are printing and writing grades which have a recycling rate of about 25% in the USA. The most often cited reason is that they often contain personal and/or commercial financial and proprietary information that end users do not want in the recycling stream unless shredded so it often ends up in landfill.

And, both the USA and EU export substantial amounts of wastepaper to Asia to feed their increasing demand for fibre.

As a result of high wastepaper recycling rates, the quality has declined. With added pressure to further increase recycling rates as well as Asian fibre demand, it is anticipated that the quality will decline further over time accompanied by cost increases.

There is a growing consumer perception that "tree-free" moulded products are more environmentally friendly than wood-based products. While I believe that products made from sustainably grown wood and wastepaper are just as environmentally friendly as those made from nonwoods, this perception does provide new market opportunities.

There are many nonwood fibre raw materials that can and are being used to produce moulded products. In a properly designed mill, they can produce a cost effective alternative to virgin woodpulp and recycled fibre. But, there are also challenges to implementing nonwood pulping systems.

Nonwood Fibre Availability

Table 1 provides an estimate of the global annual amount of some nonwood fibre raw materials that can be sustainably used for pulping without impacting on soil quality. It is by no means all inclusive as there are literally thousands of nonwoods.

Cereal Straws		
	Barley	195,000
	Oat	55,000
	Rice	360,000
	Rye	40,000
	Wheat	600,000
Pith Containing		
	Corn stalks	750,000
	Grain & sweet sorghum stalks	252,000
	Sugarcane bagasse	102,000
Bast Fibre Plants (whole stalk)		
	Cotton stalks	68,000
	Oil seed flax straw	2,000
	Textile flax, hemp, jute, kenaf etc.	14,000
Bamboo, Reeds & Grasses		
	Bamboo	30,000
	Grass seed straw	3,000
	Papyrus	5,000
	Reeds	30,000
	Sabai grass	200
Cotton		
	1st & 2nd cut linters	2,700
	Staple fibre	18,300
Leaf fibres		
	Abaca (Manila hemp)	100
	Sisal, henequen, maguay	500
Other		
	Oil palm empty fruit bunches	10,000
TOTAL		**2,537,800**

Table 1 Global Availability (1000 bdmt/y)

Given that *Table 1* shows that about 2.5 billion tonnes of nonwoods are available annually, from both agricultural residues and some fibre crops, it is very likely that some of the nonwoods listed are available within a reasonable economic collection radius of most moulded product producers.

General Comments on Nonwoods

Nonwood fibres include a very wide range of raw materials, fibre characteristics and forms of delivery. Exceptions are typical or, in other words, "one size doesn't fit all". Nonwoods can be broadly categorised as "common" fibres and "speciality" fibres.

Common nonwoods have short fibre length and are considered hardwood substitutes due to similar properties. These include:

Fibre Source	Length (mm)			Diameter (μm)			L/D Ratio
	Max.	Min.	Avg.	Max.	Min.	Avg.	
Bagasse	2.8	0.8	1.7	34	10	20	85:1
Corn stalks	2.8	0.68	1.26	20	10	16	80:1
Industrial hemp (bast)	55.0	5.0	20.0	50	16	30	1000:1
Industrial hemp (core)	0.6	0.5	0.55	25	15	20	28:1
Kenaf (bast)	7.6	0.98	2.74			20	135:1
Kenaf (core)	1.1	0.4	0.6	37	18	30	20:1
Rice straw	3.48	0.65	1.48	24	7	13	110:1
Wheat straw	3.12	0.68	1.48	24	7	13	110:1
Softwood	3.6	2.7	3.0	43	32	30	100:1
Hardwood	1.8	1.0	1.25	50	20	25	50:1

Table 2
Fibre Dimensions of Selected Nonwoods Fibre

Fibre Source	Alpha Cellulose (%)	Lignin (%)	Pentosans (%)	Ash (%)	Silica (%)
Bagasse	32 - 44	19 - 24	27 - 32	1.5 - 5	0.7 - 3
Corn stalks	35 - 40	14 - 16	26 - 28	3 - 7	0.4 - 3
Industrial hemp (bast)	55 - 65	2 - 4	4 - 7	5 - 7	<1
Industrial hemp (core)	39 - 49	16 - 23	16 - 23	3 - 4.5	<1
Industrial hemp (whole stalk)	43 - 51	9 - 13	9 - 13	4.5 - 6	<1
Kenaf (bast)	31 - 39	15 - 18	21 - 23	2 - 5	<1
Kenaf (core)	34	17.5	19.3	2.5	<1
Rice straw	28 - 36	12 - 16	23 - 28	15 - 20	9 - 14
Wheat straw	29 - 35	16 - 21	26 - 32	4 - 9	3 - 7
Softwood	40 - 45	26 - 34	7 - 14	1	<1
Hardwood	38 - 49	23 - 30	19 - 26	1	<1

Table 3
Chemical Properties of Selected Nonwoods

- cereal straws
- corn stalks
- oil palm empty fruit bunch fibre
- reeds & grasses
- some bamboos
- sorghum stalks
- sugarcane bagasse

Generally, the pulp is normally made into paper at the same mill and the pulp mill capacity is smaller than the paper mill capacity with the balance of the furnish being softwood Kraft for strength. Globally, there are very few market pulp mills producing common nonwood pulps.

Speciality nonwoods have long fibre length and properties equal to or better than softwood Kraft pulp. These include:

- bast fibres from flax, hemp, jute, kenaf
- cotton staple and linters
- leaf fibres such as abaca and sisal
- some bamboos

Bast and leaf fibres produce high quality speciality pulps used in very special applications such as tea bags, sausage casing, currency etc. The pulps command very high prices in the range of US$ 2,000-4,000/admt and are made in very small pulp mills.

Cotton linters and bamboo pulps may be produced in larger mills. While linter pulp is expensive, bamboo pulp is typically in the price range of woodpulp.

Bamboo shows up in both common and speciality nonwoods because there are over 1,250 species with some having properties similar to hardwoods, some similar or better than softwoods, and some in between hardwoods and softwoods.

If cost is the sole deciding factor on the selection of a nonwood fibre for moulded products, then the selection likely will come from the common nonwoods.

However, an exception could be whole stalk pulping of bast fibre containing plants such as industrial hemp, kenaf and flax. These plants contain two types of fibre - a long bast fibre and a short "woody" core fibre. By pulping the whole stalk, the expense of separating the bast fibre is eliminated. Also, the overall pulp yield on incoming raw material will be significantly higher.

General Comments on Moulded Products

Virtually any moulded product can be made with a nonwood fibre content. It can be:

- 100% nonwoods using one or more nonwood fibres
- partly nonwood and partly woodpulp
- partly nonwood and partly recycled fibre

The nonwood content will depend on many factors including:

- end product quality requirements
- machine runnability
- economics

However, some nonwoods may be better suited to specific end products.

Currently, moulded products imported into Canada and the USA are made from:

- bamboo
- oil palm empty fruit bunch
- sugarcane bagasse
- wheat straw

Selected Nonwood Fibre Properties

Tables 2 and *3* provide fibre dimensions and chemical prop-

erties of some selected nonwoods.

The average fibre length of the common nonwoods, bagasse, corn stalks and rice and wheat straw, is similar to hardwoods. However, the average fibre diameter of these nonwoods is less than that of hardwoods. These slender nonwoods tend to be more fragile than hardwoods and require more gentle processing and less refining than hardwoods to develop their strength properties.

Hemp bast fibre is significantly longer than softwood fibre and it requires additional cutting to make it suitable for papermaking or moulding.

The core fibres from both hemp and kenaf are about half the length of hardwood fibres and do not produce very strong pulp. However, if processed as whole stalks, the combined effect of the bast and core fibres produces good quality pulps.

The common nonwoods - bagasse, corn stalks and rice and wheat straw - generally have lower lignin and higher pentosan content than hardwoods which results in lower chemical requirements for chemical pulping. However, they also have higher ash and silica content which needs to be addressed in the mill design.

Hemp and kenaf have lower lignin content than either softwood or hardwood which again indicates lower chemical requirements for chemical pulping.

Nonwood Pulping for Moulded Products

a) **General Comments**

All of the chemical processes used for producing woodpulp - Kraft, soda, sulphite - can also be used to produce nonwood pulp. The world standard for most nonwood chemical pulps is the soda or soda-AQ process. The chemical processes can be either low yield, full chemical bleachable grade pulp or high yield semi-chemical pulp.

Mechanical pulping processes - alkaline peroxide mechanical pulp (APMP), bleached chemi-thermo-mechanical pulp (BCTMP), chemi-thermo-mechanical pulp (CTMP) and thermo-mechanical pulp (TMP) - also can be used for many nonwoods.

Given the wide range of processes, one needs to consider that, for moulded products, the capacity of any nonwood pulp line would be relatively low as compared to a paper mill. Likely, the maximum size would be in the order of 100-150 bone dry metric tons/day pulp, and many will be smaller. This capacity range likely would apply to both an add-on nonwood line to an existing moulded products facility or to a greenfield mill.

The implications of this small size are that the capital cost needs to be as low as possible and this will impact on process and equipment selection.

The following sections briefly discuss various options for a small scale nonwood pulping line for moulded products.

b) **Low Yield Full Chemical Pulping**

Full chemical pulping by any process is very capital intensive. Also, due to the amount of cooking chemicals used, full black liquor recovery to reuse these chemicals for financial and environmental reasons is required. Even if only partial chemical recovery was used, at the small anticipated capacity of the nonwood pulping line for moulded products, the line likely will not be economical to produce pulp for moulded products. As such, full chemical pulping by any chemistry should not be used.

c) High Yield Semi-Chemical Pulping

High yield (60-65% pulp on cleaned material entering the digester) semi-chemical processes use significantly lower amounts of cooking chemicals, so low that chemical recovery is generally not economical under any situation. As mentioned, the soda (NaOH) process can be used with most nonwoods. Liquor and wastewater will need to be treated properly before discharge from the mill to an industrial sewer or receiving stream. Alternately, the chemistry could be changed to a potassium (KOH) or ammonium (NH_4OH) base which would allow the effluent land spread as fertilizer.

Typically, nonwoods are cooked at 165-175°C for very short periods in pressurised horizontal tube or batch digesters.

However, for high yield semi-chemical pulp, the cold soda process could be used which "cooks" the pulp at atmospheric pressure at temperatures typically in the range of 95-98°C. This can be done in a batch process using hydrapulpers similar to those used for recycling wastepaper.

High and very high yield semi-chemical processes are well suited to producing unbleached pulp cost effectively at lower capacities.

d) Extrusion Pulping

Figure 1 Twin Screw Extruder

Twin screw extruders (*Figure 1*) such as the Bivis extruder have both compaction and expansion zones. This allows for different reactions in different zones as the raw material is processed along the length of the screw. Depending on the nonwood fibre raw material, you may be able to produce either unbleached or bleached pulp in the same machine.

Chemicals are typically required and chemical charges will vary depending on the raw material and end product.

Properly prepared and cleaned nonwood raw material is critical to success and to reducing wear on the screws.

Extrusion pulping is well suited to smaller mills.

e) Mechanical Pulping

Unbleached or bleached mechanical pulp can be produced cost effectively in smaller mills.

Preprocessing the raw material into a uniform slurry is critical for good refining to develop the pulp properties. Using a Tornado pulper (*Figure 2*) which has a rotor/stator with cutting elements followed by hydrocyclone cleaning and screening to remove sand and dirt before the refiners for virtually any fibre raw material to be presented to the refiners as a uniform slurry.

Mechanical pulping is well suited for smaller pulping lines. It can also be used on a wide range of nonwood fibre raw materials provided that proper preprocessing is done. Depending on the raw material and end product, chemicals may or may not be required. If used, the chemical charges are typically small. Yield can be very high, exceeding 90% in some cases.

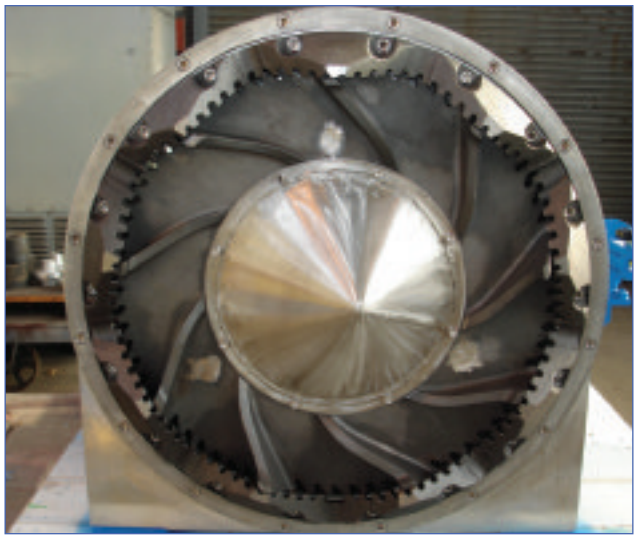

Figure 2 Tornado Pulper

Marketing

All fibre raw materials – wood, nonwoods, wastepaper – will produce moulded products that are compostable and sustainable.

Moulded products made from nonwoods may or may not be "greener" than wood or wastepaper based products. However, if one is going to make "green" claims about nonwood fibre moulded products, a peer reviewed, independent life cycle analysis (LCA) is required to support those claims in most North American and European countries.

The better approach, in my opinion, is to simply offer the nonwood product as an alternative to wood and petroleum based products, and allow the consumer to decide.

Conclusions

Nonwood fibre raw materials offer many potential opportunities for moulded products producers to create new products cost effectively.

The key will be the ability to produce the pulp on a small scale cost effectively. The foregoing touches on a only few of the possibilities for small scale nonwood pulping (there are others). Process and equipment selection will depend on many factors including end product requirements and the specific nonwood fibre raw material.

There is a wide range of nonwoods suitable for moulded products. In the US, there are several projects at various stages of development to make nonwood pulp for moulded products - two using wheat straw, one using sugarcane bagasse and one using *miscanthus*. Over time, expect to see more.

The movement towards nonwood fibre pulping for moulded products in North America has already started and one can expect to see it coming to Europe in the near future.

References

[1] CEPI
[2] www.epa.gov/osw/conserve/materials/paper/faqs.htm
[3] www.paper.org.uk/information/factsheets/recovery_and_recycling.pdf

A letter from India

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Enforcing Environmental Norms and Policy Measures

Prior to the last couple of months, non-availability of raw materials was the burning issue for the Indian pulp and paper mills, but all of a sudden the environmental issue has become the main focus. The Central Pollution Control Board (CPCB) has been assigned to enforce revised norms and policies against the pulp and paper industries, the first phase ending within the stipulated period of March-April 2015. Theoretically the second phase, long term measures, has commenced and is to be accomplished by March 2016, the final term being December 2017.

While only a handful of mills have shown accomplishments, the majority of industries are unable to bear the brunt of the legislation. However, CPCB is not prepared to hear any excuses and is not bothered if a mill has to be closed if it fails to maintain the norms and follow the revised practices. Starting from fresh water intake norms to effluent discharge norms, all have been well defined for the three categories of paper mills, with both short and long term objectives. For example, the wood based mills producing bleached grade paper and board have to achieve 60m^3/tonne of paper for water consumption while the effluent generation has to be 50m^3/tonne; the long term being 40m^3/tonne. For the recycled fibre producing bleached grades of paper, the norms are 15 and 10 (water consumption) and 10 and 6 (effluent generation) m^3/tonne for the short and long terms respectively.

A number of measures to curb pollution have been introduced in the CPCB Charter, including continuous online effluent and emission monitoring; flow meters and monitoring of pH, DO, SS, TDS, COD, BOD, colour etc. Meanwhile, the BOD norm in the effluent is being insisted to 25-20mg/litre.

The mills which are unable to meet the targets and are thus vulnerable to closure are the agro-based mills of smaller capacity (<100tpd), where a recovery boiler is techno-economically not viable. However many mills are still using agro-residues, mainly those which produce a higher volume of black liquor and operate their recovery boilers efficiently.

Few mills have just been asked to close or are on the verge of closure because of their inability to maintain the parameters and install online and other equipment. Mills have to practically demonstrate Zero Liquid Discharge (ZLD) henceforth.

Obviously, the reason behind such stricter measures is to curb the water pollution in river. It has started in a big way for the River Ganges and its tributaries but it is going to be enforced all over the country.

In fact this legislation affects all other industries as well, including sugar, leather, textile etc, which have to implement the charters of CPCB. Government is also looking seriously to restrict and improve discharging of the municipality wastes into the rivers. The whole society has to maintain cleanliness without throwing polythenes and plastics into the rivers. It is a long process and has started with the industries in the river belts.

How good it would be if the river water in India can be made drinkable like in many countries in the West!