UTILIZATION OF ANNUAL PLANTS AND AGRICULTURAL RESIDUES FOR THE PRODUCTION OF PULP AND PAPER

A.M. Hurter
Chairman
HurterConsult Incorporated
51-5450 Canotek Road
Ottawa, Ontario
Canada K1J 9G3

ABSTRACT

Non-wood plant fibers can be grouped into four classifications - stalk fibers, bast fibers, leaf fibers and seed hair fibers. The fiber and pulp characteristics of non-wood fibers within each class are, in general, similar. The stalk fibers are usually used for the production of common papers whereas the leaf, bast and seed hair fibers are used for the production of specialty papers. A wide range of papers can be produced from non-wood fibers, and the production of paper from agricultural residues permits multiple purpose land use - use of land for food and/or textiles and pulp and paper.

A. INTRODUCTION

Today, the production of pulp and paper is almost invariably associated with wood as the basic raw material. This was not always so; in fact, the production of pulp and paper from wood is a relatively recent development. For centuries, even millennia, before wood was ever used for the production of pulp and paper, paper and paper-like materials were produced from sources other than wood; thin hides and parchment from animal skins, papyrus made by the lamination of slices of papyrus reed, the amatl paper of Central American Indian civilizations made from the inner bark of trees.

The first true papers probably derived from felt made from animal hair, and it would appear that the Chinese were producing a paper-like substance by the maceration of silk fibers as early as the second century B.C. Historically, the first true papers made from vegetable fibers are credited to Ts'ai Lun in 105 A.D., and the art spread from China through Arabia to Europe, where chemical processing was slowly introduced to supplement the maceration process.

The pulping of wood was developed only in the 19th century, because the traditional raw materials, cotton and linen rags, were no longer available in sufficient supply to meet increasing demand for paper.

Today, by far the largest amount (97%) of pulp and paper is produced from wood, but interest is increasing in the utilization of non-wood fibers. In many countries, the wood supplies available will not continue to meet the rising demand for pulp and paper for very long; there are many countries wishing to produce pulp and paper where wood is not readily available; and in some countries where the market for pulp and paper products is limited, non-wood fibers offer the possibility of the construction of small economically viable mills, since the processes for pulping non-wood materials are usually simpler.

B. NON-WOOD FIBROUS RAW MATERIALS

B.1 General

Excluding non-vegetable fibrous raw materials such as silk, synthetic fibers, glass fibers and asbestos, which are used only to a very limited extent, the non-wood fibrous raw materials may be classified according to source as:

Stalk or culm fibers	Cereal straws, grasses, reeds, bamboos, sugarcane
Bast fibers	Flax, jute, hemp
Leaf fibers	Sisal, abaca
Seed hull fibers	Cotton

Table I lists some of the more common non-wood fibrous materials. As some of these materials, such as bast fibers, leaf fibers and seed hull fibers, are used primarily for the production of textiles, or in the case of sugarcane, for the production of sugar, the term "fiber" often has a different meaning and this may lead to confusion. In the textile industry, "fiber" is the material removed from the plant. In most cases, this is done mechanically, though biological treatment - retting - is used to assist in the removal of the "fiber" in the case of bast fibers. In the textile industry, the objective is to obtain material of as great a length as possible for spinning. For example, "fibers" for spinning up to 1.5 to 2 m long can be obtained from sisal and abaca plants. These are really fiber bundles or strands made up of a very large number of much smaller fiber cells, and it is these ultimate fiber cells that are termed "fiber" in the pulp and paper industry. Thus, although in textile terminology, sisal may have a "fiber" length of 1.5 m, the actual average fiber length from a papermaking point of view is only 3 mm.

In the sugar industry, "fiber" is the total solid residue discharged after extraction of the sugar. The "fiber" of the cane sugar industry, commonly known as bagasse, contains much non-fibrous material (pith and dirt) unsuitable for papermaking.

In this paper, "fiber" is the ultimate fiber cell as released from the raw material by chemical treatment. Because of the wide variety of sources of non-wood fibrous raw materials, the pulps produced from these raw materials have a far greater range of properties, than pulps produced from wood.

B.2 Fiber Dimensions

Non-wood materials have a wide range of fiber lengths and diameters. The average fiber length varies from 1.0 mm to 30.0 mm, and the average fiber diameter varies from 8 to 30 microns with length to diameter ratios ranging from 50:1 to 1500:1, as can be seen from Table II. In general, stalk fibers are short, having fiber lengths and length to diameter ratios of the same order as hardwoods. The stalk fibers, however, tend to be more heterogeneous and exhibit a wider distribution of lengths and length to diameter ratios than hardwoods. An exception is bamboo. Some bamboo have fiber lengths equivalent to softwoods and since even the shorter fiber bamboos have a relatively high length to diameter ratio, bamboo usually produces a pulp that is closer to softwood than to hardwood pulps.

Bast and leaf fibers, with the exception of jute, are long and slender and have very high length to diameter ratios and consequently, produce very strong pulps.

Cotton has the greatest average fiber length - up to 30.0 mm - if the source is rags or raw cotton staple fiber, and pulps of high strength can be produced. However, if he source is linters, the fiber length is much less, though still greater than that of most other raw materials.

B.3 Chemical Composition

The chemical composition of the non-wood fibrous raw materials also varies over a larger range than wood, as can be seen from Table III.

Unfortunately, analyses in the past have not always been consistent and consequently, data obtained from published literature are often not directly comparable.

Plant stalks (cereals, grasses, reeds and bamboos) generally have high pentosan contents, exceeding the pentosan content of hardwoods, and while the lignin content is the same or lower than in the case of wood, the ash and silica content of plant stalks is generally high, exceeding that of wood by a considerable margin. The ash and silica content of rice straw is particularly high.

Both bast and leaf fibers are low in lignin - usually having half or less than half of the lignin content of wood. Bast fibers have very low pentosan contents- lower than that of softwoods while leaf fibers have a pentosan content of the same order as hardwoods. The ash content of bast fibers is close to that of cereal straws, but the leaf fibers have a low ash content, in some cases, as low as that of wood.

Cotton has a low lignin, pentosan and ash content and consequently, it is simple to produce pulps of high chemical purity and high alpha cellulose content from cotton.

B.4 Sources, Forms, Handling and Preparation of Raw Materials

Again, because of the wide variety of sources of non-wood fibrous raw materials, these raw materials are delivered to a pulp and paper mill in a much greater range of forms than in the case of wood (See Table IV). The methods of handling, storing and preparing the raw materials for pulping can thus differ greatly, depending on the raw material and/or its source. In almost all cases, the handling, storage and preparation of non-wood raw materials for pulping differ from the well-established systems used for wood.

Because of the dominant position of wood as the raw material for pulp and paper production, the development of efficient systems for handling, storing and preparing non-wood raw materials has not received much attention, and in mills using non-wood raw materials, most of the problems encountered are in the handling, storage and preparation of the raw materials.

The problem is further complicated by the fact that only a few of the non-wood raw materials -the reeds, bamboos and some of the grasses - are harvested specifically for pulp and paper production.

Most of the non-wood raw materials are agricultural residues and wastes from other industries and consequently, any handling system must tie in with the primary use of the raw material. Also, in general, non-wood fibrous raw materials are bulky and thus costly to transport over long distances.

Of the raw materials harvested specifically for pulp and paper production, large bamboos cut to suitable lengths are handled and stored much in the same manner as wood stored in ranked piles; small bamboos and reeds usually are handled and stored in bundles.

Since grasses must be harvested over a much greater area than bamboo or reeds for a given pulp production, grasses are usually baled for transportation.

Of the agricultural residues, the cereal straws are usually baled before transportation to the mill, because of the many points from which the straw must be collected and the straw is stored in bale form in large piles. However, in regions where grains are animal threshed, which breaks the straws into pieces too small to permit baling, bulk handling and storage is used.

In the case of sugarcane bagasse, the basic raw material (the sugarcane) has already been collected by the sugar mills and the residue - the bagasse - only needs to be collected from one or more sugar mills, instead of from the fields, as in the case of cereal straws. Having large volumes of the raw material at well defined points favours bulk handling, and all of the new bagasse pulp and paper mills use bulk handling, transport and storage systems. Bagasse can be baled, if the supply must be drawn from very many small mills or transported over very long distances and if baled, storage is in bale form. But baling is expensive, and losses on handling and storage are high; consequently, bulk handling, transport and storage are used whenever possible.

Leaf and bast fibrous raw materials take several forms such as;

- rags, sacking, ropes, twine and threads made from leaf and bast fibers
- waste (tow) from the preparation of leaf and bast fibers for textile and rope production
- waste from the actual manufacture of textiles and ropes
- the retted bast ribbons or stripped leaf fibers that are the raw materials for textile and rope manufacture
- the whole plant.

In those few cases where the whole plant is processed at the pulp mill for the production of bast fiber pulp, it is necessary to remove the bast fibrous material from the woody stem and the leaf fibrous material from the fleshy material of the leaves. In the case of the other sources of leaf and bast fibrous raw materials, this separation has already been made for the production of textiles or ropes.

In some cases (kenaf), the entire stem is chipped and pulped. The pulp obtained is a mixture of the longer bast fibers and the very short fiber pulp from the woody core.

Where the raw material is in the form of rags, ropes, tow, textile waste or raw textile fiber, because of their bulky nature and many points of collection, these materials are baled for handling, transportation and storage.

In the case of leaf fibrous raw material, where the whole plant is harvested, bulk handling, transport and storage systems have to be developed.

Cotton, for the production of pulp and paper, is usually in the form of rags, textile wastes and linters. Cotton staple fiber can also be used but its use is relatively rare. Linters are today the most common source of cotton fiber for pulp and papermaking.

Linters are the short fibers left on the cotton seed after the long textile grade fibers (cotton staple fiber) have been removed. There are several grades of linters. Only the shorter grades are usually available at a cost acceptable for pulp and paper production.

Because of the many points of collection and the bulky nature of the material, cotton rags, wastes, cotton staple fiber, and linters are baled for handling and transport.

Large bamboos are sometimes crushed and chipped, or simply chipped in disk chippers similar to those used for wood, or in large drum chippers. For best results, chippers for bamboo should have a forced feed. The chips are then screened as in the case of wood, and stored prior to pulping in bins similar to those used for wood. Large volumes of dust are generated when bamboo is chipped. The bamboo chipper dust is usually used as fuel in the mill boilers.

Reeds and small bamboos are cut in cutters similar to those used for cereal straws but heavier in design. Since, in the case of reeds, a lot of leaf material normally clings to the stalks, an air separation stage for leaf removal is usually included in the reed chip screening system. Live bottom bins or bins with travelling screws at the bottom are usually employed for the storage of bamboo and reed chips.

Bales of cereal straws can be cut on special cutters, and the cut straw cleaned and screened by pneumatic and mechanical screening systems designed for the purpose. Alternatively, the straw bales can be fed to hammer mills of special design, which break up the bales and cut the straw to the desired length.

None of the bins, static or live bottom, developed for the storage of straw, work very well. Consequently, live bottom bins are usually small, for surge storage ahead of continuous and batch digesters. In the case of batch digesters, the straw is frequently cut and fed directly to the digesters; in other words, the straw cutting and preparation may operate only during digester filling.

Rice straw, because it contains a lot of dirt and leaf material is subjected to a wet cleaning stage in addition to the normal dry cleaning mentioned above.

As esparto grass is very tough, drum cutters similar to those used to cut rags, hemp, reeds, and small bamboos, are required. Special dusters are used in the case of esparto to remove the wax-rich epidermal material which comes off in the form of dust.

As about one-third of the whole bagasse from a sugar mill consists of non-fibrous material -pith and dirt - which is of no value in pulp and papermaking (and indeed detrimental to pulp and paper production), it is necessary to remove this material before the bagasse is pulped. There are several methods of depithing; dry depithing (bagasse moisture 25%), moist depithing (bagasse moisture 50%), and wet depithing (with the addition of water). The modern trend is to use moist depithing for lower pulp grades and two-stage moist and wet depithing for higher grades of pulp. Long term storage of depithed bagasse is in wet bulk piles.

Leaf and bast fibrous raw materials require special cutters in all cases. Often, a two stage cutting operation is required. Where the raw material is in the form of street-collected rags, a dusting and sorting operation may be required ahead of cutting.

In a system developed by the author for processing the whole sisal plant (which should also be applicable to abaca), the whole plant is cut up in special cutters and the cut material is shredded and slushed in a hydrapulper. The fibrous material is then separated from the fleshy material by screening from the aqueous suspension. Long term storage in the case of this system is in bulk piles, and short term storage ahead of pulping is in live bottom bins.

Cotton in the form of rags or textile wastes is prepared for pulping in the same manner as leaf and bast material in similar form.

Cotton linters should be cleaned before pulping to remove cotton seed hull fragments. This can be done in a dry system by pneumatic and mechanical separation or preferably in a wet cleaning system.

C. <u>PULPING PROCESSES</u>

C.1 <u>General</u>

To date, non-wood fibrous raw materials have been used almost exclusively for the production of chemical and semi-chemical pulps. Even though the very old maceration process for the production of pulp and paper from rags and ropes was largely mechanical, the pulp produced was essentially chemical pulp in nature.

The inherent structure of the non-wood fibrous raw materials is such that it is not possible to make mechanical pulp by the conventional stone groundwood process. However, in recent years, the refiner groundwood process, the thermomechanical process, chemi-mechanical processes and chemi-thermomechanical processes, have been developed for the production of mechanical pulp from chips of various wood species. These processes and techniques have been applied on a laboratory and pilot plant scale to a variety of plant stalks - in particular, bagasse and reeds. Bagasse "mechanical" pulps are currently being produced commercially for the production of newsprint. It is likely that the production of TMP, CMP and CTMP pulps from stalk fibers will increase for the same reason as in the case of wood - higher yields and lower cost.

As regards, the production of chemical and semi-chemical pulps, almost all of the processes used for pulping wood - the kraft process, the soda process, and the sulphite processes - have been applied to the pulping of non-wood materials. In addition, a number of special processes have been developed, such as the Pomilio process, the two-stage Cusi process and the NACO and the nitric acid process. Some of the very old lime and lime-soda processes are also used in certain cases.

For any given non-wood fibrous raw material, several processes can be applied; even for a specific end product to be produced from a given raw material, there is still a choice of processes available. Ultimately, the choice of process, while dependent to some extent on the raw material and end product. is usually determined largely by the size of mill, the chemicals available and their relative cost.

C.2 Pulping Processes and Yields

For the pulping of plant stalks, the kraft, soda, neutral sulphite, alkaline sulphite, soda-sulphur, NACO, nitric acid and the Cusi and Pomilio chemical and semi-chemical processes can be used for the production of bleachable and high grade unbleached pulps. The lime or lime-soda chemical and semi-chemical processes are usually used for lower grade unbleached pulps. However, some high grade pulps can be produced from rags and jute bast fiber using these processes. The acid sulphite process has also been used but with poor results.

For the production of bleachable and high grade unbleachable pulps, the conventional kraft or soda processes are favoured over the other processes. The Pomilio process has a high chemical consumption and recovery of chemicals is not feasible. For economic reasons, this process has virtually disappeared. The Cusi process is complicated and is used by only two or three mills. Experience with the NACO process is limited to straw and only one mill is in operation. In most cases, the sulphite or bisulphite processes offer no major advantages; they require stainless steel pulping equipment; and chemical recovery is complicated and costly.

However, the sulphite processes do produce superior pulp at higher yields in the case of some bast and leaf fibers. Also in the case of pulp mills too small to justify recovery, ammonium sulphite pulping could be a solution as the effluent can serve as a fertilizer. The same holds true for the nitric acid process.

The kraft and soda processes, which are the most frequent choices, are simple and recovery of chemicals in larger mills is readily possible by the use of well-established systems.

Most plant stalks have a very open structure and are very reactive. Consequently, they can be pulped very rapidly - in most cases, in a fraction of the time required to pulp wood.

In the case of wood, there is a considerable difference in yield and strength between pulps produced by the kraft and soda processes. This is because of the protective effect of the sulphide present in the kraft cooking liquor. However, most of the plant stalks can be pulped so rapidly, that the protective effect of the sulphide has little or no effect, and the pulps produced by the kraft or the soda process are virtually the same. It is only in the case of the denser bamboos, that there is any appreciable difference between the kraft or soda process. In the case of bamboo, the kraft process gives a stronger pulp at higher yield, than the soda process. In virtually all other cases, the choice between the kraft or soda process is a question of mill size and the availability and cost of chemicals.

The soda-anthraquinone process works well with all stalk fibers; yields are higher and in some cases, strength properties are higher than for soda alone.

Yields of stalk fiber chemical and semi-chemical pulps are, in general, of the same order of magnitude as wood pulp. Rice straw tends to give lower yields.

Although plant stalks have a lignin content similar to that of wood, the charge of chemicals for pulping is lower due to the more open structure and more rapid pulping. Again, the exception is bamboo which is closer to wood in most respects.

As mentioned earlier, it has proven to be possible to produce "mechanical" pulp from bagasse using various disk refiner processes, usually with the addition of some sodium sulphite and/or caustic soda, for the production of "mechanical" pulp content printing and writing papers or newsprint. The only problem is, that none of these "mechanical" pulping processes works very well with aged bagasse, as regards pulp brightness. The nitric acid process can also be used for the production of "mechanical" pulps from bagasse and rice straw.

Leaf and bast fibrous raw materials can be pulped by the kraft, soda, and the sulphite processes. Again, the kraft and soda processes are favoured for the same reasons as in the case of plant stalks. Pulping is rapid, but not quite as rapid as in the case of most plant stalks and the kraft process generally gives a somewhat better pulp. However, in a few cases, the sulphite processes will give a better pulp for, some applications, at a higher yield. If the material is in the form of textile wastes, rags, burlap, twine or old ropes,yields are higher than if the raw material is in the form of tow or the raw fiber strips before processing for textile fiber.

Unless maximum pulp strength is a critical factor (kraft is better), again, the choice between the kraft and soda processes is largely a question of plant size and availability and cost of chemical raw materials. The selection of the kraft process for pulp strength reasons is rarely the case, for in most instances, regardless of the process used, the leaf and bast fiber pulps have strength properties greater than softwood pulps.

Jute is an exception. Although the length of the fiber strands used for the production of burlap and twine are as long as those of sisal or hemp, the ultimate fiber length is no greater than that of hardwoods. If jute is cooked by the soda or kraft process, it will reduce the jute fiber strands to the ultimate fibers and the jute pulps so produced will be weaker than softwood pulps. For the production of durable, strong, hard pulps, mild lime or sodium carbonate cooks are used. Such mild cooks do not result in any appreciable delignification and many fiber bundles or strands remain essentially intact. So, in effect, jute cooked in this manner becomes "long fiber" pulp with strength properties greater than, or equal to, those of softwood pulps.

As both leaf and bast fibrous raw materials have a very low lignin content, chemical consumption for pulping is lower than in the case of wood, though not as low as might be expected, considering the low lignin content. Yields depend on the form, source and cleanliness of the raw material. The yield of pulp from seed flax tow, for example, may be less than that of wood pulp, if the shive content is high. However, in general, yields are high.

Cotton in the form of rags or textile wastes is usually pulped by the soda process, though lime-soda may be used where certain coloured rags are involved. Cotton linters may be pulped by either the kraft or soda process. Because of the low lignin content and the high cellulose content, pulping chemical consumptions are low. Yields depend on the purity of the raw material, and in all cases, are high.

Pulping processes and yields are tabulated in Table V.

C.3 Screening and Bleaching

Unbleached pulps for the production of unbleached papers and boards require no screening or cleaning, if fiberizing refiners are included in the system. Because of dark particles from the nodes of plant stalks, and shive and epidermal material in the case of bast and leaf fiber, screening and very thorough centri-cleaning are required for the production of bleached pulp.

Almost all of the non-wood chemical and semichemical pulps are easy to bleach. A single hypochlorite stage or three-stage bleaching - chlorination, caustic extraction, hypochlorite - is sufficient for paper pulps produced in integrated pulp and paper mills. Even dissolving pulp from cotton linters does not require more than chlorination, caustic extraction and hypochlorite. Market pulp mills may require an additional peroxide or chlorine dioxide superbleaching stage to reach the brightness demanded of market pulps today.

The "mechanical" pulps produced from bagasse are also easy to bleach with peroxide if the bagasse is fresh. However, if the harvesting season is short and bagasse must be stored for a long time, the bagasse brightness may be so low that it is not readily possible to attain an acceptable brightness.

C.4 Dissolving Pulps

The production of dissolving pulps from stalk fibers has bee tried on laboratory scale, and one mill is in commercial operation using bamboo as the raw material. Because of the high pentosan content, the prehydrolized kraft process appears to be the most promising, and most of the laboratory work and the one commercial operation are based on this process. The prehydrolized kraft process is, however, complicated and expensive from both a capital and operating point of view and small mills are not economically viable. (The minimum economic size would be in the order of 250 tons/day.)

Leaf, bast and cotton fibers are well suited to the production of dissolving pulps; particularly cotton because of its high initial purity. The highest grades of dissolving pulp are readily produced from cotton linters by a simple soda or kraft cook and three-stage bleaching. Dissolving pulp mills based on cotton linters as small as 20 tons a day can be economically viable.

Chemical properties of dissolving pulps from non-wood fibers are tabulated in Table VI.

C.5 Process Equipment

Because most plant stalks are pulped very rapidly, continuous digesters are preferred. Batch digesters can be used, but cooks are of necessity longer (because of the time required to heat up a digester charge) and more difficult to control; hence the pulps produced are not as strong and yields are lower.

Continuous digesters are also preferred for leaf and bast fibrous raw materials and cotton linters, even though there is not much difference in quality and in yield between pulps produced in continuous and batch digesters. However, if the raw material is in the form of rags or old ropes, batch digesters must be used because of the difficulty of feeding such material into, and discharging it from, continuous digesters. With the exception of bamboo, for which stationery digesters are used, batch digesters for non-wood fibers are rotary.

Another factor favouring the use of continuous digesters for non-wood raw materials is the low bulk density of most of these materials. This means that a large number of batch digesters are required for higher productions.

The low bulk density of many of the non-wood raw materials can also create problems in feeding continuous digesters at high production rates. This problem can be overcome by a continuous wilting stage ahead of digestion, in which the material is softened and the bulk density increased by the addition of liquor and steam.

The major exception is bamboo. Bamboo chips have a bulk density considerably higher than wood chips. In the case of bamboo, batch digesters are favoured for smaller mills and continuous digesters or larger mills.

For small productions, the mechano-chemical technique may be used. This consists of an atmospheric pressure cook in a hydrapulper. The hydraulic shear developed by the pulper promotes very rapid pulping and fiberizing. The main drawback is the high power consumption.

For very small productions in warm climates, non-wood fibrous raw materials can be pulped by simply mixing the cooking liquor into the material and leaving the material in pits outdoors for several days and then fiberizing the material in kollergangs or beaters.

Most of the stalk fiber pulps are slow draining, even if the freeness is relatively high. As a result, washing and thickening equipment must be larger than for wood pulp.

In the case of many leaf and bast fibers and cotton, the problem may be the reverse. Many of these pulps when unrefined have a very high drainage rate – so high that in many cases drum filters cannot be used for washing or thickening and must be replaced by rotary or belt table filters or twin-wire filters. If only low density washing and thickening are required, underflow thickeners fitted with paddles and screw or rotary drainers may be used.

D. <u>PROPERTIES OF NON-WOOD PULPS</u>

Pulps produced from plant stalks are generally short fiber pulps and have strength properties comparable to, or better than, hardwood pulps. They are, however, more heterogeneous and have a higher fines content as can be seen from Table VII. They also have a high hemicellulose or pentosan content. As regards strength properties, bamboo is an exception. Because of the high length to diameter ratio, the strength of the bamboo pulp is usually closer to that of softwood pulps.

The dimensional stability of papers produced from straw and bagasse compares favorably with those of wood; papers produced from esparto grass exhibit exceptional dimensional stability as can be seen from Table VIII. As regards opacities, straws and bagasse have slightly lower opacities than wood pulps. However, esparto pulp has a high opacity as can be seen from Table IX. Bamboo pulp also has a higher opacity.

Because of their high hemicellulose content, stalk fiber pulps hydrate rapidly. Power consumption is low as can be seen from Table X.

Leaf and bast fiber pulps (with the exception of jute) and cotton rag and staple fiber pulps are long fiber pulps and have very high strength properties. Refining power consumptions are high, as the fibers also have to be shortened for papermaking (See Table X).

In many cases, the leaf, bast and cotton pulps sold commercially have been pre-refined, and power consumption is lower than given in Table X.

Table XI shows some of the properties of non-wood pulps.

E. <u>APPLICATIONS AND USES OF NON-WOOD PULPS</u>

As mentioned previously, the fiber length, the length to diameter ratio, the fiber length distribution and the chemical composition of non-wood pulps vary over a wide range. As might be expected, the papermaking characteristics of the non-wood pulps also vary greatly - much more so than those of wood pulps.

In some cases, non-wood pulps are substituted for wood pulp, in papers normally produced from wood pulp when wood is available. In other cases, the non-wood pulps are used to produce specialty papers that cannot be produced readily from wood pulps; in yet other cases, non-wood pulps are used as additives to impart some special characteristic that cannot be obtained by using wood pulp alone.

As pulps from plant stalks are generally short fibered, it is not possible to produce papers of substantial strength from pulps based on plant stalks alone because of the short fiber length. (As mentioned before, bamboo pulp is an exception because of the high fiber length to diameter ratio which gives it characteristics closer to those of softwoods). However, short fiber pulps can be readily used for the production of writing and printing papers as strength is not an important factor. In fact, pulps from stalk fibers will form very uniform sheets free of the cloudy and wild formation that can occur when using long fiber pulps.

Although the strength of a dry sheet produced from short fiber pulp may be adequate, the wet web strength may not be sufficient to allow the sheet to be drawn off the couch. Either a small amount of long fiber pulp must be added to provide the necessary wet web strength and/or a vacuum pickup and a no-draw press section must be used.

Because of the low drainage rate, low wet web strength of stalk fiber pulp and the tendency to crushing in the presses, it is not possible to attain the same paper machine speeds, as can be achieved when wood pulp is used for the production of paper. However, with the newer machine configurations, there has been a substantial improvement as can be seen from Table XII.

Since stalk fiber pulps have a high hemicellulose content, they are easy beating pulps and very little power is required for stock preparation (See Table X). This allows the production of greaseproof and glassine papers with very low power consumption.

The high hemicellulose content makes stalk fibers ideally suited for the production of corrugating medium. Cereal straws, and especially bagasse, produce corrugating medium equal to the best produced from wood. Short fiber pulps are also suitable for the production of multi-ply boards though some long fiber pulp is required for the top layer to provide the necessary resistance to bending.

When stalk fibers must be substituted for long fiber pulp in papers and boards such as bag paper, sack paper and linerboard, the papers are inferior unless very substantial quantities of long fiber wood pulp (60-75%) are blended with the short fiber pulp. However, locally acceptable grades of wrapping, sack and bag papers can be made with much smaller quantities of wood pulp, if the basis weight is increased, and a Clupak unit is installed.

As additives (10-20%), stalk fiber pulps improve the formation, smoothness, surface and in some cases, the opacity of papers produced largely from wood pulp (See Table IX); esparto pulp improves the dimensional stability of the paper as well (See Table VIII).

Leaf, bast (with the exception of jute) and cotton pulps are long fiber pulps having a high fiber length to diameter ratio and a rather uniform fiber length distribution with very few fines. Some, such as sisal and abaca, have most of the fibers close to the average length. Because of their fiber length, and their length to diameter ratio and uniformity, leaf, bast and cotton pulps can be used for the manufacture of the strongest, most resistant and permanent papers; papers having high tear resistance, light weight papers, cigarette papers, condenser papers and security and currency papers where scuff resistance is important.

Because of the uniformity of fiber length distribution, lack of fines and low ash content, papers with a high porosity can also be produced from leaf, bast and cotton fibers, which makes these pulps well suited for the production of filter papers, tea bags and sausage skins (abaca and sisal). These pulps are also absorbent and useful where high absorbency is required. Non-woven fabrics are another application.

As additives, leaf, bast and cotton fibers can contribute toughness, tear resistance and permanence to papers made largely from wood pulp. Or, in some cases, these strong pulps can be used to reinforce mechanical pulp sheets. Sisal pulp, for example, can be used in the furnish of publication grade papers normally made from 60 to 65% bleached groundwood and 35 to 40% bleached kraft. Although sisal pulp is more expensive, because of its high strength, it can replace the bleached kraft wood pulp on a 2 for 1 basis (in other words, only 15 to 20% sisal pulp is required) so that in the end the total cost of the paper can be the same or lower and the paper has a better opacity and printability because of the higher groundwood content.

In the countries where wood is scarce, the leaf, bast and cotton pulps can serve to reinforce papers made from stalk fiber pulps to produce papers of satisfactory strength for local market requirements.

Some application of non-wood fibers are shown in Table XIII.

F. CONCLUSIONS

Non-wood fibers offer many opportunities for the production of papers to meet local requirements in areas where wood is scarce. They also offer opportunities for the production of specialty papers, for which there is an increasing demand, and as an additive to impart specific characteristics.

TABLE I

NAMES OF NON-WOOD FIBROUS CELLULOSIC MATERIAL

Group	Common Name	Scientific Name
STALK FIBERS		
Cereals	Wheat	Triticum Sativum
	Oat	Avena Sativa
	Rye	Secale Cereal
	Barley	Hordeum Vulgare and H. Distichon
	Rice	Oryza Sativa
	Corn	Zea Mays
	Sorghum (Kaffir)	Andopogogon Sorghum
	Millet	
Grasses	Esparto	Lyganum Spartum
	Esparto	Stipa Tenacissma
	Sabai (dragon's beard)	Eulaliopsis Binata
	Lemon	Cymbopogon Citratus
	Lemon	Cymbopogon Flexudsos
	Kuneria	Heteropogon Controtus
	Siru	Imerata Cylindrica
	Mawai	Penniselum Hohenackeri
	Ulla	Themeda Arundinacea
	Munj	Saccharum Bengalense
	Elephant	Themeda Cymbaria
	Elephant	Pennisetum Purpureum
	Genera	Themeda Quadrivalvis
	Guatemala	Tripsacum Lusum
	Ekra	Frianthus Ravennaf
	Khagra	Saccharum Spontaneum
	Kurukuru	
	Johnson	Sorghum Halpense
Reeds	Reed	Phragmites Vulgaris
	Reed (Quassab, delta grass, sulina)	Phragmites Communis
	Papyrus	Cyperus Papyrus
	Nal	Phragmites Karka
	Addar grass	Arundo Donax
Canes	Sugarcane (bagasse)	Saccharum Officianarum
	Bamboo - Salia	Dendrocalamus Strictus
	Kokwa	Dendrocalamus Hamiltonii
	Gamabetha	Bambusa Polymorphia
	Mitenga	Bambusa Tulda
	Daba	Bambusa Arundinaria
	Muli	Melocanna Bambusoldes
	(China)	Sinocalamus Affinis
	(China)	Phyllostachy Nidulari
BAST FIBERS		
	New Zealand Flax	Phorium Tenax
	Flax	Linum Usitatissinum
	Kenaf	Hibiscus Cannabinus
	Ramie	Bochmeria Nivea
	Jute (1)	Corchorus Capsularis
	Jute (2)	Corchorus Olitorius
	Okra	Hibiscus Esculentus
	Common Hemp	Cannabis Sativa
	Sunn Hemp	Crotalaria Juncea

TABLE 1 - NAMES OF NON-WOOD FIBROUS CELLULOSIC MATERIAL (Cont'd)

Group	Common Name	Scientific Name
LEAF FIBERS		
	Abaca (Manila Hemp)	Musa Textilis
	Sisal (Sisal Hemp)	Agave Sisalana
	Henequen	Agave Froucryode
	Caroa	Neoglazovia Varigata
	Palm	Palmae
SEED HULL FIBER		
	Cotton	Gossypium
	Coir (Coconut Fiber)	Cocos Nucifera

TABLE II

DIMENSIONS OF FIBERS OF NON-WOOD FIBROUS MATERIALS

Source of Fibers		Length in Microns Max.	Min.	Ave.	Dia. in Microns Max.	Min.	Ave.	L/D Ratio
Stalk Fibers								
Cereals	- rice	3480	650	1410	14	5	8	175:1
	- wheat, rye, oats, barley, mixed	3120	680	1480	24	7	13	110:1
Grasses	- esparto	1600	600	1100	14	7	9	120:1
	- sabai	4900	450	2080	28	4	9	230:1
	- lemon			1320			9	145:1
Reeds	- papyrus	8000	300	1500	25	5	12	125:1
	- phragmites communis	3000	100	1500	37	6	20	75:1
Canes	- sugar (bagasse)	2800	800	1700	34	10	20	85:1
	- bamboo (wide range)	3500-9000	375-2500	1360-4030	25-55	3-18	8-30	135-175:1
Bast Fibers								
Textile Flax Tow		55000	16000	28000	28	14	21	1350:1
Seed Flax Tow		45000	10000	27000	30	16	22	1250:1
Kenaf		7600	980	2740			20	135:1
Jute (1)		4520	470	1060	72	8	26	45:1
Jute (2)		5000	500	2000	68	8	20	100:1
Common Hemp		55000	5000	20000	50	16	22	1000:1
Leaf Fibers								
Abaca		12000	2000	6000	36	12	20	300:1
Sisal		6000	1500	3030			17	180:1

Seed Hull Fibers							
Cotton Staple	50000	20000	30000	30	12	20	1500:1
Cotton Linters	6000	2000	3500	27	17	21	165:1
Woods							
Coniferous	3600	2700	3000	43	32	30	100:1
Deciduous	1800	1000	1250	50	20	25	50:1

TABLE III

CHEMICAL PROPERTIES OF NON-WOOD FIBROUS MATERIALS

Fibrous Material	Cross & Bevan Cellulose	Alpha Cellulose	Lignin %	Pentosans %	Ash %	Silica %
Stalk Fibers						
Straw						
– rice	43–49	28–36	12–16	23–28	15–20	9–14
– wheat	49–54	29–35	16–21	26–32	4–9	3–7
– barley	47–48	31–34	14–15	24–29	5–7	3–6
– oat	44–53	31–37	16–19	27–38	6–8	4–7
– rye	50–54	33–35	16–19	27–30	2–5	0.5–4
Canes						
– sugar	49–62	32–44	19–24	27–32	1.5–5	0.7–3
– bamboos	57–66	26–43	21–31	15–26	1.7–5	1.5–3
Grasses						
– esparto	50–54	33–38	17–19	27–32	6–8	2–3
– sabai	54–57		17–22	18–24	5–7	3–4
Reeds						
– phragmites communis	57	45	22	20	3	2
Bast Fibers						
– textile flax	76–79	45–68	10–15	6–17	2–5	
– seed flax tow	47	34	23	25	2–5	
– kenaf	47–57	31–39	15–18	21–23	2–5	
– jute (1)	57–58		21–26	18–21	0.5–1	<1
Leaf Fibers						
– abaca	78	61	9	17	1	<1
– sisal	55–73	43–56	8–9	21–24	0.6–1	<1
Seed Hull Fibers						
– cotton staple		85–90	3–3.3		1–1.5	<1
– cotton linters		80–85	3–3.5		1–2	<1
Woods						
– coniferous	53–62	40–45	26–34	7–14	1	<1
– deciduous	54–61	38–49	23–30	19–26	1	<1

TABLE IV

SOURCE AND FORM OF RAW MATERIALS FOR NON-WOOD PULPS

Raw Material	Source	Growth Environment	Length (cm)	Width (mm)	Contaminants (%) [3]	Form of Delivery
<u>Stalk Fibers</u>						
Straws [1]	Farms	Cultivated	5-30	2-5	10	Bales
Straws [2]	Farms	Cultivated	1-2	2-5	4	Bulk
Esparto	Grassland	Wild	50-100	1-3	3	Bales
Sabai	Grassland	Wild	50-100	1-3	4	Bales
Reeds	Marshes	Wild	100-600	10-30	15	Bundles
Bagasse	Sugarcane Mills	Cultivated	4-20	1-15	35	Bulk, Bales
Bamboo	Forests	Wild	300-800	30-100	5	Bundles, Sticks
<u>Bast Fibers</u>						
Textile Flax	Tow	Cultivated	10-30	1-2	10	Bales
Linen	Rags	n/a	Random		10	Bales
Kenaf	Strips	Cultivated	300-400	14-18	10	Bales
Ramie	Strips	Cultivated	100-300	2-5	4	Bales
Jute	Strips	Cultivated	200-500	2-5	10	Bales
	Burlap	n/a	Random			Bales
Hemp	Strips	Cultivated	200-300	2-5	15	Bales
	Burlap	n/a	Random		10	Bales
<u>Leaf Fibers</u>						
Abaca	Farms	Cultivated	200-400	15-20	15	Bales
Sisal	Farms	Cultivated	200-300	20-30	9	Bales
<u>Seed Fibers</u>						
Cotton Linters	Oil Seed	Cultivated	0.3-0.5	0-.002	10	Bales
Cotton Rags	Textiles	n/a	Random		10	Bales

<u>Notes</u>:

(1) Mechanical Threshing
(2) Animal Threshing
(3) Dirt, leaves, pith, shive, bark, gums, wax and other non-fibrous material

TABLE V

PULPING PROCESSES FOR NON-WOOD FIBROUS MATERIALS

Raw Materials	Pulping Process	Use of Pulp	Pulp Yield (%)[1] Unbleached	Bleached
Mixed cereal straw	Lime	Coarse Paper	55-65	
	Lime	Strawboard	70-82	
	Soda or kraft	Paper	44-46	40-42
	Soda or kraft	Corrugating	65-68	
Rice straw	Soda	Paper	40-43	34-39
Esparto	Soda	Paper	45-50	42-46
Sabai	Soda	Paper	45-50	42-47
Phragmites communis reeds	NSSC	Paper	50-53	48-50
	Soda or kraft	Paper	46-51	42-48
Papyrus	Soda	Paper	38-35	27
Sugarcane bagasse (depithed)	Soda or kraft	Industrial paper	60	
		Corrugating	70	
		Linerboard	63	
		Bleached paper	50-52	45-48
Bamboo	Soda	Paper	44-45	40-41
	Kraft	Paper	46-47	42-43
Seed flax tow	Soda	Cigarette paper	42-45	35-40
Textile flax tow	Soda	Paper	60-67	56-62
Jute	Lime	Industrial paper	62	58
	Soda	Paper	55	50
Kenaf (bast)	Soda or kraft	Paper	46-51	41-46
Abaca	Monosulphite	Thin paper	60-63	56-62
	Soda or kraft	Paper	45-54	43-50
Sisal (agave)	Soda	Paper	69	60
Cotton linters	Soda or kraft	Paper		70-80
		Dissolving pulp		65-75
Cotton staple	Soda or kraft	Paper		75-83
Cotton rags	Lime soda	Paper		70-85
	Soda	Paper		70-85

(1) On basis of prepared and cleaned raw material

TABLE VI

CHEMICAL PROPERTIES OF DISSOLVING PULPS FROM NON-WOOD FIBERS

Chemical Properties		Bamboo	Sisal	Cotton	Bagasse	Softwood Sulphite	Prehydrolized Hardwood Kraft
Ash	%	0.06-0.11		0.10-0.15	0.04-0.15	0.06-0.08	0.08-0.15
Pentosan	%	2.5-3.5			4.0-6.0	3.0-5.0	1.6-2.5
Alpha Cellulose	%	90-94	92-93	97-98	92-94	93-95	93-96
Beta Cellulose	%	1.6-3.0	0.1		3.5-5.0	1.5-2.6	2.1
Gamma Cellulose	%	2.5-3.5	7.3		1.8-3.2	3.2-8.7	1.0-3.0
Alcohol-Benzene Extraction	%	0.3-0.5	0.2-0.3		0.3-0.5	0.2-0.4	0.03-0.26
Degree of Polymerization		1026-1030		1440	525-840	500-1000	500-1000
Viscosity C.P.			31.9		13-14	15-45	8-12
Copper Number				0.06	0.23	0.5-1.5	0.3-0.6

TABLE VII

FIBER CLASSIFICATION OF STRAW
BAGASSE AND OTHER UNREFINED BLEACHED PULPS
(Bauer McNett Classifier)

Type of Pulp	24 mesh %	48 mesh %	Retained on 100 mesh %	200 mesh %	Passing Through 200 mesh %
Softwood	82.5	6.5	5.0	4.0	2.5
Hardwood	0.9	47.1	28.0	10.5	13.5
Bagasse	7.5	37.5	27.0	12.5	16.5
Cereal Straw	3.5	23.5	37.0	16.0	20.0
Rice Straw	2.5	19.5	29.0	6.5	42.5

TABLE VIII

DIMENSIONAL STABILITY

Pulp	Unbeaten Wet Expansion %	Wet Expansion at 50 S.R. %
Softwood	3.8	5.3
Hardwood Kraft	2.2	3.1
Straw Soda	4.2	5.3
Straw Monosulphite	3.8	4.8
Bagasse Soda	1.9	3.0
Esparto Soda	1.3	2.1

SOURCE: Dr. Julius Grant, World's Paper Trade Review 8/10/59

TABLE IX

TYPICAL RELATIVE OPACITIES(1)

Pulp	Unbeaten	at 50° SR
Hardwood Kraft	100	92
Softwood Sulphite	98	88
Wheat Straw Monosulphite	100	90
Rice Straw Soda	99	90
Wheat Straw Soda	96	85
Bagasse Soda	98	86
Esparto Soda	115	110

(1) Setting hardwood at 100

TABLE X

COMPARATIVE STOCK PREPARATION REFINING POWER REQUIREMENTS

FOR PRODUCTION OF WOODFREE PRINTING AND WRITING PAPERS

Type of Bleached Pulp	Net Power kWh/Ton
Linen Half Stuff	500 - 750
Raw Textile Flax	450 - 650
Flax Tow	400 - 600
Sunn Hemp	400 - 600
Abaca	400 - 550
Cotton Linters	400 - 550
Cotton Staple	400 - 550
Cotton Rag Half Stuff	300 - 450
Softwoods	275 - 350
Common Hemp Half Stuff	250 - 320
Jute (fully cooked)	200 - 300
Sisal Hemp	160 - 250
Bamboo	175 - 200
Kenaf Bast Fiber	150 - 200
Hardwoods	125 - 175
Bagasse	50 - 100
Cereal Straw	15 - 35
Rice Straw	0 - 20

Note:

Refining power consumption figures do not include the power required to disintegrate textiles to "half stuff" in beaters. In the case of very long fiber pulp, the power consumption includes the power for both cutting (fiber shortening) and strength development. All pulps bleached to 80+ brightness.

TABLE XI

TYPICAL PHYSICAL PROPERTIES OF NON-WOOD PULPS

Raw Material	Process	Type of Pulp	Freeness	Breaking Length(m)	Burst TAPPI	Tear TAPPI	Fold	Bulk cc/g
Wheat straw	Soda	Unbleached	50 SR	7200	40	40	100	1.50
		Bleached	50 SR	6800	42	36	70	1.48
Rice straw	Soda	Unbleached	50 SR	5420	38	54	110	1.45
		Bleached	50 SR	5300	41	50	90	1.43
Reeds	Kraft	Bleached	50 SR	6700	30	45	250	1.65
Bagasse	Soda	Unbleached	20 SR	7700	40	72	300	1.58
		Bleached	25 SR	6800	42	70	210	1.54
Bamboo	Kraft	Bleached	40 SR	6500	40	155	450	1.40
Esparto	Soda	Bleached	40 SR	4000	40	48	100	2.00
Kenaf (bast)	Kraft	Bleached	40 SR	10300	56	72	570	1.60
Jute	Lime	Unbleached	35 SR	5800	45	135	700	1.75
Flax	Soda	Bleached	28 SR	5000	35	200	200	1.90
Hemp	Soda	Bleached	28 SR	7000	53	180	460	1.85
Sisal	Soda	Bleached	28 SR	9000	79	310	1470	2.10
Softwood (spruce)	Kraft	Bleached	28 SR	11000	90	110	1900	1.70
Hardwood (beech)	Kraft	Bleached	45 SR	4000	22	45	20	1.54
(birch)	Kraft	Bleached	45 SR	7600	50	82	350	1.40

TABLE XII

SOME TYPICAL WOODFREE PAPER MACHINE SPEEDS FOR STRAW AND BAGASSE(1)
(meters per minute)

Furnish(2)	Older Machines (open draws)	New Machines(3) (no draw press section)
Rice Straw	100 - 180	200 - 400
Other Straws	150 - 250	300 - 500
Bagasse	200 - 350	400 - 650
Wood	250 - 500	500 - 800

(1) Without using drainage aids
(2) 15% of fiber furnish, in the case of papers produced largely from non-wood fibers, is bleached softwood kraft pulp
(3) Established technology 1985

TABLE XIII

SOME USES OF NON-WOOD PULPS FOR PAPERMAKING

Source of Non-Wood Fiber	Type of Paper	% Non-Wood Fiber in Furnish<1>	Fiber Forming Balance of Furnish<2>
Straw	Woodfree<3> printing and writing	20-90	Woodpulp
	Mechanical printing and writing	30-50	10-20% Woodpulp balance groundwood
	Glassine and greaseproof	50-90	Sulphite pulp
	Duplex and triplex	60-80	Woodpulp
	Corrugating medium	80-90	Wastepaper
	Strawboard	80-100	Wastepaper
	"B" quality wrapping	50-60	Wastepaper and/or woodpulp
Bagasse	Woodfree<3> printing and writing	80-90	Woodpulp
	Mechanical printing and writing	50-60<4>	10-20% woodpulp, balance groundwood
	Bristol board	70-100	Woodpulp
	Tissue	70-90	Woodpulp
	Glassine and greaseproof	50-90	Sulphite pulp
	Duplex and triplex	60-80	Woodpulp
	Corrugating medium	80-90	Wastepaper
	Linerboard	50-80	Kraft pulp
	Wrapping and bag papers	50-85	Kraft pulp
	Multiwall sack<6>	30-80	Kraft pulp
	Newsprint substitute	70-80<4>	Kraft pulp
	Newsprint substitute	50-65%	Woodpulp 20% and Bleached Bagasse

Notes: (see also next page)

(1) Chemical pulp unless otherwise noted.

(2) In all cases, "kraft" or "sulphite" means kraft or sulphite chemical pulp made from softwoods, bleached, semi-bleached or unbleached according to the type of paper. The term "woodpulp" is used when either softwood sulphite or softwood kraft chemical pulp or a mixture of the two may be used; in some instances, however, where the non-wood fiber fraction of the furnish is low or the non-wood fiber is very strong, hardwood kraft pulp may also form part of the furnish together with softwood sulphite or softwood kraft.

TABLE XIII - SOME USES OF NON-WOOD PULPS FOR PAPERMAKING (Cont'd)

Source of Non-Wood Fiber	Type of Paper	% Non-Wood Fiber in Furnish<1>	Fiber Forming Balance of Furnish<2>
Phragmites communis reeds	Woodfree<3> printing and writing	70-80	Woodpulp
	Duplex and triplex	60-80	Woodpulp
	Corrugating medium	70-90	Wastepaper
	Bogus linerboard	50-70	Kraft pulp
	"B" grade wrapping	50-60	Kraft pulp
	Chemical pulp		
Bamboo	Woodfree<3> printing and writing	70-100	Woodpulp and/or straw or bagasse pulp
	Mechanical printing and bristol board	50-100	Woodpulp and/or bagasse pulp
	Linerboard	60-100	Kraft pulp
	Duplex and triplex	30-80	Woodpulp and/or straw or bagasse pulp
	Wrapping and bag	80-100	Kraft pulp
	Multiwall sack	80-100	Kraft pulp
Sisal	Woodfree<3> printing and writing papers	20-100	Woodpulp
	Security papers, bonds, and ledgers	20-100	Woodpulp Cotton pulp
	Currency papers	30-50	Cotton pulp
	Non-Wovens	10-50	Synthetic fibers
	Publication grades	15-20	10-15% Woodpulp balanced groundwood
Cotton	High-grade bond, ledger, book and writing	25-100	Woodpulp
	Currency papers	50-60	Flax pulp

Notes: (see also next page)

(3) The term "woodfree" means that there is no mechanical pulp in the furnish.
(4) CTMP bagasse pulp
(5) TMP bagasse pulp
(6) Clupak unit required

TABLE XIII - SOME USES OF NON-WOOD PULPS FOR PAPERMAKING (Cont'd)

Source of Non-Wood Fiber	Type of Paper	% Non-Wood Fiber in Furnish<1>	Fiber Forming Balance of Furnish<2>
Phragmites communis reeds	Woodfree<3> printing and writing	70-80	Woodpulp
	Duplex and triplex	60-80	Woodpulp
	Corrugating medium	70-90	Wastepaper
	Bogus linerboard	50-70	Kraft pulp
	"B" grade wrapping	50-60	Kraft pulp
	Chemical pulp		
Bamboo	Woodfree<3> printing and writing	70-100	Woodpulp and/or straw or bagasse pulp
	Mechanical printing and bristol board	50-100	Woodpulp and/or bagasse pulp
	Linerboard	60-100	Kraft pulp
	Duplex and triplex	30-80	Woodpulp and/or straw or bagasse pulp
	Wrapping and bag	80-100	Kraft pulp
	Multiwall sack	80-100	Kraft pulp
Sisal	Woodfree<3> printing and writing papers	20-100	Woodpulp
	Security papers, bonds, and ledgers	20-100	Woodpulp Cotton pulp
	Currency papers	30-50	Cotton pulp
	Non-Wovens	10-50	Synthetic fibers
	Publication grades	15-20	10-15% Woodpulp balanced groundwood
Cotton	High-grade bond, ledger, book and writing	25-100	Woodpulp
	Currency papers	50-60	Flax pulp

<u>Notes</u>: (see also next page)

(3) The term "woodfree" means that there is no mechanical pulp in the furnish.
(4) CTMP bagasse pulp
(5) TMP bagasse pulp
(6) Clupak unit required

TABLE XIII - SOME USES OF NON-WOOD PULPS FOR PAPERMAKING (Cont'd)

Source of Non-Wood Fiber	Type of Paper	% Non-Wood Fiber in Furnish<1>	Fiber Forming Balance of Furnish<2>
Jute (bast)	Cigarette paper	30-50	Hemp pulp
	Printing and writing	20-80	Woodpulp
	Tag, wrapping and bag	60-80	Woodpulp or bamboo pulp
Flax	Writing and book	20-60	Woodpulp or cotton pulp
	Lightweight printing and writing	20-80	Woodpulp or cotton pulp
	Condenser	20-60	Woodpulp or cotton pulp
	Currency and security	60-80	Cotton or woodpulp
	Cigarette paper	20-100	Woodpulp
Abaca	Woodfree<3> printing and writing papers	20-100	Woodpulp
	Security papers, bonds, and ledgers	20-100	Woodpulp Cotton pulp
	Currency papers	30-50	Cotton pulp
	Tea bag, sausage skins	90-100	Flax
	Non-wovens	10-50	Synthetic fibers
	Linerboard, wrapping and bag	10-30	Bagasse or straw pulp
Esparto	Woodfree<3> printing and writing	30-100	Woodpulp
	Lightweight papers	50-70	Woodpulp
	Cigarette papers	20-30	Flax or woodpulp
	Cigarette filter paper	50-70	Flax or kraft
	Blotting paper	50-80	Woodpulp
Sabai grass	Woodfree<3> printing and writing	70-100	Woodpulp or straw or wastepaper
Ekara, Knagra & Nal grass mixed	Woodfree<3> printing and writing	50-70	Woodpulp
	Wrapping paper	40-60	Kraft pulp
Kenaf (bast)	Printing and writing	20-100%	Straw or bagasse pulp
Kenaf (whole)	Newsprint	75-85%	Kraft pulp