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GLOBAL PATTERNS IN THE USE OF NON-WOOD PLANT FIBERS FOR PAPER GRADE PULPS

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Abstract

The worldwide increase in capacity for production of nonwood plant fiber pulps has increased dramatically since 1970, going from 6.7 percent of total world papermaking pulp capacity in 1970 to 8.6 percent in 1987. It is projected that this percentage will increase to 9.1 percent by 1990. The average annual increase in non-wood plant fiber pulp capacity since 1975 has been more than double the average annual increase in total paper grade wood pulp capacity.

Straw, bagasse and bamboo are the leading fibers being used from a quantity standpoint, but many other non-wood plant fibers are being used for speciality pulps. Pulp production in many countries is based 100% on non-wood fibers, and some 25 countries depend on non-wood plant fibers for more than 50% of pulp production with China and India being the leaders.

Tables are presented, showing all of the major producers of non-wood plant fiber pulp, and separate tables are shown for the leading producers of pulp from each of the major non-wood fibers.

The properties, fiber length and photo-micrographs of the major non-wood fiber pulps are also included.

In the development of advanced technology for pulping non-wood plant fibers, a major portion of the efforts world wide have been concentrated upon the utilization of bagasse.

Fortunately, a major part of the advanced technology, which has been developed, for pulping bagasse can also be applied to other non-wood plant fibers as well.

A vast majority of the non-wood pulp mills are integrated with paper mills. However, a few bleached market pulp mills are operating for production of pulps from bagasse, straw, kenaf and abaca. Several other bagasse based market mills are being considered and at least one each for straw and kenaf.

I. Introduction

It is a pleasure to be with you today to discuss one of my favorite subjects; that is the use of non-wood plant fibers for the manufacture of pulp and paper. For more than 20 years, I have periodically appeared before your group to give you an update on the use of these raw materials, and it has been my main area of activity worldwide for more than 40 years.

Althouth the economics of pulp production favor wood in most of the developed countries of the world, many of the developing countries do not have adequate supplies of wood, but do have large quantities of non-wood plant fibers available, which can be used for production of every type paper from tissue to liner board, and even newsprint. Furthermore, every type of reconstituted panelboard can likewise be produced from these non-wood raw materials.

The worldwide increase in capacity for production of non-wood plant fiber pulps has increased dramatically since 1970, going from 6.7 percent of total world papermaking pulp capacity in 1970 to 8.6 percent in 1987. It i projected that this percentage will increase to 9.1 percent by 1990.

In fact, according to the FAO pulp and paper capacities surveys for 1985-90 and 1986-1991, the average annual increase in non-wood plant fiber pulp capacity has consistently been more than double the annul increase for all papermaking grade wood pulping capacity, from 1980 through 1991.

Unfortunately, however, for the 1987-1992 FAO capacities survey, a number of the major non-wood pulp producers did not submit their data for this period, including China, India, and Indonesia. Therefore FAO shows no increased non-wood capacity for China from 1989 onward, none for India from 1987 onward and none for Indonesia from 1988 onward. Yet we know conclusively that all of these countries, and especially China, are expanding their non-wood papermaking pulp capacity extensively between 1987 and 1992. On the other hand, the non-wood pulping capacities for Pakistan is grossly overestimated in all three of the most recent surveys.

Comparative FAO data, for the three most recent capacities surveys, is as follows :

1. DATA IN FAO PULP AND PAPER CAPACITY SURVEY FOR THE PERIOD 1985 - 1990

(a) TOTAL CAPACITY MILLION METRIC TONS

	1975	1980	1985	Est. 1990
TOTAL WOOD PULP PAPER GRADES	126.8	139.2	151.2	167.1
NON-WOOD FIBER PULP	9.3	11.6	13.3	16.8
NON-WOOD AS % OF TOTAL	6.8	7.7	8.1	9.1

(b) AVERAGE ANNUAL INCREASE - PER CENT

	1975-80	1980-85	1985-90
TOTAL WOOD PULP PAPER GRADES	1.9	1.7	2.0
NON-WOOD FIBER PULP	4.5	2.7	4.7

2. DATA IN FAO PULP AND PAPER CAPACITY SURVEY FOR THE PERIOD 1986 - 1991

(a) TOTAL CAPACITY IN MILLION METRIC TONS

	1976	1981	1986	1991
TOTAL WOOD PULP PAPER GRADES	129.9	142.1	154.4	165.6
NON-WOOD FIBER PULP	9.7	11.6	13.9	16.5
NON-WOOD AS % OF TOTAL	6.9	7.5	8.3	9.1

(b) AVERAGE ANNUAL INCREASE — PER CENT

	1976-81	1981-86	1986-91
TOTAL PAPER GRADE WOOD PULP	1.8	1.7	1.8
NON-WOOD FIBER PULP	3.7	3.7	3.4

3. DATA IN FAO PULP AND PAPER CAPACITY SURVEY FOR THE PERIOD 1987-1992

(a) TOTAL CAPACITY IN MILL IN METRIC TONS

	1977	1982	1987	1992
TOTAL PAPER GRADE WOOD PULP	133.3	142.9	156.5	173.2
NON-WOOD FIBER PULP	10.0	8.6*	14.8	16.8
NON-WOOD AS % OF TOTAL	7.0	5.7*	8.6	8.8*

(b) AVERAGE ANNUAL INCREASE — PER CENT

	1977-82	1982-87	1987-92
TOTAL PAPER GRADE WOOD PULP	1.4	1.8	2.1
NON-WOOD FIBER PULP	--2.9*	11.3*	2.5*

NOTE: * THE DATA FOR NON-WOOD IN THE 1982-1992 CAPACITY SURVEY APPEARS TO BE IN SERIOUS ERROR.

Based on personal knowledge of expansion taking place and projected for the major non-wood pulp producers, who apparently failed to report these expansion programs to FAO, the data for non-wood pulp in the 1987-92 FAO Capacity Survey appears to be in serious error. For the five year period from 1985 through 1989, for example China indicated an average annual expansion of non-wood pulping capacity amounting to 9.5%, whereas for the period for 1989 through 1992, no increase in capacity is shown for China in this survey. Likewise no increase is shown for India from 1987 onward and no increase for Indonesia from 1988 onward, yet we know that capacity for non-wood pulping will increase substantially in all of these countries from 1987 to 1992.

Therefore, instead of 16.8 million metric tons of non-wood pulping capacity worldwide by 1992, as shown in the FAO Survey, The Speaker predicts a capacity of at least 19 to 20 million metric tons or approximately 10% of total papermaking pulp capacity, with the average annual increase for non-wood being substantially greater than for all wood pulp.

This is entirely due to the large increase in non-wood pulping capacity in the developing countries such as China and India, who do not have adequate wood supplies. **However, very little of this increased capacity will be for market pulp. Practically all of the increased capacity in the developing countries will be for integrated mills, many of which will still have to import some long fibered pulp, because most of the non-wood pulps are short fibered.**

II. Non-Wood Plant Fibers of Potential use for Manufacture of Paper-Making Pulp

The non-wood plant fibers, which are currently being used and those which offer potential for future use for manufacture of papermaking pulps include agricultural residues such as bagasse and straw, the natural growing plants such as bamboo and grasses, and the fibers which are grown for their fiber content such as kenaf, crotalaria, jute, hemp, abaca, sisal and cotton.

In the past, almost every known fiber has been tried for the manufacture of pulp and paper, and nearly every one will result in a product having some desirable properties. However, when all of the economic factors are taken into consideration; only a very few of the hundreds of thousands of non-wood plant fibers can qualify. At the present time, straw, bagasse and bamboo are the leading fibers being used from a quantity standpoint, but many of the others are being used for specialty pulps and have special properties which are not found in any of the best wood pulps.

III. Estimates of Annual Collectable Yields of Various Non-Wood Plant Fibrous Raw Materials per Hectare

In considering the utilization of non-wood plant fibers as sources of paper-making raw materials, it is interesting to compare the yields of fiber perhectare, for these various plants. These are given in TABLE I anong with the estimated equivalent in bleached pulp per hectare of land. It can be seen from this data that among agricultural residues, sugar cane bagasse takes a top position. The same data based on yield/acre is given in TABLE 1-A

IV. Estimates of Total Worldwide Availability of Specific Non-Wood Fibrous Raw Materials

In TABLE II, estimates are presented which do give a reasonably good indication of the tremendous quantities of these non-wood plant fibers which can become available if the economic necessity should require their utilization as papermaking raw materials.

It can be seen that straw represents the greatest overall potential from strictly a quantity standpoint. However, based on present methods of collection, handling and storage, the use of large quantities of straw is limited mainly to those countries in which labor costs for its collection and handling are extremely low.

From an economic standpoint in most countries, it is believed that the use of bagasse will surge ahead of all of the other non-wood plant fibers, especially in countries in which the cost of replacement fuel is relatively low. However, the use of straw could increase dramatically if more efficient methods are developed for its collection, handling and storage.

Kenaf, which is a fast-growing stem plant, may also become a major source of pulp, especially whole stalk chemi-mechanical pulp for newsprint. You will be hearing more about this development from Jerry Stanners, of Kenaf International, the next speaker.

Some of you may remember that I presented a paper on the potential for kenaf at your 1968 annual meeting at the Waldrof. At that time, I pointed out several different approaches for using Kenaf and/or Jute which are still all being considered for future mills. These are :

(a) The production of thermomechanical or chemi-thermo mechanical pulp from whole stalk kenaf and/or jute for 90% to 100% of the newsprint furnish with the remainder being long fiber pulp, which could also be from kenaf or jute bast fibers.

(b) The separation of the two components of kenaf and/or jute into bast fiber and core fractions followed by chemical pulping of the bast fiber, mechanical or chemimechanical pulping of the core fraction and blending the two pulps together for the newsprint furnish.

(c) The use of thermo-mechanical or chemi-thermo-mechanical pulp from whole stalk kenaf and/or jute or from the core material as a supplementary fibrous furnish blended with the normal newsprint furnish in an existing mill.

(d) Use of only the core material mechanical type pulp blended with the normal newsprint furnish or using the core material for particle boards, and using the high quality bast fiber pulp for speciality papers such as cigarette paper. Its use for cigarette paper is already being practiced in Yugoslovia and India and Jute bast fiber is being used for that purpose in Bangladesh.

(e) Production of chemical pulp from the whole stalk kenaf, with a mixture of long and short fibers. Market pulp from whole stalk kenaf is already being produced in Thailand.

I shall be interested in hearing the approach which kenaf International and CIP plan to use for the Texas Newsprint Mill.

V. Total Worldwide Non-Wood Plant Fiber Pulp Capacity by Country and by Principal Raw Materials

A. General Comments

Since neither the 1987–1992 nor the 1986–1991 pulp and paper capacity surveys give accurate data for several of the largest producers of non-wood pulp for 1991 and 1992, the projected capacities for this paper are carried only to 1990. Based on rather extensive personal knowledge of actual progress in developing non-wood fibers pulp production in these countries, it appears that the data up through 1990 is far more realistic than for 1991 and 1992.

This is due to lack of reports for many of the developing countries to FAO on their future projects in this field beyond 1989 in some cases and even beyond 1987 and 1988 in others.

In TABLE III the total capacity for non-wood plant fiber pulp is shown by country for 1987 and 1990. This data is based on the FAO capacities survey for the period 1987 through 1992, combined with data obtained from some of the individual countries by Atchison Consultants.

It can be seen that the People's Republic of China is by far the leader in this field, with more than 55% of the total world pulping capacity for non-wood fiber pulps. This represents 76.1% of total papermaking pulp capacity in China. India is second largest producer of non-wood fiber pulp with 73.1% of its total pulp capacity being from non-wood raw materials. It can be seen that, for many countries non-wood represents 100% of their total pulp capacity and some 25 countries depend on non-wood plant fibers for more than 50% of pulp production, with China and India being the leaders.

In Table IV, the leading countries in total non-wood plant fiber pulp production capacity are shown, along with the percentage of the world total produced by each of these countries. It can be seen that China produces more than 55% of the world total, and that China and India together produce more than 2/3 of the world total of non-wood pulp. Neither of these consider that China has a population of more than one million and India more than 700 million, if they are to satisfy their increasing requirements for paper, they must continue to increase their non-wood pulping capacity at a rapid rate. Many other developing countries face a similar situation, which accounts for the rapid growth percentage wise of non-wood pulping capacity.

B. Leading Countries in Production Capacity for Straw Pulp

In Table V, a list is shown of the leading countries in production capacity for straw pulp, including both ceral straw and rice straw. In this area, also The Peoples Republic of China is far in the lead with 84 percent of the world total in 1987 and 85.8 percent of the world total projected for 1990.

C. Leading Countries in Production Capacity for Bagasse Pulp

In Table VI, a list is shown of the leading countries in production capacity for bagasse pulp.

It can be seen that Mexico was the leader in bagasse pulp production in 1985, but due to the closure of two high cost market pulp mills, capacity decreased in 1987 and China forged ahead as the leader in bagasse pulping, as well as in straw pulping. However, for the long term future India, Cuba and Brazil have tremendous potential as bagasse pulp producers, whereas China has a limited supply of bagasse available.

Due to the favorable economics of bagasse pulp production it is expected that its use will spread more widely in all cane sugar producing countries than the use of other non-wood fibers.

D. Leading Countries in Production Capacity for Bamboo Pulp

In Table VII, a list is given of the leading countries in production capacity for bamboo pulp, and the percentage of the world total produced by each country. It can be seen that India is the leader, by a wide margin, as it has been for many years, with more that 70% of the world's total production of bamboo pulp. China is second, with 14.8 percent of the total.

E. Leading Countries in Production Capacity For Miscellaneous Non-Wood Plant Fiber Pulps

In TABLES VIII, a list is given of leading countries in production capacity for pulp from miscellaneous non-wood plant fibers, including reeds, sisal, kenaf, abaca, esparto grass, sabai grass and other grasses, jute, hemp, flax straw, cotton linters, rags, etc.

China, again is in the lead, because they use practically every plant fiber they have available, including reeds of all types, grasses, hemp, jute, kenaf, cotton linters and others as well s straw, bagasse and bamboo.

However, it can be seen that the U. S. ranks third in the capacity for miscellaneous non-wood plant fibers which includes cotton linters, flax, abaca (manila hemp) and other specialty fibers for papers which sell at very high prices.

F. Estimated Actual Production of Non-Wood Plant Fiber Pulp in 1985 and 1987

In Table IX, an estimate is given of the actual producton of all types of non-wood fiber pulp for 1985 and 1987. It can be seen that straw is in first place, with bagasse second, bamboo third and various types of reeds fourth.

VI. Properties of Non-Wood Plant Fiber Pulps in Comparison to Softwood and Hardwood Pulps

In figure I, graphs have been drawn to show the comparative strength characteristic of the various non-wood plant fiber pulps and a number of wood pulps which are familiar, plus a few which might not be so familiar. It is believed that this graphical analysis of the BURST-TEAR relationship gives a reasonable indication of the relative strength characteristic of these various pulps.

Table X indicates the fiber dimensions of the various non-wood fiber pulps, along with the dimensions of various wood pulps, for comparison. This gives a reasonably good indication of the potential usefulness of these pulps from a technical standpoint. In fact, from a technical and quality standpoint, any grade of paper can be produced by using a combination of various non-wood plant fibers. **Their greater use awaits only the economic necessity.**

VII. Photomicrographs of Typical Non-Wood Plant Fibers

In figure 2 some photomicrographs are shown of the principal non-wood plant fibers which might be used for manufacture of pulp and paper along with photomicrographs of eucalyptus and monterey pine which are typical hardwoods and softwoods which are in wide use.

Now a few words about the advanced technology for non-wood plant fiber pulping.

VIII. Bagasse, the Leader in Advanced Technology for utilizing Non-Wood Plant Fibers For Pulp, Paper Paperboard, and Reconstituted Panelboard

In the development of advanced technology for pulping nonwood plant fibers, a major portion of the efforts world-wide have been concentrated upon the utilization of bagasse. Suprisingly a major portion of the work on bagasse has been carried out in the U. S., by American Companies and Research Institutions.

The speaker personally started working on bagasse pulping in 1939 as a Master's Thesis Topic at The Institute of Paper Chemistry. By coincidence, in that same year - 1939 - the first three successful bagasse based pulp mills began operation. Small integrated mills started up in Peru and the Philippines, each of 25 tons daily and a bleached bagasse market pulp mill, built by the Japanese started up in Taiwan.

However, progress was very slow and as recently as 1950, there were only six pulp mills in the world based on utilizing bagasse, with total capacity amounting to 120,000 tons and actual production about 80,000 tons. Then during the period from 1950 to 1960, a concentrated drive was made to fully investigate the utilization of bagasse. During this period, leading research and development institutions and large industrial companies concentrated their efforts on over-coming the technical obstacles which had held back the use of bagasse. These efforts resulted in greatly improved methods of storing, preparing, depithing, handling and pulping bagasse, which drastically improved the economic relative to its use.

During this period, the work of the Hawaiian Sugar Planters Association in collaboration with Crown Zellerbach corporation deserve special mention. This group carried out, over a period of more than 10 years, the most comprehensive research and development program on bagasse which had ever been carried out on any non-wood plant fiber. In fact, the entire technial groundwork for the modern bagasse pulping inductry was developed as a result of these efforts, which were published in the August 1957, October 1957, and November 1957 issue of TAPPI Magazine. The speaker is proud to have been associated with this activity, as well as many major developments in bagasse utilization since that time.

Since that time, additional concentrated work on bagasse has continued in Cuba by the CUBA-9 Group, in Taiwan, in Peru and in other countries as well as in the U. S.

As a result, the quality of bagasse pulp has been vastly improved and in general, these efforts have brought the level of technology related to pulping bagasse up to the level of technology of wood pulping.

There are now no technical problems to prevent this raw material from literally "taking off" in the rate of expansion of its use on a worldwide basis. Fortunately a major part of this advanced technology can be applied to other non-wood plant fibers as well.

The principal areas in which advanced technology has been developed and processes perfected, relative to utilization of bagasse for manufacture of pulp, paper, paperboard, and reconsittuted panelboard are as follows :

1. Perfection of procedures and equipment for both moist depithing and wet depithing of bagasse.
2. Optimizing procedures for wet bulk storage of bagasse and for storage in large bales without deterioration.
3. Developing of rapid continuous pulping of bagasse in the horizontal tube digester with screw feeder and orifice discharge, reducing the overall digester cycle from 4 to 6 hours to 10 to 15 minutes or less.
4. Improved methods of washing, screening and cleaning.
5. Optimization of the bleaching process to obtain high brightness pulps with minimum consumption of bleaching chemicals, including use of oxygen, chlorin dioxide, and peroxide when appropriate.
6. Optimization of the refining of bagasses pulps.
7. Optimization of paper machine design for high speed operation with as much as 90% bagasse pulp or higher.
8. Development of optimum furnishes with a relatively high content of bagasse pulp for all grades of paper and paperboard from tissue to linerboard, including newsprint.
9. Development of efficient and economical methods of producing bagasse mechnical, thermomechanical and chemimechanical pulps for use in newsprint and mechanical pulp containing printing paper.
10. Optimization of processes for production of newsprint with a high content of bagasse mechanical and chemical pulps.
11. Optimization of methods of preparing bagasse for use in all types of reconstituted panelboard including medium density fiberboard.

As a result of this sound technology, which has been developed for bagasse, there has been tremendous progress made in the development of complete bagasse pulp and paper mill projects which have increased in size year by year to the 250 to 300 MT/D production level.

From a pulp capacity level of only 120,000 MT in 1950, the bagasse pulping capacity in 1987 reached about 2,325,000 MT and actual bagasse pulp produced reached the 2 million MT level. By 1990 bagasse pulping capacity is expected to reach 2,500,000 MT, with production being about 2,200,000 MT.

In Table XI the historical development of bagasse pulping capacity, actual pulp production and the number of mills of 30 tons daily capacity or more, are shown. An indication is also shown of the bagasse pulp production as a percentage of total pulp production from 1965 to 1990.

Bagasse pulps are now used in practically all grades of paper, including bag, wrapping, printing, writing, toilet tissue,toweling, glassine, corrugating medium, linerboard, bleached boards and coated base stock, newsprint and mechanical containing printing paper. In Table XII typical uses of bagasse pulps in various grades of paper and paperboard are shown. In addition, bagasse is now being used in practically all type of reconstituted panelboard, including insulation board, wet and dry process hardboard, particleboard and medium density fierboard.

IX. Application of Advanced Techonology for Bagasse Pulping to other Non-wood Plant Fibers

A. General Comments

Although practically all of the initial efforts in developing advanced technology for handling,preparing, pulping and papermaking with non-wood plant fibers, has been concentrated upon bagasse, this same technology can and is being applied to other non-wood plant fibers, as well.

For example, wet cleaning of straw was developed from procedures for wet depithing of bagasse. The rapid continuous horizontal tube digester, for many years has been in highly successful operation for cooking wheat straw, esparto grass, reeds and bamboo, and more recently for cooking rice straw. However, it has been found that for certain large diameter reeds and bamboo, the cooking time must be 20 to 30 minutes, instead of 10 to 15 minutes for bagasse and straw.

Methods of production of mechanical type pulps, from well depithed bagasse, have been applied to whole stalk kenaf and to kenaf core material. Washing, screening, cleaning, bleaching and stock preparation techniques developed for bagasse are being applied to straw. The perfection of techniques and design for high speed machine operations, when using 90% bleached bagasse chemical pulp in the furnish (speeds of 500 meters and above) has been extremely valueable toward development of similar techniques for using slower draining straw pulps in high percentages.

In Chemical recovery systems, the major concentration has also been on bagasse black liquor the most modern bagasse recovery systems, such as Ledesma in Argentina, PROPAL in Colombia and Taiwan Sugar Corporation in Taiwan, are now approaching 90% overall recovery of caustic soda.

In large scale pilot work, a number of the other non-wood plant fibers, have been cleaned in wet cleaning systems and cooked very successfully in the horizontal tube digester, including whole stalk kenaf, kenaf bast fiber, kenaf core material, sisal, sabai grass and other grasses, reeds of various types, abaca, decorticated flax straw and others.

Rather large scale edxperimental trails have been made with wet bulk storage of straw,after it has been chopped, and with whole stalk kenaf, and these trials were also successful. It is believed that once the advanced technology, for utlizing bagasse, has been applied more widely to the other non-wood plant fibers, their use may accelerate much faster than the most optimistic projections.

B. Special Comments On The Use of Cereal Straws

Wheat straw is the most commonly used among the cereal straws, for manufacture of pulp. However, rye straw, barley straw and oats straw are also being used to a limited extent. Among the non-wood plant fibers, cereal straw is used to a greater extent than any of the others, due mainly to the existence of a tremendous number of mini-mills in China and India. However, most of these mills are not utilizing the advanced technology which has been developed for bagasse. Most of them are still using the old type rotary globe spherical digester or cylindrical tumbling type digesters and very few of these mills, in China and India have recovery systems.

Undoubtedly the advanced technology developed for bagasse, will be used more and more in new straw bsed mills, as it is being used in Greece, Romania, Hungary, Denmark, Italy and Spain.

The principal drawback, to greater use of straw, involves the high cost of collection and storage because, by present methods these procedures are highly labour intensive. This limits the large scale use of both cereal straw and rice straw to countries which have extremely low labor rates.

As better collection and storage methods are developed, the total worldwide straw availability could easily exceed one million metric tons. Already, it has been shown that chopped straw can be stored successfully by means of the wet bulk storage system used for bagasse. New collection systems in which large round tightly compacted bales or large one ton highly compacted rectangular bales are produced, are already in wide use in the U.S. which greatly reduce labor costs. A limited scale of dry bulk storage is being used in India and China and these costs reduction procedures are certain to result in greatly expanded use of straw.

Even if 10% of the world's straw were used for pulp production, this could mean more than 30 million tons of pulp worldwide.

C. New Prospects For Rice Straw

In addition to the high cost of collecting and storage of rice straw, the principal factor, which has been detrimental to its wide spread use, has been its high silica content, which made it impossible to operate an efficient black liquor recovery system. Therefore, all of the rice straw pulp mills, in existence up until 1987, have been operating without recovery systems.

However, as a result of intensive pilot plant work over the past ten years, a breakthrough has been made in perfecting efficient desilication processes for black liquor from rice straw pulping. Three such processes are now being offered, for commercial use all of which use readily available flue gas from the recovery boiler itself for precipitation of the silica. This development could revolutionize the use of rice straw and result in a dramatic increase in its use.

This same technology can then be applied to improve the recovery system when pulping bagasse, wheat straw, bamboo and other raw materials with a medium or high silica content.

Now what about market pulp from non-wood plant fibers?

X. Prospects for Market Pulp from Non-Wood Plant Fibers

Up to the present time a vast majority of non-wood fiber pulp is produced and used in intergrated operations and this situation will likely prevail in the future.

However, there are a few exceptions which might be mentioned.

A. Bleached Bagasse Pulp Mills

The largest bleached bagasse market pulp mill is a 300 to 350 T/D mill operated by Taiwan Sugar Corporation, with about 50% of the production being sold very sucessfully on the world market in competition with bleached hardwood pulp. Smaller bleached bagasse market pulp mills operate in Thailand, Cuba and Mexico for domestic use.

However, for the future, bleached bagasse market pulp mills are being seriously considered in South Africa and Australia and are also likely to be built in Cuba for export, with mills of 300 to 400 T/D being of optimum size.

B. Bleached Straw Pulp Mills

The only bleached straw market pulp mill now existing is the Fredericia mill in Denmark which markets all of its production domestically. However, a bleached straw market pulp mill is now being considered in Western Australia.

C. Kenaf Market Pulp Mills

At the present time, whole stalk kenaf is being used in a bleached market pulp mill in Thailand, which has a capacity for production of 70,000 MT of pulp annually. With mixtures of long and very short fibers this pulp is sold in competition with bleached hardwood pulp.

A kenaf based market pulp mill is presently under consideration in Queensland Australia in which the long fibered kenaf bark would be separated from the short fibered core, with each being pulped separately. Then the long fibered pulp would be sold as a specialty pulp, and the short fibered core pulp would be sold for purposes for which it is suitable. In some cases they envisage blending the two pulps together for specific purposes.

D. Sisal Pulp Mill

A 250 T/D bleached sisal pulp mill was operated in Brazil for several years, producing a premium grade pulp. However, the mill has been temporarily closed because, they could not develop adequate market at the price which they had to charge for this pulp which was about $850, when bleached kraft softwood pulp was selling for $500/MT.

E. Abaca or Manila Hemp

Presently there are 5 abaca pulp mills operating in The Philippines, with total capacity of about 20,000 MT. They produce about 10,000 to 12,000 MT annually, some of which is used locally for cigarette paper with the remainder being exported to Japan, Europe and The U.S.

XI. Conclusions Relative to Future use of Non-Wood Plant Fibers for Papermaking

There appears to be no doubt that the non-wood plant fibers will play an increasing role in the world's pulp and paper industry. It appears that the necessary fibrous resources either exist already or can be grown in the developing countries to sustain the increasing pulp and paper requirements in these areas.

When it is considered that more than two billion tons of such material could be made available, and even greater quantities grown if necessary, tremendous expansion possibilities in their use present themselves.

It has been proven that by properly selecting the appropriate mixture of non-wood fibers and the appropriate pulping processes, any grade of paper and paperboard can be produced. If circumstance require it, all grades can be produced without the addition of any wood pulp. In fact, some grades are already being produced with 100% non-wood fibers. However, in most cases, it is expected that non-wood fibers will be used in blends with at least small proportion of wood pulp.

The future use of renewable non-wood plant fibers for pulping indeed looks very promising. However, it must be stressed that only a very few of the hundreds of thousands of non-wood plant fibers will ever reach the stage of commercial utilization. From a technical standpoint, almost any plant that grows can be converterd into useful pulp for papermaking. However, very few can be grown, collected, stored and processed economically. The future for those few raw materials is indeed bright and exciting for everyone in this field.

INDEX
to
TABLES and FIGURES

TABLE I

ESTIMATED ANNUAL COLLECTABLE YIELDS OF VARIOUS NON-WOOD PLANT FIBROUS RAW MATERIALS PER HECTARE

	RAW MATERIALS	ESTIMATED COLLECTABLES FIBROUS RAW MATERIALS (BDM/HA)	ESTIMATED EQUIVALENT IN BLEACHED PULP (BDMT/HA)
1.	Sugar Cane Bagasse	5.0 to 12.4	1.3 to 3.2
2.	Wheat Straw	2.2 to 3.0	0.7 to 1.0
3.	Rice Straw	1.4 to 2.0	0.4 to 0.6
4.	Barley Straw	1.4 to 1.5	0.4 to 0.5
5.	Oat Straw	1.4 to 1.5	0.4 to 0.5
6.	Rye Straw	2.5 to 3.5	0.8 to 1.0
7.	Bamboo, Natural Growth	1.5 to 2.0	0.6 to 0.8
8.	Bamboo, Cultivated	2.5 to 5.0	1.0 to 2.1
9.	Reeds in the USSR	5.0 to 9.9	2.0 to 4.0
10.	Kenaf-Total Stream Weight	7.4 to 24.7	3.0 to 9.9
11.	Kenaf Bast Fibre	1.5 to 6.2	0.7 to 3.2
12.	Crotalaria Bast Fibre	1.5 to 5.0	0.7 to 2.5
13.	Papyrus in Upper Sudan	20.0 to 24.7	5.9 to 7.4
14.	Abaca (Manila Hemp) Fibre	0.7 to 1.5	0.4 to 0.7
15.	Seed Flax Straw	1.0 to 1.5	0.18 to 0.27
16.	Cotton Staple Fibre	0.3 to 0.9	0.25 to 0.86
17.	Second Cut Cotton Linters	0.02 to 0.07	0.015 to 0.062
18.	Corn Stalks	5.5 to 7.0	1.55 to 1.95
19.	Sorghum Stalks	5.5 to 7.0	1.55 to 1.95
20.	Cotton Stalks	1.5 to 2.0	0.60 to 0.80

SOURCE: JOSEPH E. ATCHISON CONSULTANTS, INC.

TABLE I — A

ESTIMATED ANNUAL COLLECTABLE YIELDS OF VARIOUS NON-WOOD PLANT FIBROUS RAW MATERIALS PER ACRE OF LAND

		ESTIMATED COLLECTABLE FIBROUS RAW MATERIAL BDMT/ACRE	ESTIMATED EQUIVALENT IN BLEACHED PULP BDMT/ACRE
1.	Sugar Cane Bagasse	2 to 5	0.56 to 1.4
2.	Wheat Straw	0.9 to 1.2	0.3 to 0.4
3.	Rice Straw	0.5 to 0.8	0.15 to 0.24
4.	Barley Straw	0.5 to 0.6	0.15 to 0.20
5.	Oat Straw	0.5 to 0.6	0.15 to 0.20
6.	Rye Straw	1.0 to 1.4	0.33 to 0.42
7.	Bamboo, Natural Growth	0.6 to 0.8	0.25 to 0.34
8.	Bamboo, Cultivated	1.0 to 2.0	0.42 to 0.84
9.	Reeds in the USSR	2.0 to 4.0	0.80 to 1.6
10.	Kenaf-Total Stem Wt.	3 to 10	1.2 to 4.0
11.	Kenaf Bast Fibre	0.6 to 2.5	0.30 to 1.3
12.	Crotalaria Bast Fibre	0.6 to 2.0	0.30 to 1.0
13.	Papyrus in Upper Sudan	8 to 10	2.4 to 3.0
14.	Abaca (Manila Hemp) Fibre	0.3 to 0.6	0.15 to 0.3
15.	Flax Seed Straw	0.4 to 0.6	0.07 to 0.1
16.	Cotton Staple Fibre	0.1 to 0.35	0.10 to 0.35
17.	Second Cut Cotton Linters	0.008 to 0.030	0.006 to 0.025
18.	Corn Stalks	2.2 to 2.8	0.62 to 0.78
19.	Sorghum Stalks	2.2 to 2.8	0.62 to 0.78
20.	Cotton Stalks	0.6 to 0.8.	0.24 to 0.32

Source: Joseph E. Atchison Consultants, Inc.

TABLE II

ESTIMATED AVAILABILITY OF SPECIFIC NON-WOOD PLANT FIBROUS RAW MATERIALS 1987

	RAW MATERIALS	POTENTIAL WORLDWIDE AVAILABILITY (BDMT)
1.	Sugar Cane Bagasse	80,000.00
2.	Wheat Straw	580,000.000
3.	Rice Straw	320,000.000
4.	Oat Straw	60,000.000
5.	Barley Straw	150,000.000
6.	Rye Straw	40,000.000
7.	Seed Flax Straw	2,000.000
8.	Grass Seed Straw	3,000.000
	Subtotal Straw	1,155,000.000
9.	Stem Fibers, Including Jute, Kenaf, Hemp & Allied Fibers (bast Fibers Only)	3,700.000
10.	Core Material from Stem Fibers	10,000.000
11.	Leaf Fibers	
	(a) Sisal	420,000
	(b) Henequen and Maguey	100,000
	(c) Abaca	80,000
	Subtotal Leaf Fibers	600,000
12.	Reeds	30,000.000
13.	Bamboo	30,000.000
14.	Papyrus	5,000.000
15.	Esparto Grass	500,000
16.	Sabai Grass	200.000
17.	Total Cotton Staple Fiber	15,000.000
18.	Total Second Cut Cotton Linters	1,000.000
19.	Corn Stalks and Sorghum Stalks	900,000.000
20.	Cotton Stalks	70,000.000
	GRAND TOTAL	2,301,000.000

Source: Joseph E. Atchison Consultants, Inc.

TABLE III

CAPACITY FOR PRODUCTION OF NON-WOOD PLANT FIBER PULP BY COUNTRY AND PERCENTAGE OF TOTAL PULP PRODUCTION WHICH IS FROM NON-WOOD FIBERS 1987 AND 1990

	1987			PROJECTED FOR 1990		
	TOTAL PAPER GRADE PULP CAP 1000 MT	NON-WOOD PULP CAP 1000 MT	PERCENT FROM NON-WOOD PULP	TOTAL PAPER GRADE 1000 MT	NON-WOOD PULP CAP 1000 MT	PERCENT FROM NON-WOOD
SOUTH AFRICA	1549	99	6.4	1549	99	6.4
ALGERIA	105	105	100.0	105	105	100.0
EGYPT	85	85	100.0	85	85	100.0
KENYA	80	10	12.5	92	12	13.0
TUNISIA	17	17	100.0	18	18	100.0
UNITED STATES	54468	310	0.6	57,725	321	0.6
ARGENTINA	780	140	17.9	918	140	15.4
BOLIVIA	1	1	100.0	1	1	100.0
BRAZIL	4380	175	4.0	4887	175	3.6
COLOMBIA	263	97	36.9	337	158	51.1
CUBA	108	108	100.0	108	108	100.0
ECUADOR	21	15	71.4	21	15	71.4
MEXICO	947	295	31.1	1166	295	25.3
PERU	311	296	95.7	311	296	95.2
VENEZUELA	174	140	80.5	174	140	80.5
CHINA	10,679	8122	76.1	13325	10141	76.1
KAMPUCHEA	6	6	100.0	6	6	100.0
KOREA NORTH	106	50	47.2	106	50	47.2
MONGOLIA	2	2	100.0	2	2	100.0
VIETNAM	107	63	58.9	107	63	58.9
JAPAN	12,246	4	--	13606	4	---
BANGLADESH	116	63	54.3	116	63	54.3
BURMA	18	18	100.0	18	18	100.0
INDIA	2790	2040	73.1	2790	2040	73.1
INDONESIA	474	327	69.0	1089	477	43.8
IRAN	285	60	21.0	285	60	21.0
IRAQ	101	101	100.0	101	101	100.0
NEPAL	3	3	100.0	5	5	100.0
PAKISTAN	100	100	100.0	150	150	100.0
PHILIPPINES	162	33	20.4	162	33	20.4

	1	2	3	4	5	6
SRI LANKA	17	17	100.0	33	18	54.5
SYRIA	32	32	100.0	32	32	100.0
TAIWAN	400	150	37.5	450	150	33.3
THAILAND	110	110	100.0	140	140	100.0
TURKEY	625	103	16.5	625	103	16.5
ALBANIA	15	5	33.3	15	5	33.3
BULGARIA	303	28	9.2	303	28	9.2
CZECHOSLOVAKIA	1228	25	2.0	1217	25	2.0
GERMANY, EAST	1,097	77	7.0	1,097	77	7.0
HUNGARY	69	11	15.9	95	33	34.7
POLAND	1019	2	0.2	1048	2	0.2
ROMANIA	932	102	10.9	932	102	42.1
DENMARK	100	30	30.0	121	51	42.1
FRANCE	2250	20	0.9	2690	20	0.7
ITALY	1085	185	17.0	1085	185	17.0
NETHERLANDS	198	2	1.0	268	2	0.7
U.K.	507	17	3.3	737	17	2.3
GREECE	150	60	40.0	150	60	40.0
PORTUGUAL	1409	45	3.2	1595	45	2.8
SPAIN	1630	130	8.0	1770	130	7.3
YUGOSLAVIA	734	28	3.8	734	28	3.8
AUSTRALIA	1046	11	1.1	1207	11	0.9
USSR	12,675	625	4.9	12,675	625	4.9
WORLD TOTALS						
COUNTRIES	171,200	14,700	8.6	186,807	17,070	9.1

SOURCE: BASED ON FAO CAPACITY SURVEYS 1987-92 AND DATA OBTAINED FROM INDIVIDUAL COUNTRIES

BY: JOSEPH E. ATCHISON CONSULTANTS, INC.

TABLE IV

LEADING COUNTRIES IN TOTAL NON-WOOD PLANT FIBER PULP PRODUCTION CAPACITY AND PERCENTAGE OF WORLD TOTAL CAPACITY FOR EACH COUNTRY

	COUNTRY	1987 CAPACITY 1000 MT	PER CENT OF WORLD TOTAL	CAPACITY 1000 MT	1990 PER CENT OF WORLD TOTAL
1.	CHINA	8122	55.2	10141	59.4
2.	INDIA	2040	13.9	2040	12.0
3.	USSR	625	4.2	625	3.7
4.	INDONESIA	327	2.2	477	2.8
5.	USA	310	2.1	321	1.9
6.	PERU	296	2.0	296	1.7
7.	MEXICO	295	2.0	295	1.7
8.	ITALY	185	1.3	185	1.1
9.	BRAZIL	175	1.2	175	1.0
10.	TAIWAN	150	1.0	150	0.9
11.	ARGENTINA	140	1.0	140	0.8
12.	VENEZUELA	140	1.0	140	0.8
13.	SPAIN	130	0.9	130	0.8
14.	THAILAND	110	0.8	140	0.8
15.	CUBA	108	0.7	108	0.6
16.	ALGERIA	105	0.7	105	0.6
17.	TURKEY	103	0.7	103	0.6
18.	ROMANIA	102	0.7	102	0.6
19.	IRAQ	101	0.7	101	0.6
20.	PAKISTAN	100	0.7	150	0.9
21.	COLOMBIA	97	0.6	158	0.9
	Subtotal for 1st 21 Countries	13,761	93.6	16,082	94.2
	ESMTED TOTAL ALL COUNTRIES	14,700	100	17.070	100

SOURCES: BASED ON FAO CAPACITY SURVEY 1987-92 AND INFORMATION OBTAINED FROM INDIVIDUAL COUNTRIES

BY: JOSEPH E. ATCHISON CONSULTANTS, INC.

TABLE V LEADING COUNTRIES IN PRODUCTION CAPACITY
FOR STRAW PULP AND PERCENTAGE OF WORLD TOTAL CAPACITY FOR EACH COUNTRY

COUNTRY	1985		1987		1990	
	PERCENT OF WORLD TOTAL	CAPACITY 1000 MT	CAPACITY 1000 MT	PERCENT OF WORLD TOTAL	CAPACITY 1000 MT	PERCENT OF WORLD TOTAL
1. CHINA	5037	81.7	6039	84.0	7540	85.8
2. INDIA	350	5.7	400	5.6	400	4.5
3. SPAIN	115	1.9	115	1.6	115	1.3
4. ITALY	92	1.5	92	1.3	92	1.0
5. TURKEY	77	1.5	77	1.1	77	0.9
6. DENMARK	70	1.1	30	0.4	51	0.6
7. EGYPT	67	1.1	67	0.9	67	0.8
8. ROMANIA	58	0.9	58	0.8	58	0.7
9. GREECE	50	0.8	60	0.8	60	0.7
10. INDONESIA	43	0.7	43	0.6	43	0.5
11. PAKISTAN	33	0.5	35	0.5	80	0.9

1	2	3	4	5	6	7
12. SYRIA	32	0.5	32	0.4	32	0.4
13. BULGARIA	28	0.5	28	0.4	28	0.3
14. YUGOSLAVIA	28	0.5	28	0.4	28	0.3
15. ALGERIA	25	0.4	25	0.3	25	0.3
16. HUNGARY	19	0.3	11	0.15	33	0.4
17. SRI LANKA	16	0.3	17	0.25	18	0.2
SUB-TOTAL FOR 1st 17 COUNTRIES	6140	99.6	7157	99.5	8747	99.6
ESTIMATED TOTAL FROM ALL COUNTRIES	6166	100	7191	100	8783	100

SOURCES: DATA BASED ON FAO CAPACITY SURVEYS OF 1987-92 AND 1985-1990 AND INFORMATION OBTAINED FROM INDIVIDUAL COUNTRIES BY: JOSEPH E. ATCHISON CONSULTANTS, INC.

TABLE VI LEADING COUNTRIES IN PRODUCTION CAPACITY FOR BAGASSE PULP AND PERCENTAGE OF WORLD TOTAL CAPACITY FOR EACH COUNTRY

	1985		1987		1990	
COUNTRY	CAPACITY 1000 MT	PER CENT OF WORLD TOTAL	CAPACITY 1000 MT	PERCENT OF WORLD TOTAL	CAPACITY 1000 MT	PERCENT OF WORLD TOTAL
1. MEXICO	408	17.9	292	12.6	292	11.7
2. CHINA	351	15.4	420	18.1	525	21.1
3. PERU	308	13.5	296	12.8	296	11.9
4. INDONESIA	183	8.0	183	7.9	183	7.4
5. TAIWAN	135	5.9	150	6.5	150	6.0
6. ARGENTINA	135	5.9	135	5.8	135	5.4
7. VENEZUELA	125	5.5	140	6.0	140	5.6
8. CUBA	108	4.7	108	4.7	108	4.3
9. BRAZIL	99	4.3	78	3.3	78	3.1
10. COLOMBIA	93	4.1	93	4.0	154	6.2
11. SOUTH AFRICA	90	4.0	99	4.3	99	4.0

1	2	3	4	5	6	7
12. IRAN	60	2.6	60	2.6	60	2.4
13. PAKISTAN	30	1.3	30	1.3	30	1.2
14. INDIA	30	1.3	90	3.9	90	3.6
15. IRAQ	27	1.2	27	1.2	27	1.1
16. THIALAND	24	1.0	45	1.9	50	2.0
17. PHILIPPINES	22	1.0	22	0.9	22	0.9
18. EGYPT	18	0.8	18	0.8	18	0.7
19. BANGLADESH	15	0.7	15	0.6	15	0.6
20. ECUADOR	15	0.7	15	0.6	15	0.6
SUBTOTAL FOR 1st 20 COUNTRIES	2276	99.8	2316	99.8	2487	99.8
ESTIMATES TOTAI ALL COUNTRIES	2281	100	2321	100	2492	100

SOURCE: BASED ON DATA IN FAO CAPACITY SURVEYS OF 1987-92 AND 1985-1990 AND INFORMATION OBTAINED DIRECTLY FROM SPECIFIC COUNTRIES BY: JOSEPH E. ATCHISON CONSULTANTS, INC.

TABLE VIII

LEADING COUNTRIES IN PRODUCTION CAPACITY FOR MISCELLANEOUS FIBER PULPS OTHER THAN STRAW, BAGASSE AND BAMBOO AND PERCENTAGE OF WORLD TOTAL CAPACITY FOR EACH COUNTRY *

COUNTRY	1985		1987		1990	
	CAPACITY 1000 MT	PERCENT OF WORLD TOTAL	CAPACITY 1000 MT	PERCENT OF WORLD TOTAL	CAPACITY 1000 MT	PERCENT OF WORLD TOTAL
1. CHINA	1212	36.8	1453	40.2	1814	44.9
2. USSR	625	19.0	625	17.3	625	15.5
3. USA	321	9.7	310	8.6	321	7.9
4. INDIA	250	7.6	250	6.9	250	6.2
5. BRAZIL	135	4.1	52	1.4	52	1.3
6. ITALY	93	2.8	93	2.6	93	2.3
7. ALGERIA	80	2.4	80	2.2	80	2.0
8. EAST GERMANY	77	2.3	77	2.1	77	1.9
9. IRAQ	74	2.2	74	2.0	74	1.8
10. THAILAND	60	1.8	60	1.7	60	1.5
11. NORTH KOREA	50	1.5	50	1.4	50	1.2
12. ROMANIA	44	1.3	44	1.2	44	1.1
13. PORTUGAL	45	1.3	45	1.2	45	1.1
14. PAKISTAN	35	1.1	35	1.0	40	1.0
15. BANGLADESH	27	0.8	6	0.2	6	0.2

	1	2	3	4	5	6
16. TURKEY	26	0.8	26	0.7	26	0.6
17. CZECHOSLOVAKIA	25	0.8	25	0.7	25	0.6
18. TUNISIA	21	0.6	17	0.5	18	0.4
19. FRANCE	20	0.6	20	0.6	20	0.5
20. UNITED KINGDOM	17	0.5	17	0.5	17	0.4
21. SPAIN	15	0.5	15	0.4	15	0.4
22. PHILIPPINES	11	0.3	11	0.3	11	0.3
23. AUSTRALIA	11	0.3	11	0.3	11	0.3
24. INDONESIA	0	0	190	5.3	240	5.9
SUBTOTAL FOR 1st 24 COUNTRIES	32.74	99.3	3586	99.3	4014	99.3
ESTIMATED TOTAL FOR ALL COUNTRIES	3297	100	3610	100	4042	100

* INCLUDES: REEDS, SISAL, KENAF, ABACA, ESPARCO GRASS, SABAI GRASS, JUTE, HEMP, FLAX STRAW, COTTON LINTERS, RAGS, ETC.

SOURCE: BASED ON DATA IN FAO CAPACITY SURVEYS OF 1987-92 AND 1985-1990 PLUS INFORMATION OBTAINED FROM INDIVIDUAL COUNTRIES

BY: JOSEPH E. ATCHISON CONSULTANTS, INC.

TABLE VII LEADING COUNTRIES IN PRODUCTION CAPACITY FOR BAMBOO PULP AND PERCENTAGE OF WORLD TOTAL CAPACITY FOR EACH COUNTRY

		1985		1987		1990	
	COUNTRY	CAPACITY 1000 MT	PER CENT OF WORLD TOTAL	CAPACITY 1000 MT	PERCENT OF WORLD TOTAL	CAPACITY 1000 MT	PERCENT OF WORLD TOTAL
1.	INDIA	1200	78.1	1300	77.2	1300	73.6
2.	CHINA	175	11.4	210	12.5	262	14.8
3.	BRAZIL	55	3.6	45	2.7	45	2.6
4	VIETNAM	47	3.1	53	3.1	53	3.0
5.	BANGLADESH	30	1.9	42	2.5	42	2.4
6.	BURMA	18	1.2	20	1.2	20	1.1
7.	INDONESIA	11	0.7	11	0.7	11	0.6
8.	NEPAL	0	0	2	0.1	2	0.1
9.	KAMPUCHEA	1	0.06	1	0.06	1	0.06
10.	THAILAND	0	0	0	0	30	1.7
	SUBTOTAL FOR 1st 10 COUNTRIES	1537	100	1684	100	1766	100
	ESTIMATED TOTAL FOR ALL COUNTRIES	1537	100	1684	100	1766	100

SOURCES: BASED ON DATA FROM FAO CAPACITY SURVEY OF 1987-92 AND 1985-1990 AND INFORMATION OBTAINED DIRECTLY FROM SPECIFIC COUNTRIES BY: JOSEPH E. ATCHISON CONSULTANTS, INC.

TABLE IX

ESTIMATED TOTAL ACTUAL PRODUCTION OF VARIOUS NON-WOOD PLANT FIBER PULPS IN 1985 AND 1987

RAW MATERIALS	ESTIMATED WORLD PRODUCTION OF PULP (ADMT)	
	1985	1987
1. STRAW, INCLUDING WHEAT STRAW, RYE STRAW, BARLEY STRAW, AND RICE STRAW	4,600.000	5,400.000
2. BAGASSE	1,900 000	2.000.000
3. BAMBOO	1,260.000	1,400.000
4. REEDS	1,400.000	1,600.000
5. COTTON LINTERS	380.000	400.000
6. MISCELLANEOUS, INCLUDING ESPARTO GRASS, SABAI GRASS, JUTE, HEMP, FLEX STRAW, SISAL, KENAF, ABACA, RAGS, ETC.	900.000	950.000
ESTIMATED TOTAL ACTUAL PRODUCTION	10,440.000	11,750.000

SOURCE: ESTIMATES BY: JOSEPH E. ATCHISON CONSULTANTS, INC. BASED ON INFORMATION OBTAINED FROM VARIOUS COUNTRIES.

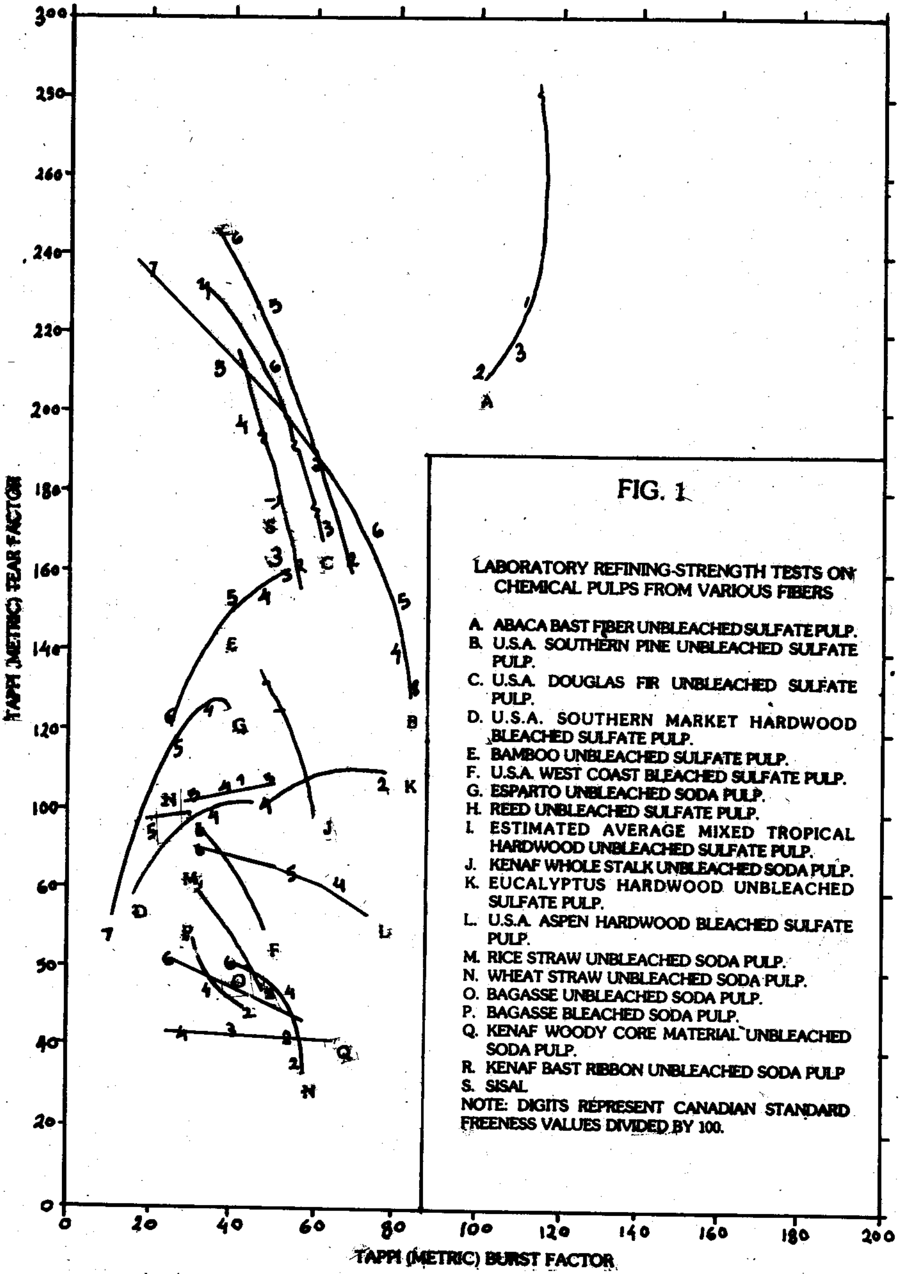


FIG. 1

LABORATORY REFINING-STRENGTH TESTS ON CHEMICAL PULPS FROM VARIOUS FIBERS

A. ABACA BAST FIBER UNBLEACHED SULFATE PULP.
B. U.S.A. SOUTHERN PINE UNBLEACHED SULFATE PULP.
C. U.S.A. DOUGLAS FIR UNBLEACHED SULFATE PULP.
D. U.S.A. SOUTHERN MARKET HARDWOOD BLEACHED SULFATE PULP.
E. BAMBOO UNBLEACHED SULFATE PULP.
F. U.S.A. WEST COAST BLEACHED SULFATE PULP.
G. ESPARTO UNBLEACHED SODA PULP.
H. REED UNBLEACHED SULFATE PULP.
I. ESTIMATED AVERAGE MIXED TROPICAL HARDWOOD UNBLEACHED SULFATE PULP.
J. KENAF WHOLE STALK UNBLEACHED SODA PULP.
K. EUCALYPTUS HARDWOOD UNBLEACHED SULFATE PULP.
L. U.S.A. ASPEN HARDWOOD BLEACHED SULFATE PULP.
M. RICE STRAW UNBLEACHED SODA PULP.
N. WHEAT STRAW UNBLEACHED SODA PULP.
O. BAGASSE UNBLEACHED SODA PULP.
P. BAGASSE BLEACHED SODA PULP.
Q. KENAF WOODY CORE MATERIAL UNBLEACHED SODA PULP.
R. KENAF BAST RIBBON UNBLEACHED SODA PULP
S. SISAL

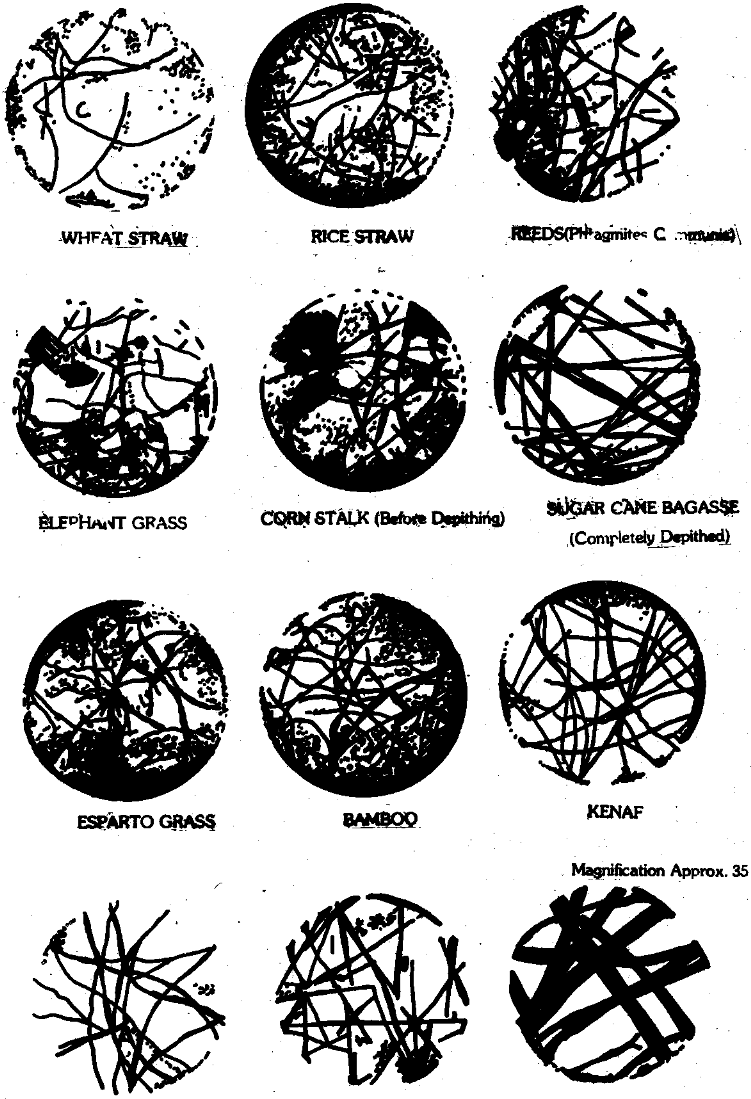
NOTE: DIGITS REPRESENT CANADIAN STANDARD FREENESS VALUES DIVIDED BY 100.

SOURCE: JOSEPH E. ATCHISON CONSULTANTS INC.

TABLE X

FIBER DIMENSION OF THE NON WOOD FIBER PULPS

MATERIAL	AVERAGE FIBER LENGTH (IN MM)	AVERAGE DIAMETER (IN MICRONS)
ABACA (MANILA HEMP)	6.0	24
BAGASSE — DEPITHED	1.0- 1.5	20
BAMBOO	2.7- 4	15
CORNSTALK & SORGHUM (DEPITHED)	1.0- 1.5	20
COTTON FIBER	25	20
COTTON STALKS	0.6- 0.8	20- 30
CROTALARIA (SUN HEMP)	3.7	25
ESPARTO	1.5	12
FLAX STRAW	30	20
HEMP	20	22
JUTE	2.5	20
KENAF BAST FIBER	2.6	20
KENAF CORE MATERIAL	0.6	30
RAGS	25	20
REEDS	1.0- 1.8	10- 20
RICE STRAW	0.5- 1.0	8- 10
SISAL	3.0	20
WHEAT STRAW	1.5	15
FOR COMPARISON PURPOSES		
TEMPERATE ZONE CONI-FEROUS WOOD	2.7-4.6	23-43
TEMPERATE ZONE HARDWOODS	0.7-1.6	20-40
MIXED TROPICAL HARDWOODS	0.7-3.0	20-40
EUCALYPTUS	0.7-1.3	20-30
GMELINA	0.8-1.3	25-35



PHOTOMICROGRAPHS OF VARIUS AGRICULTURAL FIBERS AND OTHER FAST GROWING MATERIALS USED FOR PULP MANUFACTURE

FIG. 2

TABLE XI

ESTIMATES OF WORLD BAGASSE PULP PRODUCTION CAPACITY AND ACTUAL PRODUCTION 1939-1987

YEAR	NO. OF MILLS	CAPACITY MT	ACTUAL PRODUCTION MT ESTIMATE
1939	3	40,000	15,000
1950	6	120,000	80,000
1965	25	400,000	300,000
1970	35	600,000	450,000
1975	60	1,250,000	900,000
1980	80	1,800,000	1,300,000
1985	90	2,275,000	1,900,000
1987	93	2,325,000	2,200,000
1990 EST.	96	2,500,000	2,200,000

TOTAL WORLDWIDE PAPERMAKING PULP CAPACITY IN RELATION TO BAGASSE PULP CAPACITY

YEAR	PAPER GRADE TOTAL PULP CAPACITY	BAGASSE PULP AS PERCENTAGE OF TOTAL
1965	87,000,000 MT	0.5 %
1970	113,400,000 MT	0.5 %
1975	136,100,000 MT	0.9 %
1980	150,800,000 MT	1.2 %
1985	164,500,000 MT	1.4 %
1987	171,200,000 MT	1.4 %
1990 EST.	186,800,000 MT	1.4 %

SOURCE: JOSEPH E. ATCHISON CONSULTANTS, INC.

TABLE XII

TYPICAL USES OF BAGASSE PULPS IN VARIOUS GRADES OF PAPER AND PAPERBOARD

		BAGASSE PULP %
I.	BLEACHED BAGASSE MECHANICAL, CHEM-MECHANICAL AND/OR THERMO MECHANICAL PULPS	
	NEWSPRINT	75--80
	MECHANICAL-TYPE PRINTING PAPERS	50
	TISSUE	50
II.	HIGH YIELD UNBLEACHED BAGASSE SEMI-CHEMICAL PULP	
	CORRUGATING MEDIUM	75--100
III.	UNBLEACHED BAGASSE CHEMICAL PULP	
	MULTI-WALL BAG PAPER	40 (UP TO 60 FOR CLUPPAK)
	TEST LINERBOARD	40--60
	WRAPPING PAPER ("B GRADE)	75
	FRUIT WRAP AND TISSUES	60--90
	GLASSINE AND GREASEPROOF	50--90
IV.	BLEACHED BAGASSE CHEMICAL PULP	
	PRINTING AND WRITING PAPERS	80--100
	WHITE-LINED COMBINATION BOARD (LINER PORTION)	50
	FOOD AND MILK BOTTLE BOARD AND BRISTOL BOARD	75--90
	FRUIT WRAPS AND TISSUES	60--90
	GLASSINE AND GREASEPROOF	50--90