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# NON-WOOD PULPING

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**Abstract**

The theme of this paper is a comparison of the role, properties and technology of fibrous paper-making raw materials other than wood, with those of wood. Aspects considered are the economic role in world pulp supplies, the nature and properties of the fibres, technological problems arising in pulping, the properties and economic status of the resulting pulps, and the present and likely future role of fundamental research.

To the vast majority of those connected with paper manufacture "cellulose pulp" is instinctively synonymous with wood pulp, especially in North America and Scandinavia. The aim of this paper is to redress this tendency, in particular from the point of view of the title of this Symposium. This is attempted by a comparison from all relevant aspects of the role, properties and technology of fibrous cellulose paper-making raw materials other than wood with those of wood. Thus, non-cellulose fibres (as of asbestos or glass) and modified cellulose fibres (usually derived from wood) are excluded.

Such a comparison between wood and non-wood fibres should not be over-emphasised from a purely statistical point of view. As Table 1 shows, non-wood fibres as sources of cellulose pulp occupy a very modest position in world-wide pulp consumption. Indeed, when one considers the individual role of any one of the numerous non-wood fibrous raw materials at present in use, then

| | 1977 million tons | % | 1982 million tons | % |
|---|---|---|---|---|
| 1. Whole World | | | | |
| Wood Pulp | 133.3 | 93 | 152.4 | 93 |
| Other Fibres | 10.0 | 7 | 11.9 | 7 |
| Total | 143.3 | 100 | 164.3 | 100 |
| 2. Developed Economies | | | | |
| Wood Pulp | 112.6 | 98 | 124.6 | 99 |
| Other Fibres | 1.8 | 2 | 1.8 | 1 |
| Total | 114.4 | 100 | 126.4 | 100 |
| 3. Developing Economies | | | | |
| Wood Pulp | 5.5 | 68 | 9.2 | 73 |
| Other Fibres | 2.6 | 32 | 3.4 | 27 |
| Total | 8.1 | 100 | 12.6 | 100 |
| 4. Centrally-Planned Economies | | | | |
| Wood Pulp | 15.2 | 73 | 18.5 | 73 |
| Other Fibres | 5.7 | 27 | 6.7 | 27 |
| Total | 20.9 | 100 | 25.2 | 100 |

Source: FAO Pulp and Paper Capacity Survey, 1977-1982

Table 1

Paper Grade Pulp Manufacturing Capacity in 1977 and 1982 the importance of this material in world-wide cellulose pulp production becomes so small as to be virtually negligible. However, when considered in the context of the pulp requirement of the country in which it is produced, the reverse usually applies. Criteria which determine the importance of a fibrous raw material for cellulose manufacture are, principally:

1 availability
2 cost
3 ease of harvesting
4 pulpability
5 yield
6 final pulp quality

These are set out above, not necessarily in order of precedence, because such an order will vary with the raw material and with the locality and circumstances of its production. In many areas these criteria are met far more successfully by non-wood fibres than by wood, usually because no suitable wood is available for pulping.

Unfortunately the extent to which fundamental research has been applied to the preparation and use of non-wood fibres is proportional (or perhaps rather less than proportional) to the extent to which these fibres are produced. This is understandable because their use has been confined almost exclusively to countries where resources for research purposes are scant, or indeed, are not available. In other countries the problems associated with the use of wood are so numerous and of such immediate practical importance that they inevitably take precedence.

J.E. Atchison(1) has compiled a comprehensive list of non-wood plant fibres of interest for paper pulp manufacture. However, it is important to distinguish between those in current use on a relatively large scale, and those of potential use, either at present not in use or else used in small quantities (e.g., to supplement waste paper or wood pulp). These are listed in brackets below, in each class of plant material.

(a) Agricultural residues e.g. sugar cane bagasse, cereal straws (sorghum, rice).

(b) Natural growing plants e.g. bamboo, reeds, sabai grass, esparto grass (papyrus).

(c) Crops grown for their fibre content - mainly for textiles. In such cases the lower grade portions or rejects from the textile processes are available for paper pulp manufacture e.g. cotton linters, manila hemp, flax tow, old ropes and cotton or linen rags, jute and sisal waste (ramie, abaca, kenaf, crotolaria, henequen, banana, palm and pineapple fibres).

The above list can be supplemented considerably by inclusion of fibres which have undergone laboratory pulping tests, often with favourable indications, but have been rejected because of harvesting and handling difficulties. Often cleaning (as distinct from bleaching) the pulp is a critical factor in this connection.

For various reasons fundamental research, as understood by this symposium, is virtually unknown in its application to the pulping of most of the above non-wood materials.

Such work as has been carried out has been concerned with specific problems arising with those of the above fibres used on a relatively (with respect to non-wood fibres) large scale. Examples are sugar cane bagasse (pith problems), bamboo (pulping and bleaching conditions) and cereal straws (recovery of black liquors).

An exception is perhaps kenaf. A great deal of work has been carried out on the mass cultivation of this plant (also known as Hibiscus cannabinus) as grown for rope fibre manufacture. Laboratory and small scale tests yielded pulps claimed to be suitable for qualities as wide apart as newsprint and kraft. However difficulties were encountered with drainage, yield and other things. It has been suggested that the best fibre component (comprising up to 25% of the dry weight) could be used to produce a high-grade chemical pulp, while the woody portion was used for mechanical pulp. A recombination of the resulting pulps would then give a `ready-made´ newsprint furnish[2].

However, after much work and many optimistic forecasts, a pulp mill using kenaf on any important scale has yet to be built.

| Plant Material | Lignin Content (per cent) | Fibre Dimension Ratio Length:diameter |
|---|---|---|
| Woods | | |
| Aspen | 27 | 40 |
| Pine | 26 | 75 |
| Spruce | 30 | 85 |
| Non-Woods | | |
| Bagasse | 19 | 100 |
| Bamboo | 23 | 190 |
| Esparto | 15 | 120 |
| Jute | 11 | 140 |
| Rags | 3 | 85 |
| Ramie | 10 | 3500 |
| Sisal | 6 | 130 |
| Cereal Straw | 16 | 110 |
| Rice Straw | 12 | 170 |

Table 2
Comparison of wood and non-wood fibres

Table 2 sets out two key properties of these potential non-wood raw materials for pulping in comparison with those of some common woods at present used for this purpose. The table emphasises the wide variation in average dimensions of the non-wood fibres as compared to wood fibres; and their generally slender character. The difference in lignin content is probably the most striking overall feature of the differences. As is well known, pulping processes for wood are designed principally to eliminate this particular plant constituent with the minimum of damage to the paper-making properties of the cellulose fibres present. The fact that there is so much less in non-wood fibres precludes many of the results of fundamental research on this aspect of paper-making's being applied directly to non-wood.

In a sense this limitation has some indirect advantages. The most important of these is that the relatively complicated chemical reactions involved in removal of lignin from the plant arise to a reduced extent with non-wood fibres. In particular the sulphite process with its relatively complicated chemistry and difficult chemical recovery operation offers no advantage in most non-wood fibre processes, and is actually disadvantageous in others. The same principle applies, but perhaps to a less degree, to the kraft process and in most instances a straightforward alkaline cook is both the simplest and the most convenient solution to the problem. The importance of this is accentuated by three factors.

In the first place, the non-wood fibres are used mainly in areas where sophisticated technology and the additional expertise required to run a process satisfactorily are less readily available than in Scandinavia, North America, or elsewhere where wood pulp is commonly produced.

Secondly, the mills that use these fibres are generally smaller production units than those concerned with wood pulp manufacture.

Thirdly, the use of a straightforward alkaline cook involves a minimum of chemicals and those required are of the simplest nature. Limestone is cheap and its occurrence is widespread in the world: salt, which by means of electrolysis can be used to provide caustic soda for cooking and chlorine for bleaching, is also available in many of the areas concerned, which are usually in the tropics. If not, it can usually be imported relatively cheaply.

It follows from the above considerations that:

(a) A non-wood fibre pulp can be cheaper for local use than imported wood pulp, even when financial allowance is made for the technical superiority of the latter.

(b) Locally-produced non-wood fibres can save foreign currency as compared with wood pulp imported at the same (or even at a lower) price.

(c) Wood pulp is an international market commodity. Non-wood fibres are almost always produced for local use mainly in integrated mills, and rarely figure in the international wood pulp market.

(d) There is likely to continue to be a great disparity between the total quantity of wood pulp and non-wood pulp fibre produced in the world.

(e) Future additions to world market pulps are more likely to come from wood than from non-wood fibres. The reasons for this are the existence of planned long-term re-forestation, and also the exploitation of vast existing tropical hardwood forests either directly and/or by replacement after clear-cutting with woods more suitable for paper-making, such as tropical conifer and Gmelina species.

It is thus apparent why fundamental research on the manufacture of paper-making pulps from non-wood fibres has lagged behind that of wood pulp to the extent almost of non-existence. A single example will suffice to illustrate this, namely the use of anthraquinone and related compounds in alkaline pulping. Such compounds serve essentially as polysaccharide stabilisers and delignification accelerators. They can be used effectively in this connection with the alkaline pulping of wood(3), but work to date suggests little advantage of value with non-wood fibres.

Although there are no direct commercial applications of this method to non-wood fibres, it is interesting to speculate from our knowledge of what occurs with wood whether it could be successful in such cases. The following advantages have been attributed to the process as compared with the conventional kraft process: higher yield: higher brightness of the unbleached pulp: good paper-making qualities: easier bleachability at lower cost: lower production cost per tonne: elimination of foul odours of condensates and black liquor: potential production of sulphur-free turpentine and tall oil.

It is obvious that in the case of non-wood fibre advantages due to the elimination of odour from liquor or condensates are unlikely to arise, and similarly there is no advantage lost as regards the production of sulphur-free turpentine and tall oil. The other advantageous features are related mainly to the lignin content of the wood: but lignin does not occur to a major extent in non-wood fibres.

On the mechanical or engineering side of pulping methods however, the position is somewhat different. Indeed it may even be claimed that wood pulping followed the lead of developments in non-wood pulping (although it ultimately overtook them). Thus the middle 1930's saw the introduction of a completely novel technique of pulping. Actually it was applied to cereal straw which was then the only non-wood fibre of any paper-making significance (with the possible exception of esparto grass). This was the Pomilio process which used the then novel operation of treatment of the fibre with weak alkali combined with light mechanical disintegration, followed by alkaline extraction, chlorination, and hypochlorite bleaching, in stages. The great advantages at the time of this process were continuity of operation as distinct from the hitherto traditional batch digester processes, and the production of a better-draining pulp than was usual with a caustic soda digestion process. This latter feature has always been important with straw pulps. Continuous processes are now of course common for use with wood and other fibres with however, mechanical action under the influence of temperature and pressure as the first stage, followed by a suitable combination of sophisticated bleaching stages, a matter referred to further below. The marked success of the continuous system with wood has obscured its importance for non-wood fibres, although these were its original raw materials. A paper by J.N. McGovern and J. Grant[(4)] bridged the gap between the Pomilio process for straw, and the now conventional continuous process for wood, using (it is to be noted) a non-wood fibre (esparto grass) as the raw material.

In considering the importance of fundamental research on the pulping methods of non-wood fibres, the case of bamboo is of particular interest.

Bamboo is of course one of the most important non-wood sources of cellulose pulp, especially in India, where it has been used for over a century. Its potential elsewhere is limited only by the problem of harvesting in large quantities, especially in countries where the local variety has a flowering tendency. This can interrupt growth, and therefore the supply of raw material, for as long as two years, and it is not always possible to forecast flowering and to make provision for it. The other aspect that makes bamboo of special interest is the fact that although it is botanically a grass, the bamboo sticks have many of the structural and chemical characteristics of wood. It follows that bamboo has been considered and found satisfactory as a source of viscose pulp.

Production of this involves a pre-hydrolysis process, as is usual in such instances, but the kinetics of the pulping reactions are insufficiently known to enable the pulp quality to be controlled, predicted and monitored. It is well-known that time and temperature in the cooking cycle can be expressed as a single variable and can be related to certain characteristics of the final pulp. Thus Vroom[(5)] in 1957, introduced the concept of the H factor based on the Arrhenius equation, relating reaction rate and temperature. Other workers have tried to assess pulp quality by a simple H factor. M.K. Gupta[(6)] has studied the possibility that these findings, which were based on experiments with the kraft pulping process for hardwoods and softwoods, are also applicable to the pre-hydrolysis of bamboo. Simple relationships were obtained between the H factor and the prehydrolysed kraft pulp properties. The H factor may therefore be used in quantifying bamboo pulp mill dissolving operations, where it serves as a guide to adjust a cooking cycle when operational difficulties necessitate changes from standard times or temperature schedules. It thus serves its normal useful role in controlling and improving production. This is a somewhat rare illustration of the application of fundamental research in wood pulping to a non-wood fibre. However, it must be remembered that, as stated above, bamboo has similarities with wood. It seems less likely that similar success could be obtained with many of the other non-wood fibres mentioned in this paper.

Following the digestion and washing of the pulp is the bleaching stage. Here there is some divergence of methods according to the morphological features of the original plant material, and these are reflected in the draining capacity of the unbleached pulp. Thus the ease of washing after digestion can vary considerably: cereal straw and rice straw are notoriously difficult to handle in this respect while esparto grass and cotton (as linters or `rags´) represent the other extreme. However, so far as bleaching is concerned, more attention has probably been given to sugar cane bagasse than to any other non-wood fibre. This is understandable since it is more extensively used than any other. In general, however, bleaching is less of a problem with non-wood fibres than with wood pulp, mainly because of the lower lignin content. On the other hand unbleached wood pulp has a greater inherent strength than many non-wood fibres and the reduction in strength which inevitably occurs on bleaching has less of an effect on the final pulp in the case of wood pulp. Non-wood fibres do not in general have great reserves of strength available to be sacrificed in the interests of high brightness.

From his studies of this, D.K.Misra[7] concludes that most unbleached non-wood fibres in the Kappa-number range 8 to 12 can be bleached to 75 to 80% brightness using the CEH bleaching sequence, i.e., chlorination, extraction, and hypochlorite. The D (chlorine dioxide) stage common with wood pulp is therefore not needed, which is obviously a great advantage where sophisticated facilities and labour are not available. The D stage is usually regarded as a way of reducing colour reversion of wood pulp after bleaching because it deresinates the unbleached pulp. G.V. Rao[8] and his co-workers found that this did not apply to bamboo pulp, the more important reversion factor being the presence of carbonyl and carboxyl groups in the cellulose.

Another problem which may prove of fundamental scientific importance arises from the operation of the soda recovery process in the case of non-wood fibres. With rice straw in particular, where the silica content is high, this both militates against effective sludge removal after causticising, and also produces relatively rapid and resistant scaling of the evaporators. Such problems and their possible solutions are referred to by M. Judt in a paper to be presented to the present Symposium.

The stated purpose of this Symposium is to consider the role that fundamental research has played and is able to play in the paper industry and its allied technology. It is appreciated that most of the papers do this by discussing such work already achieved. The paucity of existing work in the case of non-wood fibres is unfortunate but understandable. It is hoped that this present paper has served a useful purpose in drawing attention to this problem and in sowing the seed of future investigations.

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