PULPING OF NEW ZEALAND BEECHES (NOTHO FAGUS SPP.) AND ASSOCIATED FOREST SPECIES

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Abstract

The prospects for pulping the beeches (Nothofagus spp.) by mechanical, semichemical and chemical pulping procedures are reviewed. The response of the associated species quintinia (Quintinia acutifolia), kamahi (Weinmannia racemosa), rata (Metrosideros robusta), and rimu (Dacrydium cupressinum) to kraft pulping is also described.

Beech refiner pulps are dark in colour and have very poor papermaking quality. Cold soda pulps have only moderate strength and would generally require bleaching prior to paper production. Beech neutral sulphite semichemical pulps have strength properties which are about two-thirds of those of corresponding kraft pulps, but are suitable for corrugating media.

Although bisulphite pulps (50% yield) are obtainable from beech, the pulps have lower strength than kraft pulps. Nitric acid pulps of the same yield have similar strength properties.

Chemical pulps are best prepared by alkaline pulping methods. Kraft pulps from the beeches are obtained in yields of between 42 and 52%, and the average yield for all species is about 49%. Associated species also give pulps within this yield range. Pulps beaten for 4000 rev. in the PFI mill had tear index of 10, and tensile index of about 80. Beech kraft pulps can be bleached to high brightness. The use of a prehydrolysis stage prior to kraft pulping gives pulps rich in cellulose, of 38% yield, which after bleaching are comparable to rayon-grade commercial pulps.

Soda pulps are obtained from beech in 47% yield. Pulps of similar yield can be obtained from the beeches using soda-oxygen pulping. The papermaking properties of these pulps are similar to those of normal kraft pulps.

Of the various alternatives available, the manufacture of bleached kraft pulps holds most promise.

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INTRODUCTION

This paper reviews the properties and yields of pulps obtainable from beech species (*Nothofagus*). The kraft pulping of other species which occur in beech forest is also briefly described. The species examined were quintinia (*Quintinia acutifolia*), kamahi (*Weinmannia racemosa*), rata (*Metrosideros robusta*), and rimu (*Dacrydium cupressinum*).

There is currently considerable interest in the utilisation of beech in the Southland region, where the major species of interest is silver beech (*N. menziesii*), and the volume of wood available annually has been estimated to be 170,000 m³. The West Coast region contains the four beech species — red beech (*N. fusca*), silver beech (*N. menziesii*), hard beech (*N. truncata*), and mountain beech (*N. solandri* var. *cliffortioides*)—and the associated species given above. Although the quantity of wood potentially available from the West Coast region has been estimated to be 785,000 m³ annually (New Zealand Forest Service, 1974), this region's wood supply will now be considered in conjunction with that of the Nelson area, as was announced by the Minister of Forests at the 1975 Forestry Development Conference in Wellington. Because of the wide variety of species present in the West Coast area, many of the data recorded in this paper are based on wood samples collected from that region.

Yields from kraft pulping of red and silver beech, and the bisulphite pulping of red, silver, and hard beech samples from the Nelson area have been described in a previous paper (Uprichard, 1968), which also gave data on the neutral sulphite semichemical (NSSC) pulping of silver beech. A later communication (Uprichard, 1972) described the procedures involved and wood requirements of the above pulping methods when applied to beech. In this review all beech-pulping studies made at the Forest Research Institute are summarised, and only brief descriptions of processing methods are given.

WOOD PROPERTIES

Pulp yield and papermaking quality depend to a large extent on raw material properties. Extractive content and wood density are of most importance. Properties of the beeches are as follows:

1. The extractive content of the beeches is between 3 and 10% of oven-dry wood. Extractives are mainly water-soluble polyphenols. For individual species, pulp yield decreases as extractive content increases.
(2) Wood density is in the range 420 to 620 kg/m³. Hard beech wood density is generally greater than that of other species (Orman and Harris, 1965). Wood density affords a measure of cell wall thickness when vessel content by volume is approximately constant (Uprichard, 1968). In agreement with this, hard beech kraft pulps require more beating (or mechanical treatment) prior to paper formation than pulps from other beech species, if a given level of tensile strength is required in the finished paper.

(3) Fibre length is about 1 mm, and fibre diameter 18 micrometres.

(4) All species contain about 65% of fibres by volume.

In many respects wood properties of the beeches are similar to those of eucalypt species (Batchelor et al., 1970) which are used for the production of chemical pulps.

MECHANICAL AND SEMICHEMICAL PULPING

Refiner (Mechanical) Pulping

Mechanical pulps prepared from beech (Corson, 1974a) using a 1000 mm 400 kW Bauer 410 double disc refiner are dark in colour, and consist mainly of shives and flour. The pulps have very poor strength. The process holds very little promise for beech species.

Cold Soda Pulping

The preparation of cold soda pulps from beech species is facilitated if chips are impregnated with sodium hydroxide using pressure treatment (Corson, 1974b). The soaked chips are then disc refined. Power requirement for refining is about

| TABLE 1: YIELDS AND PAPERMAKING PROPERTIES OF CHEMICAL AND SEMICHEMICAL PULPS FROM BEECH |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| **Pulp Type**                  | **Yield %**     | **Freeness Csf**| **Tear Index**  | **Burst Index** | **Tensile Index** |
| Semichemical pulps:            |                 |                 |                 |                 |                 |
| Cold soda                      | 83              | 60              | 4.9             | 2.9             | 44              |
| Neutral sulphite semichemical  | 71              | 455             | 6.2             | 2.3             | 49              |
| Chemical pulps:                |                 |                 |                 |                 |                 |
| Bisulphite                     | 50              | 322             | 7.3             | 4.3             | 69              |
| Nitric acid                    | 43              | 215             | 7.0             | 3.9             | 56              |
| Kraft                          | 49              | 380             | 10.4            | 5.7             | 83              |
400 kWh/tonne of pulp. The cold soda pulps are obtained in about 80% yield and, if beaten prior to paper formation (4000 rev PFI beater), have strength properties which are about half those of beech kraft pulps (Table 1). Because the pulps are dark in colour, they would require bleaching if they were to be used for the manufacture of newsprint or other printing grades of paper.

Cold soda pulps have high bleach demand but can be bleached by a one-stage process. Disposal of bleach effluent could be a problem under commercial conditions.

**Neutral Sulphite Semichemical (NSSC) Pulping**

Neutral sulphite semichemical pulps are readily prepared from beech species in 71% yield (Table 1). After mild refining the pulps have papermaking strength approximately half that of beech kraft pulps but, if given further beating, can develop tensile strength approaching that of corresponding kraft pulps.

![Diagram showing wood components and pulp yields](image)

**Fig. 1:** Components of wood present in pulps of various yields.
PULPING OF BEECHES

(The yields and papermaking properties of semichemical and chemical pulps from beech are compared in Table 1, and also in Fig. 1.) Beech NSSC pulps have reasonable Concora crush characteristics and are therefore suitable for corrugating media. They could also be used in packaging and linerboard production if mixed with softwood kraft pulps.

CHEMICAL PULPING

Bisulphite Pulping

Bisulphite pulps can be obtained from beech in 50% yield. The pulps have about two-thirds the papermaking strength of corresponding kraft pulps, and also have high bleach demand (Uprichard, 1968). Because pulp yield and colour depend largely upon extractive content, and the pulp bleach demand is high compared with that of kraft pulps, the bisulphite process is unsuitable for beech.

Nitric Acid Pulping

Treatment of beech chips with solutions of nitric acid, and subsequent alkali extraction of the chips, gives pulps with papermaking properties (Kerr, 1975) similar to those of bisulphite pulps. Depending upon the conditions used, pulps with yields of between 40 and 60% may be obtained. The low-yield pulps contain little hemicellulose, and resemble dissolving pulps. The process was of interest because its byproducts, nitrate salts and nitrolignin, could possibly be used as fertilisers.

Kraft Pulping

Kraft pulps of low lignin content and suitable for bleaching are obtained in good yield from all beech species (Table 2). For red and silver beech, average yield is 48%. The yields of pulp from hard and mountain beech are about 50% of oven-dry wood (Uprichard, unpublished data). For all trees examined, pulp yield was in the range 42 to 52% of oven-dry wood.

Quintinia and kamahi are readily pulped by the kraft process. The yield of pulp from South Island kamahi, 45%, is similar to that previously recorded for North Island material (Jamieson and Nicholls, 1966). Quintinia gives pulp in 47% yield, and in its appearance and response to pulping resembles silver beech.

Rimu can be kraft pulped if mixed with beech. When cooked under conditions suitable for beech, the rimu pulps have twice the lignin content of beech pulps and would therefore
TABLE 2: KRAFT PULPS FROM THE BEECHES AND OTHER WOODS FROM THE WEST COAST

<table>
<thead>
<tr>
<th>Wood</th>
<th>Pulp Yield (total)</th>
<th>Freeness Csf</th>
<th>Tear Index</th>
<th>Burst Index</th>
<th>Tensile Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red beech</td>
<td>48.0</td>
<td>354</td>
<td>10.3</td>
<td>6.2</td>
<td>87</td>
</tr>
<tr>
<td>Silver beech</td>
<td>48.1</td>
<td>390</td>
<td>10.8</td>
<td>6.2</td>
<td>90</td>
</tr>
<tr>
<td>Hard beech</td>
<td>49.7</td>
<td>429</td>
<td>10.5</td>
<td>4.8</td>
<td>73</td>
</tr>
<tr>
<td>Mountain beech</td>
<td>51.2</td>
<td>360</td>
<td>10.0</td>
<td>5.4</td>
<td>80</td>
</tr>
<tr>
<td>Quintinia</td>
<td>47.4</td>
<td>450</td>
<td>15.9</td>
<td>5.4</td>
<td>81</td>
</tr>
<tr>
<td>Kamahi</td>
<td>45.1</td>
<td>530</td>
<td>13.0</td>
<td>5.6</td>
<td>75</td>
</tr>
<tr>
<td>Rata</td>
<td>42.2</td>
<td>450</td>
<td>10.4</td>
<td>4.0</td>
<td>66</td>
</tr>
<tr>
<td>Rimu</td>
<td>48.8</td>
<td>705</td>
<td>14.7</td>
<td>7.1</td>
<td>83</td>
</tr>
</tbody>
</table>

require more chemicals if the pulps were to be bleached. The yield of pulp from rimu (4% lignin content) is 49% of oven-dry wood.

Pulps of low lignin content are obtainable from rata in about 42% yield, but this species is more difficult to pulp than the others examined. Cooked chips from rata are more difficult to defibre than those from beech probably because rata, a species of high wood density (700 kg/m³), is less permeable to cooking liquor than is beech.

Kraft pulping data show that all of the beeches give pulps in reasonable yield, that the minor species can be pulped in admixture with them, and that of all the species examined, rata is the least attractive raw material. Although all species can be pulped together, the segregation of rimu and rata for separate pulping would be worth considering in a commercial operation, thus leaving the beeches, quintinia, and kamahi to be pulped together.

Recent studies by Kerr (unpublished data) show that it is possible to prepare pulps rich in cellulose from beech, using the prehydrolysis-kraft procedure. In this technique the chips are hydrolysed using water at high temperature (170°C) to remove hemicelluloses; the treated chips are then kraft pulped. On the basis of their analyses the bleached beech pulps prepared in 37% yield by this technique are equivalent to rayon-grade pulps. The procedure therefore holds promise. It was earlier used (Brasch et al., 1962) to prepare dissolving pulps from radiata pine: the same investigators also prepared a few such pulps from beech species (Brasch, pers. comm.).

**Soda Pulping**

Soda pulps of low lignin content are readily prepared from the beeches. They require somewhat more cooking chemical
(sodium hydroxide) than corresponding kraft pulps and appear to be produced in slightly lower yield. Beech soda pulps have papermaking properties (Table 3) very similar to kraft pulps.

There are only a few soda pulpmills in existence. All use hardwoods, and all appear economically successful. The pulps are bleached, since they are generally used in printing papers.

In soda pulping, only sodium hydroxide is used as cooking chemical. A soda pulpmill will therefore not have the "odour problem" characteristic of most kraft mills. Kraft mill odour arises from the volatile sulphur compounds formed during kraft pulping, and is difficult to control.

**Soda-oxygen Pulping**

Much commercial interest has recently been shown in the technique of oxygen pulping (Chang *et al.*, 1973). One process, soda-oxygen pulping, involves the preparation of high yield soda pulp, mechanical defibration of the cooked chips, and, finally, treatment of alkali-impregnated pulp with oxygen at high pressure and temperature (500 kPa and 120°C). It is generally considered that this system, if used commercially, would give rise to less aerial and aqueous pollution than kraft pulping.

Soda-oxygen pulps are obtainable from beech in 47% yield. They have papermaking properties (Table 3) similar to kraft pulps. For beech the process appears to have considerable promise.

**Bleaching**

Beech kraft pulps can be bleached to high brightness or whiteness using multi-stage chlorination sequences. The reagents used in such sequences are chlorine, chlorine dioxide, sodium hypochlorite, and sodium hydroxide. Crosby (1974) has studied the bleaching of kraft pulps from beech. On the basis of his results it is now possible to predict conditions required for particular brightness level. On the brightness
scale used, magnesium oxide has a brightness of 100 units. Four-stage treatment yields pulps with 80 brightness, and five-stage treatment (chlorination, extraction, chlorine dioxide, extraction, chlorine dioxide) gives pulps of 88 to 90 brightness and requires only 6% available chlorine. Even higher brightness pulps (92 brightness) are obtainable if a hypochlorite bleaching stage is also used. Red beech pulps are slightly harder to bleach than those from other species, but all beech pulps can be satisfactorily bleached.

Crosby (1975) has also shown that oxygen bleaching is effective on beech pulps. The various bleaching sequences effective on kraft pulps would be equally effective on soda and soda-oxygen pulps. Bleaching data therefore show that pulps of high brightness, suitable for fine paper production, are obtainable from the beeches, since all the bleached pulps examined had good papermaking strength.

**Papermaking Properties and Utilisation Prospects**

The yield and chemical composition of mechanical, semi-chemical, and kraft pulps from beech are compared in Fig. 1. The semichemical pulps contain much more lignin and hemicelluloses, mostly xylan (V. D. Harwood, pers. comm.), than kraft pulp. As the lignin content of pulp is reduced, the fibres become more flexible and there is an improvement in papermaking properties. Thus, as is shown in Table 1, the chemical pulps have greater burst and tensile strength than the semichemical pulps.

The neutral sulphite semichemical pulps have good papermaking properties. They could be used either for corrugating media, or for paper and board products. Such pulps are, however, difficult to market and production costs are fairly high. Unless the pulps are converted directly into paper and board products the prospects for their utilisation are poor.

Cold soda pulps have technically poorer strength than those made by the NSSC process. On the other hand, the cold soda process is basically simple and requires less capital investment than most other processes. While the pulps themselves would be very difficult to market, it is possible that bleached cold soda pulps could be made into products such as newsprint or other papers if mixed with other pulps. The cold soda process and the problems of chemical recovery and effluent disposal therefore merit further attention.

Kraft pulps of good quality and in reasonable yield are obtained from the beeches and the species associated with them, except for rata which technically seems unattractive. All such pulps can be bleached using economic quantities of
chlorine and other chemicals. These bleached pulps would be marketable and suited for the production of fine papers.

The prospects for the preparation of dissolving grade pulps from beech by the prehydrolysis-kraft process also appear good. It appears feasible to construct a mill which manufactures both paper grade and dissolving pulps, particularly if the prehydrolysis step could be carried out in a separate digester made of stainless steel of the necessary high quality. If the prehydrolysed chips were transferred to a normal kraft digester made of mild steel, the alkaline conditions of the kraft process would prevent digester corrosion by wood acids. A mill of the type envisaged could manufacture a small proportion of its total production as dissolving pulp, or could turn entirely to papermaking grades if the market so demanded. Such a mill would probably be less costly to construct than one making dissolving pulp only.

Pulps made by the soda or soda-oxygen processes also have good papermaking properties. While the soda-oxygen process holds promise, it is technically new, and its commercial use may present problems. On the other hand, the oxygen bleaching of low lignin-content pulps is now a well established process (Jamieson and Smedman, 1974), and it appears likely that a kraft mill with an oxygen bleach plant of sufficiently large capacity could eventually bleach pulps of fairly high lignin content. Such a mill could gradually develop its own form of modified oxygen pulping. Viewed in this light, oxygen delignification could be successful on beech pulps.

Of the various processes available, the manufacture of bleached kraft pulps for papermaking appears to hold most promise. The beeches, overall, can be regarded as a good resource of pulpwood.

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