High Yield Pulps

ILPO PALENIUS

Reasons for the general interest in high-yield pulps are discussed. The correlation between chemical composition and physical characteristics of the pulps is studied in the light of the present knowledge of the position of lignin in the cell wall. Lignin preserving bleaching of high-yield pulps has also been studied and it is implied that its applicability is restricted mainly to pulps having inferior strength characteristics.

INTRODUCTION

The cost of the wood raw material in the wood processing industry varies largely from one country to the other. It seems that a trend exists in recent development towards an increase in the share of the raw material in the production costs, despite the appearance of equipment and means for rationalisation of the cutting, collection and transport of the wood. Obviously this has not met with as much success as rationalisation within the mill itself, enlargement of the production units, automation, and so on. It is thus understandable that attempts are being made to save raw material in pulp manufacture, or in other words to obtain yields which are as high as possible. As definite relationships exist between the pulp yield and pulp properties, a raise in the yield level also enables the production of exceptional pulp grades, more appropriate for special purposes than the low-yield pulps.

DIFFERENT TYPES OF HIGH-YIELD PULPS

Grinding process is the most economical pulping method when considering only the consumption of raw material. Application of this method results in about 97 per cent of the wood dry substance being recovered. The small loss is attributable to the water-soluble components of the wood, and to very small broken fibre fragments. Nevertheless, the factors which contribute to the limitations in the applicability of groundwood are also related to the high yield. In wood, the fibres are attached to each other by the agency of lignin; in softwood this constitutes nearly 30 per cent of the wood material, and in hardwood more than 20 per cent of the substance. In wood, this lignin is a very good binder, but in paper it makes a poor contribution to interfibre bonding; consequently the lignin remaining in the fibres during groundwood process weakness these bonds. For this reason, a product made solely from groundwood is inferior in strength.

Accordingly, pulp in which the fibres are more intact. and which contains smaller amounts of lignin than groundwood, must be added to groundwood to improve the strength characteristics of paper. This pulp is manufactured by the cooking of chipped wood, that is, the lignin is dissolved from the space between the fibres. Unfortunately, the practicable cooking methods are insufficiently specific to permit of the dissolution of lignin alone; simultaneously there is lost a large proportion of the wood carbohydrates, mainly the hemicelluloses. This situation is illustrated in **Fig. 1**, which is a schematic representation of the amounts of sprucewood **(Picea abies)** components in pulps obtained by sulphite cooking to different yields. In extract-free wood, the proportions of the cellulose proper, lignin, and so-called hemicellulose, slighlty exceed 40%, about 30% and slightly less than 30%, respectively. Line AB indicates the border between the hemicellulose and lignin fractions in this type of cooking. The primary aim of the coking is removal of the lignin located between. the wood fibres. When a sufficient quantity of lignin has been removed, the fibres are easily detachable. This point, which may be termed the defibration-point, is in this particular case attained when the pulping yield is 55 per cent based on wood (point D normal). It is observable from the figure that at this stage the amount of the original lignin has been reduced to less than 3 per cent based on wood, but that simultaneously there has occurred a loss of carbohydrates, in the form o fhemicelluloses, which is almost as great as the quantity of lignin removed. However, the cellulose component proper has

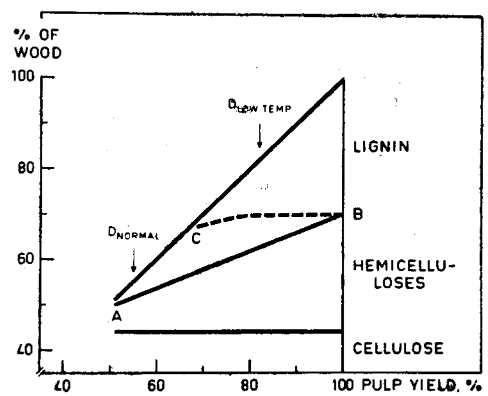

Fig. 1 Chemical composition of spruce (Picea abies) bisulphite pulp.

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not been affected. Had this been a sulphate cooking, the amount of cellulose would also have been reduced, and the final yield would have been below 50 per cent.

With this as the background, it is reasonable to try to induce a situation between these two extremes, viz. groundwood and chemical pulp. One method is to select the cooking chemicals and conditions so that carbohydrates are preserved during the delignification. This is possible to some extent also in practice. Another alternative is to develop pulp grades in which the lignin has been removed only partially, with a saving of the carbohydrates at the same time. In addition to the chemical treatment, pulps of this type need complementary mechanical difibration, and can accordingly appropriately be named chemimechanical pulps. With softwoods, the most interesting yield range seems to be 65-70 per cent; for hardwoods, the level is slightly higher. Manufactured correctly, these chemi-mechanical pulps can in many respects replace chemical pulps.

CARBOHYDRATE - PRESERVING COOKING METHODS

The current improvement in knowledge of the wood carbohydrates and their reactions has made possible the choice of cooking conditions such that at least the most important of the carbohydrate components can be preserved. At the same time, it has been clarified that different wood species behave differently in cooking. One way of carbohyrate preservation is conduction of the digestion in such a manner that the dissolution of the carbohydrates is retarded in comparison with removal of lignin. Even in the acid bisulphite method, where the defibration-point normally lies at the 55 per cent level mentioned above, it is possible to achieve a yield-level exceeding 80 per cent. **Eliashberg** (1) carried out cookings of this type at a temperature of 50°C, and obtained defibratable pulp at 82% yield from sprucewood. The low cooking temperature reduces the rate of carbohydrate hydrolysis more than the rate of delignification, and thus this type of cooking represents an almost pure porcess of delignification. Naturally, the cooking time becomes disproportionately long; it may last for weeks and even months, and in practice a process of this kind is hardly feasible. However, use has been made of the changes which take place in the disolution process owing to a reduced temperature, for example in the manufacture of glassine-pulp rich in carbohydrates. In **Fig. 1**, curve C represents the border between lignin and hemicellulose in the pulp cooked at 50° C.

The two-stage bisulphite cook of decreasing pH may be mentioned as an example of the carbohydrate preserving cooking of softwood. The first cooking stage takes place near neutrality, a pH level at which the major proportion of the wood glucomannan is stabilised, although the second cooking stage is carried out at lower pH to speed up the cook. In the sulphate digestion of coniferous wood, the yield is rather low in the chemical pulp region, but by oxidising the aldehyde groups in the polysaccharides to carboxyls, for instance by the addition of polysulphide, or by reducing these groups to alcoholic groups, the preservability of the glucomannan can be improved, and the pulping yield increases. In the case of hardwoods, the hemicellulose component, of which the solubility should be diminished to augment the yield, is xylan. The xylan dissolves more easily in an acidic cooking liquor than in an alkaline solution, and as a consequence the sulphate method is more favourable than the sulphite digestion in regard to yield. Our results have indicated that the yield of defibratable birch pulp can be raised even to almost 60 per cent by polysulphide cooking.

A newcomer among high-yield pulping methods is the Holopulp process developed by the Institute of Paper Chemistry (2). In this method, the wood lignin is transformed by chlorine dioxide oxidation into an alkali-soluble modification. Subsequently, the product is bleached with hypochlorite. The yield-range reported is 65-80 per cent; chemical pulp can be obtained from aspen wood at about 70% yield. There is thus considerable preservation of carbohydrates.

CARBOHYDRATE — AND LIGNIN-PRESERVING METHODS

Although the methods mentioned above provide opportunities of attaining a pulping yield which is higher than normal, the high-yield pulps are usually produced by a combination of chemical and physical defibration, that is by chemimechanical methods. Here, the lignin is removed only to the extent which is expedient from the aspect of the consumption of defibration energy, and end use of the product. At the same time, the carbohydrates have naturally been largely preserved. It can be said that any cooking method is employable in the manufacture of high-yield pulps by interrupting the cook at a raw stage, and continuing the defibration by mechanical means. In conjunction with this type of procedure, it is of course completely possible to apply carbohydrate-preserving cooking methods as well.

From the aspect of the strength characteristics of the product, it is important that the cook be carried out at least to the extent that the lignin in the middle lamella has been dissolved and softened sufficiently to ensure that during the course of the mechanical defibration the fibres will be detached from each other in as intact a condition as possible. In contrast to earlier conceptions, recent investigations have shown that the major proportion of the lignin is situated in the fibre wall, and only a minor proportion of the lignin is situated in the fibre wall, and only a minor proportion is apparent in the middle lamella. Moreover, **Goring** et al. (3, 4) have remarked that the solubilising action of the cooking liquor is primarily directed towards the fibre wall lignin, and that the vigorous reaction with the middle lamella does not take effect until about half of the original wood lignin has been removed. According to **Fig. 1,** this state has been reached at a yield of about 70 per cent, on normal bisulphite cooking of sprucewood. It has been noted that at this very point a very marked change occurs in defibration energy consumption, with the energy requirement beginning to rise steeply for increased yields.

It is interesting to observe that in low-temperature cooking, about 50 per cent of the lignin has already dissolved when the yield is somewhat below 85%. Accordin gto **Eliashberg,** pulp of this kind does not call for any mechanical defibration. Consequently, in high and low temperature cooks entirely different defibration-points are obtained. This may be accounted for by the temperature affecting the order of topochemical reactions.

PULP PROPERTIES

In principle, some difficulties are encountered on comparison of the properties of high-yield pulps with those of normal-yield pulps. Thus, a smaller number of fibres is present at equal sheet weight in sheets made from high-yield pulps. However, in general the common strength properties, such as the tensile strength and tear strength, diminish with the rise in yield, whereas at the same time the porosity and fibre stiffness increase. This abatement in the characteristics does not take place suddenly, but gradually, as is observable from **Fig. 2,** which indicates the beating product at 20°SR as a function of the pulping yield for a calcium sulphite pulp and magnesium bisulphite pulp made from the same sprucewood chips. The beating product, expressed in arbitrary units, is derived by multiplication of the breaking length by the tear factor. A chemical pulp of 55% yield, made without mechanical treatment, is no better than a 60% yield chemimechanical pulp. On the other hand, a chemimechanical magnesium-bisulphite pulp, cooked at pH 3.5, is significantly superior to a calcium sulphite pulp cooked to a normal yield level, although the sheets of the latter pulp contain a larger amount of fibres at equal sheet weight.

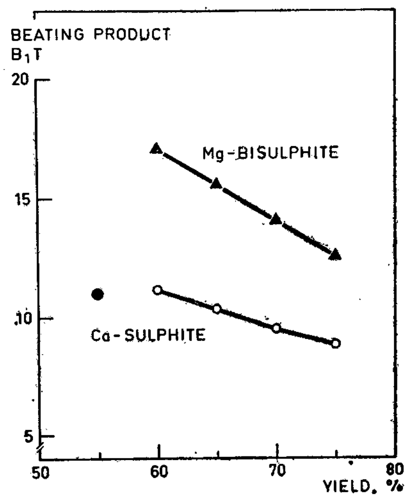

Fig. 2 Strength properties given as beating product (tensile x tear in arbitrary units) of acid calcium sulphite and magnesium bisulphite pulps from spruce.

It can be inferred from **Eliashberg's** results that the differences in the numbers of fibres in the sheets are insufficient to account for the differences in tensile strength between pulps of different yield. At the same lignin content, the breaking length of a pulp cooked at a low temperature was found to be distinctly more than that the loss in strength is not completely attributable to the lignin, as e.g. the folding endurance of the high-yield pulp is inferior to that of the low-yield pulp, regardless of whether the yield-difference arises from the lignin or the hemicellulose. Rather to the contrary, it is conceivable that the fibre proper has been less damaged in the high-yield pulps than in normal ones if the defibration has been effected carefully. Consequently, the strength per fibre may be higher, but the interfibre bonds are weaker, and the net bonding area per weight unit will be smaller. The fact that the bonded area remains small may be accounted for simply by the fibre stiffness, which hinders fibre collapse. If the yield level is so high that a large amount of lignin is left on the surface of the fibres, the interfibre bonds remain weak, since the hydrogen-bonding ability of lignin is no more than a fraction of the corresponding property of the carbohydrates. Several explanations are thus discoverable, although a detailed clarification is a difficult task which calls for considrably more intensive research work.

BRIGHTNESS AND BLEACHABILITY OF THE PULPS

The brightness of high-yield pulps is largely dependent upon the properties of the wood raw material, the original colour, and th freshness. Factors which contribute to an improved brightness are a high sulphur dioxide dose for sulphite pulps, and a high alkali charge for sulphate pulps.

It is possible, although uneconomical, to effect the bleaching of high-yield pulps with chlorine chemicals in a normal manner. Attempts have accordingly been made to develop lignin-preserving bleaching procedures, in which the chemicals react with

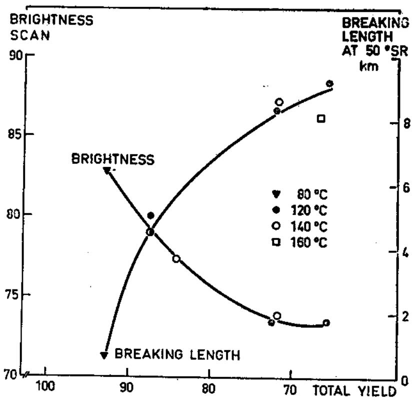

Fig. 3 Breaking length and brightness after peroxide bleaching of birch pulp (Betula verrucosa) vs. pulping yield. Temperatures given refer to the different conditions used in neutral sulphite cooking.

the lignin in the pulp in such a manner that the chromophore-groups in the lignin are removed without undue lowering of the pulp yield. The commonest methods applied are an oxidising peroxide treatment, or a reducing hydrosulphite bleach. Our own investigations of peroxide bleaching have disclosed that at very high yields, and also in the yield region of chemical pulps, the improvement in brightness is considerable, whereas in the yield region in which the strength properties of the pulp are favourable with a view to the high yield, the effect of peroxide is either minute or non-existent. This is observable in **Fig. 3** (5), which indicates the final brightness after peroxide bleaching of neutral sulphite pulps cooked at different temperatures, as compared with the breaking length of the pulps at 50° SR beating degree. It has also been noted that a considerable loss in yield is experienced within the region of inferior bleaching.

CONCLUSION

For a number of reasons, high-yield pulps are today arousing general interest. They may replace a part of chemical pulp, as in the use of bisulphite pupls in newsprint instead of acid sulphite pulp, or they may be especially suitable in a specific end product by reason of their special characteristics, as in the case of hardwood NSSC-pulp in fluting. High-yield pulps find a greater variety of uses if clarification were possible of the factors which impede bleachability in the 65-75% yield region.

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