Use of spruce tannin as a binder in particleboards and medium density fiberboards (MDF)

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In the recent past, increasing attention has been paid to the use of natural adhesives as a binder in the wood-based panel industry. Nowadays, two German companies are using Quebracho tannin and Wattle tannin for the production of particleboards and medium density fiberboards (MDF), respectively. To date no serious attention has been given to bond fiberboards using tannin derived from spruce bark. Results of research work on the use of spruce tannin as a binder for medium density fiberboards carried out in the last two years are presented. The results reveal that spruce tannin can be used to partially substitute Quebracho tannin in MDF up to about 60%. Such boards still meet the specification of moisture resistant MDF (according to EN 319 and EN 321). Moreover, spruce tannin can be used to 100% as a binder for the production of MDF for indoor use (type MDF EN 622-5).

Fichten-Tannin als Kleber für Spanplatten und MDF


1 Introduction

Utilization of bark is one of the utmost pressing problems facing the wood industry. The quantities of bark available are substantial, since approximately 10–15% of the volume of every log consists of bark. In Germany, about 2 million tons of bark are produced annually. Dealing with such enormous quantities of bark has created thorny disposal problems, particularly with the outcome of more stringent environmental regulations regarding air and water pollution enacted in the recent past. It has become imperative that the industry no longer considers bark as a waste. Bark is a low cost material with a limited market for diverse applications such as a high-quality mulch or as energy source. However, the current uses do not require bark in sufficient quantities to consume the supply available.

Bark and heartwood of limited wood species contain large quantities of water soluble extractives of polyphenolic nature suitable as a starting material for the production of adhesives. The extractives are mainly concentrated in the inner layer of the bark (Fig 1).

Figure 2 shows the extractable amounts by water at about 100 °C from different barks and wood species. In general the hot water extract of bark or heartwood comprise about 60–80% of polyphenolic tannin polymers as measured by the so called “hide powder” method. The remainder is a mixture of many polymeric and monomeric compounds, such as free sugars, pectin, hemicelluloses as well as lower polymeric substances.

As can be seen from the data compiled in Fig. 2, mimosa bark, mangoave bark and quebracho wood contain a relatively high amount of extractives, whereas the amount extracted from spruce bark is relatively low.

The preparation of extract-based adhesives is based on the reaction between extractives and formaldehyde (Fig. 3). Polyphenolic extractives can react with formaldehyde, even at normal temperature to yield condensation products with high bonding potential. However, the reactivity of various extractives vary widely, as measured by a new method based on the following principle: formaldehyde is added to the extract with increasing quantities in the presence of hydrochloric acid as a catalyst. The amount of the condensation product formed is determined gravimetrically and used as a measure of the reactivity. As can be seen from the curves in Fig. 4, both quebracho and mimosa tannin possess a very high reactivity towards formaldehyde. With a relatively small amount of formaldehyde a high amount of tannin-formaldehyde polymer is precipitated; in case of extracts from spruce and mangrove bark the curves are relatively flat and the amount of reacted polyphenolics is generally less than that obtained by reacting quebracho or mimosa polyphenols. Thus, extractives from spruce bark are low in yield and of relatively poor reactivity towards formaldehyde.
2 Methods
For the studies on the suitability of extractives from spruce bark, two main objectives were proposed. These are
1. to increase the yield obtained by extraction of spruce bark,
2. to increase the reactivity of extract towards formaldehyde.

Besides these two main objectives, the suitability of different extracts as a binder for particleboards and fiberboards was tested. For this reason water and aqueous urea solution were used as extracting agents (Table 1).

3 Results
In the first set of experiments, the influence of the extraction temperature has been assessed. As can be deduced from the data presented in Fig. 5, increasing the temperature of extraction has a significant positive influence on the yield of extract. However, the Stiasny number, which is a measure for the reactivity of the extract towards formaldehyde, declined rapidly. The negative influence of high temperature extraction on the reactivity can be overcome by using urea as an extraction agent. The question raised in this connection was, whether there is any correlation between the reactivity of the polyphenolic substances towards formaldehyde on the one hand and the physical-mechanical properties of the boards bonded with tannins on the other hand. For this reason quebracho tannin which is presently used in Germany in one company for the production of particleboards, was replaced partially by extracts from spruce bark derived by different extraction media (water and urea solution). The results are shown in Fig. 6.

Accordingly, the bending strength of the boards was more or less at the same level when substituting quebracho tannin up to 20% with spruce extracts obtained by water extraction. Extracts obtained by urea solution as extracting medium led to boards with lower bending strength. The same trend is also revealed for the internal bond strength. Boards made by substituting 20% of quebracho extract by spruce extracts obtained by water extraction are more or less on the same level (Fig. 7). Despite the relatively high reactivity of extracts obtained by cooking bark with urea solution, the properties of the boards were weaker than those bonded with quebracho extract.

As far as the thickness swelling is concerned, Fig. 8 shows that only subtle differences exist between the boards bonded with quebracho extract and those bonded with a mixture of quebracho and spruce bark extract. It must also be mentioned that the boards were prepared without any addition of sizing agents to reduce thickness swelling.

Fig. 1. Scheme of the outer part of a stem with the various tissues (according to Fengel and Wegener 1984)

Bild 1. Schema der äußeren Stammgewebe (nach Fengel and Wegener 1984)

Condensation product of tannins and formaldehyde

Fig. 2. Average yield of extractives from different woods and barks

Bild 2. Mittlere Ausbeute an Extractstoffen verschiedener Holzarten und Rinden

Condensation product of tannins and formaldehyde

Fig. 3. Reaction between extractives (tannins) and formaldehyde

Bild 3. Reaktion zwischen Extrakten (Tannine) und Formaldehyd