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Extraction of hemicellulose from south african *Eucalyptus grandis* using weak white liquor activation technology and its impact on kraft pulping efficiency

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Abstract

This work summarises the findings of our research on the activation of woodchips using weak white liquor as an alternative mill self-generated alkaline solvent. The ultimate goal was to gain a better understanding on: the effectiveness of the weak white liquor in terms of wood loss, pH and concentration of the hemicellulose in the resulting extract, Kraft pulping efficiency, and critical pulp and paper properties. It appears that in order to minimise wood loss and to maintain the pH of the extract, near neutral pH during woodchips activation, a short wood activation time (15 min), and weak white liquor to water ratio of 20:80 is required. The concentration of hemicelluloses in the extract was approximately 2.0 g/L. During kraft pulping, weak white liquor activated woodchips responds much faster than the control. To maintain the same kappa number as the control pulps, a 20% reduction in pulping chemicals and improvement in pulp washing efficiency of 6% are achievable. Critical pulp and hand-sheet properties of the pre-activated woodchip's pulp samples were comparable to those of the control pulp samples. Therefore, the most attractive benefits that could be obtained from the weak white liquor woodchip activation technology are decreased mill energy demands, reduction in kraft pulping chemicals, and additional revenues from new value chains from the hemicellulose stream.

Keywords: eucalyptus grandis, activation, weak white liquor, kraft pulping efficiency, pulp quality, paper strength properties.

Introduction

In recent years, there have been growing concerns about the economic performance of the pulp and paper industry. This is due to the continual rise of operational costs, environmental concerns, decreasing demands for some paper grades, high product quality demand, and tight competitions in local and international markets. For kraft pulp mills to remain competitive, improving pulping efficiency to reduce energy and pulping chemicals is now seen as an essential business risk management strategy. One promising option for improving kraft pulping efficiency is woodchip activation. Wood chip activation entails pre-treating the woodchips to open up/disrupt the cell wall prior to pulp production. As a result, during pulp production, pre-treated woodchips respond much faster than non-activated ones. This is due to better penetration of pulping chemicals and can lead to savings in pulping chemicals that in turn can lead to downsizing in requirement of limekiln (an energy intensive process in kraft pulp mill operations) [1]. This is critical in achieving cost reductions, mitigating environmental impacts, and increasing productivity in kraft pulp mill operations. On the other hand, during the woodchip activation, the solubilisation of low molecular weight carbohydrates, "hemicelluloses", also occurs [2]. Thus such a hemicellulose rich stream has potential to be used as a feedstock for a wide range of applications, e.g., re-adsorption onto recycled linerboard fibres which is also part of this research.

Generally, hot water/steam and alkaline solvents such as black liquor, green liquor, and white liquor that are directly accessible at kraft pulp mills are more economically attractive to the industry than other solvents [1, 2]. These mill self-generated woodchip activation solvents, however, have limited industrial applications. For example, it is well documented that hot water/steam "autohydrolysis" causes excessive loss of pulp yield and produces hemicelluloses that are in monomeric and polymeric form. It is worth noting that only hemicelluloses that are polymeric form can be integrated into paper making process e.g., re-adsorption onto pulp fibres. Similarly, pre-treating woodchips with white liquor appears to cause excessive loss of pulp yield, whereas pre-woodchips activation with green liquor is limited by associated carbonate loading problems that can lead to severe calcium carbonate scaling in the chemical recovery and digester (delignification rate/), spent liquor quality, pulp yield, pulp quality, and paper strength properties are summarised as follows:

Pulp and spent critical quality properties

Following the determination of the effects of the weak white liquor on woodchip activation, activated wood samples which gave wood loss of 14% and pH of 6.30 were selected for the subsequent pulping experiments. As evident in Table 2, weak white liquor activated wood chips responded much faster than the control. To maintain the same kappa number as the control pulps, a 20% reduction in pulping chemicals is required (e.g., from 20% to 16%). Reduction in pulping chemicals at appropriate AA balance could lead to downsizing of the limekiln, an energy intensive operation, saving energy costs, increasing productivity, and reducing environmental impacts associated with lime kiln operations [1, 2]. It can also be noted that variations in screened pulp yield (SYP), viscosity and residual alkali appear to be insignificant.

Table2. Effects of cooking liquor dosage on kappa number of hemicelluloses pre-extracted hardwood chips during Kraft cooking.

Types of Cooks	Liquor dosage (%)	Kappa number	SYP (%)	viscosity (ml/g	Residual AA (g/L as Na_2O)
Control cooks	**20**	**20.3±0.6**	**47±1.8**	**1064±6.2**	**5±0.6**
WA+ Kraft cooks	20	9.3±1.2			
WA+ Kraft cooks	**16**	**20.1**±0.8	**47**±1.2	**1082**±7.0	**4.4**±0.3
WA+ Kraft cooks	14	22.0±1.0			
WA+ Kraft cooks	12	23.0±1.2			

Note: control cooks were performed without woodchips activation and WA+ Kraft cooks; refer to pulp produced from pre-activated wood chips that were kraft pulped. Liquor dosage is expressed as percentage of woodchips oven dried mass.

Inorganic balance and pulp washing efficiency

Amount of inorganic present in spent liquor (black liquor) has negative impact on the mill's inorganic balance as well pulp washing efficiency. To determine the impact of woodchips activation using weak white liquor on inorganic balance and pulp washing efficiency, material balance based on a pulp mill with capacity of 1000 tons/day of pulp was performed. It can be seen in Table 3 that reduction kraft cooking liquor (20%), leads to reduction in amount of inorganic materials dissolved in black liquor. Consequently, pulp washing efficiency is improved (6%). Improvement in pulp washing efficiency implies that less amount of water will be used to wash the pulp in the pulp washing plant. Black liquor sent the evaporation plant will relatively contain lesser amount of water than the black liquor from the control cooks. This can help to improve the steam economy of the evaporation plant. This also provides benefit to the mills.

Table3. Effects of wood chips pre-activation on inorganic balance and pulp washing efficiency

Types of Cooks	AA (%)	Inorganics (tons/day)	Reduction in organics (%)	Washing efficiency (%)
Control cooks	20	400	0.0	0.0
WA+ Kraft cooks	16	320	20.0	6

Note: Woodchips moisture (50%), woodchips charged into digester (2000 tons/day), organic balance (1000 tons/day)

Paper strength properties

The results presented in Table 4 show that the strength properties of control pulps are slightly higher than their counterparts. This is also supported by the pulp hemicelluloses data. Pulp from weak white pre-activated woodchips pulp contained lesser amounts of hemicelluloses. Pulps with lower amo unts of hemicelluloses are known to be stiff and may require more refining energy to achieve the de sired strength properties [2]. Generally, hemicelluloses are responsible for inter-fibre bonding and therefore have an influence on the strength properties, especially tensile and burst strengths [4, 5].

Table 4: Effect of weak white liquor woodchip pre-activation on hand sheet pulp strength properties (PFI beating: 4000 rpm)