Hexenuronic acid in South African Eucalyptus hybrid clones: Optimization of the acid hydrolysis (A) stage

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ABSTRACT: Hexenuronic acid (HexA) is formed during kraft pulping by the conversion of 4-*O*-methyl-glucuronic acid groups in strong alkali conditions. HexA can be removed from the pulp by including an acid hydrolysis (A) stage in the bleaching sequence. Despite a significant body of work in this area, very little research has been carried out to examine HexA in pulps produced from South African-grown tree species under the conditions of the local pulp and paper industry.

The objective of this paper, which is part of a broader study, was to determine the optimum conditions in the A-stage that resulted in maximum removal of HexA, but with minimum impact on the physical and chemical properties of the pulp after bleaching. For this purpose, oxygen delignified pulps produced from a *Eucalyptus* hybrid clone, *E. grandis x E. urophylla*, were subjected to acid hydrolysis at varied temperature and reaction times. The pH was kept constant at 3.5 for all experiments. The results showed that the A-stage was efficient in the removal of HexA; acid hydrolysis carried out at 125°C-180min removed as much as 98% of the HexA, resulting in a kappa number reduction of approximately 6 units.

Application: Mills can assess the effect of the A-stage on the physical and chemical properties of pulps. The conditions used during the A-stage can be optimized to reduce its impact and produce bleached pulps with strength properties comparable to that of pulps bleached using a conventional sequence without the A-stage.

BACKGROUND

The presence of hexenuronic acid (HexA) in kraft pulps is an active area of research with important implications for the manufacture of bleached chemical pulps. During kraft pulping, the reaction of 4-*O*-methyl-glucuronic acid groups in the strong alkali conditions result in the formation of HexA [1-3]. Hexenuronic acid has been found to be unreactive in alkaline oxygen and peroxide bleaching stages [4]. However, due to their unsaturated nature, the acid groups react readily with chlorine dioxide, chlorine, ozone and peracids [5]. This leads to higher bleaching chemical consumption, increased production costs, and increased effluent emissions [6]. Hexenuronic acid is also known to consume permanganate in the kappa number test [7]. Since kappa measurements are widely used in the control of pulping and bleaching processes, the presence of these unsaturated constituents affect the results of analysis and yields higher measurements for the amount of residual lignin in the pulp.

Several acid hydrolysis studies [4,8-10] have identified reaction conditions under which HexA can be removed from kraft pulps without affecting pulp quality. Despite the significant amount of research carried out elsewhere, very little has been done to examine HexA in pulps produced from South African-grown tree species and its impact on our local bleaching operations. It is common practice in South Africa to adopt and run, usually at non-optimal levels, pulp and paper technologies that were developed for overseas tree species. However, because of the considerable variability of hardwood resources, both morphological and chemical, and their varying response to the heterogeneous nature of wood pulping and the subsequent bleaching processes, it is important to understand the response of our local resources to these technologies to ensure superior performance under optimum processing conditions.

To this end, the primary focus of our study was to identify the reaction conditions of the acid hydrolysis (A) stage that resulted in maximum removal of HexA, but with minimum impact on the physical and chemical properties of kraft pulps bleached to 90% ISO brightness using an O/OAD_0ED_1 sequence.

EXPERIMENTAL

Ten trees of a *Eucalyptus* hybrid clone, *E. grandis x E. urophylla* (GU) were sampled from a single site and a 3m bottom billet was taken from each tree. The billets were debarked and chipped into approximately 25mm lengths using a 38" diameter, horizontal feed disc chipper (Precision Husky Corporation, Alabama, USA). The chips were screened to remove knots, bark, dirt, rot, and any over- and under-sized material. They were then combined to produce a consolidated sample and were air dried. A drying period of approximately three weeks proved to be sufficient for the chips to reach equilibrium moisture content with the atmosphere. The moisture content of the chips was determined by drying a representative sample in an oven at 105 ± 3°C.

We pulped the chips to a target kappa number of 20 ± 2

Temp (°C)	Reaction time (min)
95	60
95	120
95	180
110	60
110	120
110	180
125	60
125	120
125	180

I. Temperature and reaction times for acid hydrolysis stage. All experiments were carried out in triplicate and at constant pH of 3.5.

Measured Property	Test Method
Burst index	Tappi T403 om-91
Tear index	TAPPI T414 om-88
Tensile index	TAPPI T494 om-88
Zero-span tensile index	TAPPI T231 cm-96
Bending resistance (stiffness)	ISO 2493
Brightness reversion	TAPPI T260 om-91
Diffuse opacity	TAPPI T519 om-96

II. Properties measured on bleached pulps.

(uncorrected for HexA). The conditions used during kraft pulping are described elsewhere [11]. The pulping time required to reach the target kappa number was obtained by varying the time at maximum temperature to produce a rate of delignification (ROD) curve from which the time required to reach the target kappa number could be estimated. After pulping, the cooked chips were washed with tap water through a 10-mesh screen onto a 200-mesh screen to separate the fibers from the rejects. Screenings remaining on the 10-mesh screen were considered rejects. The pulp remaining on the 200-mesh screen was then processed through a Somerville screen to remove shives, before being subjected to a double oxygen delignification stage.

We then divided the oxygen-delignified pulp into two subsamples. One sub-sample was used as a control and was bleached using a D_0ED_1 sequence to 90% ISO brightness. The second subsample was subjected to the same bleaching sequence, except for an acid hydrolysis stage (A) included between the oxygen delignification (O/O) and first chlorine dioxide (D_0) stages, to remove HexA from the pulp. In order to determine the A-stage conditions that resulted in maximum removal of HexA, but with minimum effect on pulp quality, the pulps were subjected to a varied range of temperature and reaction times (**Table I**). All acid treatments were carried out at a constant pH of 3.5, adjusted with sulfuric acid, and at 10% pulp consistency.

We evaluated pulp quality by preparing and testing handsheets. Pulps were beaten in a PFI mill at 10% consistency for 1000, 3000, and 5000 revolutions. Unbeaten pulps (0 revolutions) were also included in the evaluation. Freeness of pulps at each level of beating was determined according to the Canadian Standard Freeness (CSF) method using TAPPI Test Method T227 om-94. Handsheets with a basis weight of 60g/m² were prepared on a Rapid Köthen sheet-forming machine using a combination of TAPPI Test Method T205 sp-96 and the ISO standard method ISO 5269-1. This procedure involved one pressing and heated drying of the handsheets. Twelve handsheets per level of beating were prepared and allowed to stabilize in an atmosphere controlled at 23 ± 1°C and 50 ± 2% relative humidity for at least 24 hours. We then tested the conditioned handsheets for the properties listed in **Table II**.

We measured hexenuronic acid content in the pulp at various points in the pulping and bleaching process, according to the method developed by Chai *et al.* at the Institute of Paper Science and Technology (IPST) in Atlanta, Georgia, USA [12]. Kappa number measurements, uncorrected for HexA, were carried out according to TAPPI Test Method T236 cm-85. Glucose and xylose contents in pulp were determined by acid hydrolysis of the pulp (TAPPI T249 cm-85), followed by analysis of the hydrolyzate using high performance anion exchange chromatography coupled with pulse ampherometric detection [13-14]. Lignin was determined by quantitatively filtering the hydrolyzed sample, obtained in the determination of glucose and xylose, under vacuum through a 0.45µm filter paper. The material remaining on the filter paper was defined as the Klason lignin. Pulp viscosity was measured using 1% cupra-ammonium solution according to TAPPI Test Method T206 05-63 [15].

We carried out all bleaching experiments and subsequent tests in triplicate and the mean results together with the standard deviations, denoted by the error bars, were recorded. We then tested the differences in the measured properties using analysis of variance (ANOVA) and Duncan's multiple range tests. The ANOVA tested for significant differences among the means of each property. If there were significant differences, the multiple range tests showed which means were significantly different at a 0.05% level of error. The mean results displayed in the graphs and tables were also represented by letters, with common letters indicating that there were no significant differences amongst the means.

RESULTS AND DISCUSSION

Effect of A-stage on hexenuronic acid content of pulp

The concentration of HexA in pulp decreased during acid hydrolysis as the temperature and reaction times of the A-stage increased (**Fig. 1**). As with the findings of other researchers [5,16-19], the unbleached and oxygen bleached

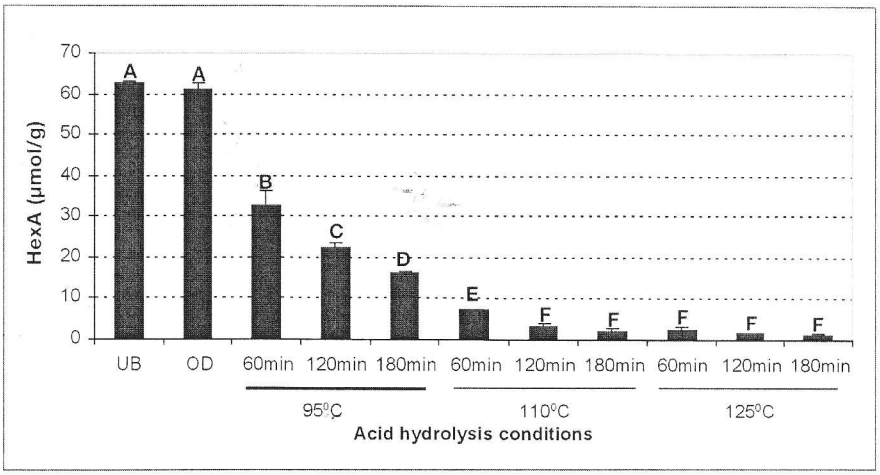
pulps showed no significant difference in HexA content, due to its un-reactivity during oxygen delignification. However, when acid hydrolysis was applied, there was a significant drop in the concentration of HexA with increasing reaction time and temperature, and this decreasing trend continued until reaching 110°C and 120 minutes, where approximately 95% of HexA was removed. Beyond this point, increasing the temperature and/or reaction time had little effect on the residual concentration of HexA in the pulp.

Effect of A-stage on kappa number of pulp

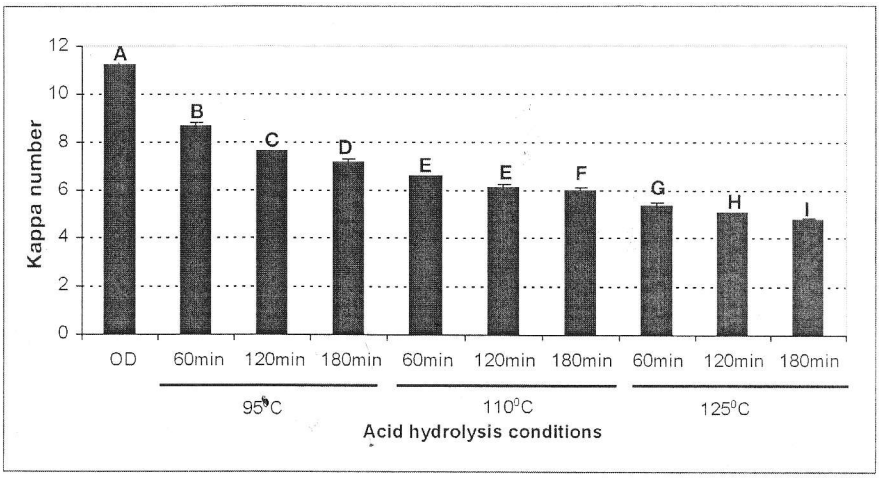
An increase in the temperature and reaction time during acid hydrolysis significantly reduced the kappa number of the oxygen delignified pulps for all tested conditions (**Fig. 2**). For the longest time (180 min) and at the highest temperature (125°C), the kappa number was reduced by as much as 6.5 units, from 11.3 (no hydrolysis treatment) to 4.8. The reason for this decrease may be largely due to the removal of HexA, as shown in Fig. 1, which is known to consume potassium permanganate in the kappa number test [7,20].

Effect of A-stage on lignin content of pulp

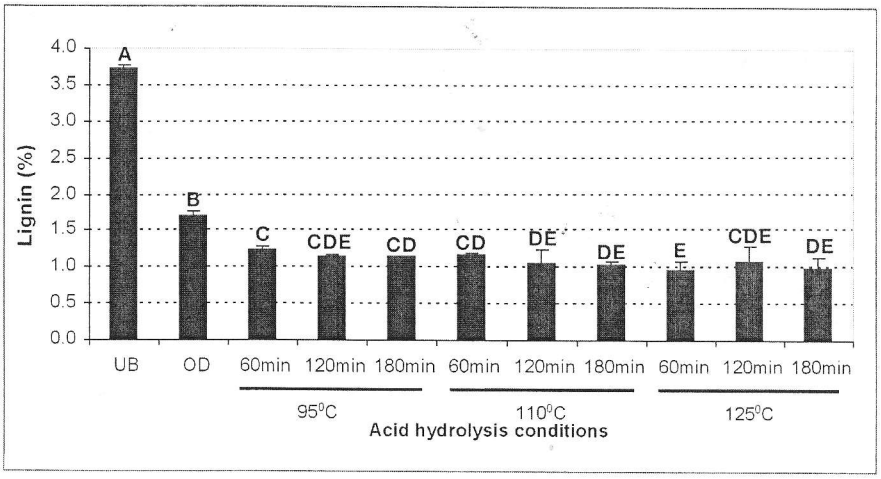
Analysis of the lignin content of the pulp showed that lignin was removed during acid hydrolysis (**Fig. 3**). At 95°C-60min, there was approximately 0.6% removal of lignin which resulted in these pulps having a significantly lower ($p<0.05$) lignin content compared to the oxygen delignified pulps. Beyond this point, the lignin content appeared to remain fairly constant during acid hydrolysis, even with further increases in temperature and reaction time. The pulps hydrolyzed at 125°C-180min showed no significant differences ($p>0.05$) in terms of lignin content, compared to the pulps hydrolyzed at 95°C-120min. Overall, the reduction in kappa, shown in Fig 2, appeared to be due to the combined removal of both HexA and lignin.



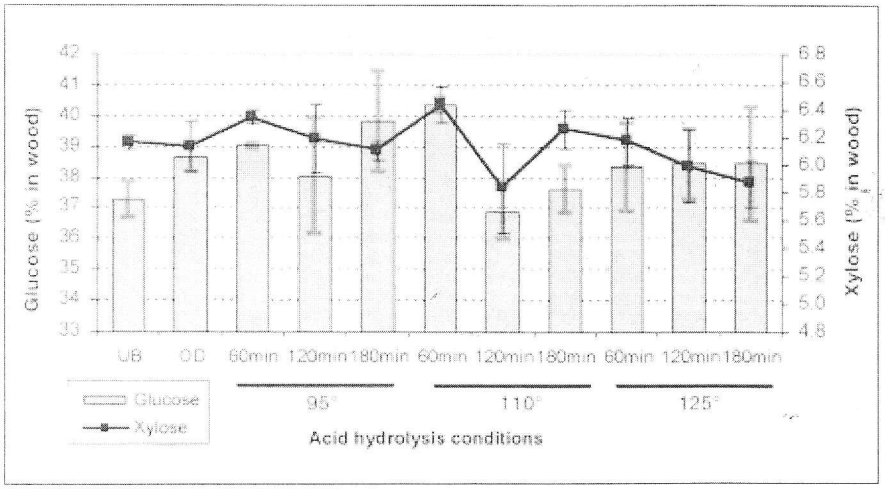
1. Effect of acid hydrolysis on HexA content of pulp (UB=unbleached pulp; OD=oxygen delignified pulp). Common letters indicate no significant differences among the mean values, at 95% confidence levels.



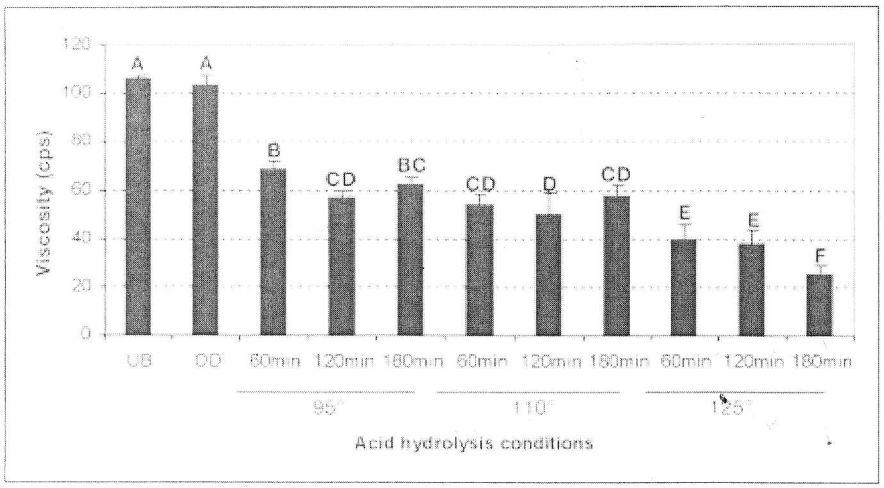
2. Effect of acid hydrolysis on kappa number of pulp (OD=oxygen delignified pulp). Common letters indicate no significant differences among the mean values, at 95% confidence levels.



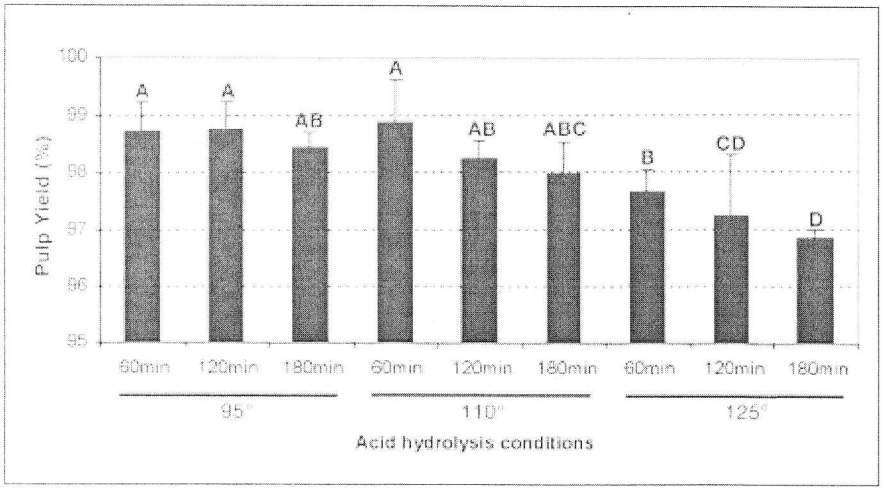
3. Effect of acid hydrolysis on lignin content of pulp (UB=unbleached pulp; OD=oxygen delignified pulp). Common letters indicate no significant differences among the mean values, at 95% confidence levels.



4. Effect of acid hydrolysis on glucose and xylose content of pulp. (UB=unbleached pulp; OD=oxygen delignified pulp).



5. Effect of acid hydrolysis on viscosity of pulp. (UB=unbleached pulp; OD=oxygen delignified pulp). Common letters indicate no significant differences among the mean values, at 95% confidence levels.



6. Effect of acid hydrolysis on pulp yield. Common letters indicate no significant differences among the mean values, at 95% confidence levels.

Effect of A-stage on glucose and xylose content of pulp

We found the glucose and xylose contents in pulp to be more resistant to acid hydrolysis (**Fig. 4**). After pulping, the glucose and xylose contents were, on average, approximately 38% and 6%, respectively, and remained fairly constant at these values as the temperature and reaction times of the A-stage were increased.

Effect of A-stage on viscosity of pulp

Viscosity decreased significantly as the temperature and reaction times of the A-stage increased (**Fig. 5**). This decrease was more pronounced at the higher temperature, with the viscosity reduction exceeding 50% at 125°C, compared to the pulps hydrolyzed at 95°C. For the pulps hydrolyzed at 95°C and 110°C, the viscosity was significantly lower, compared to the oxygen delignified and unbleached pulps, but appeared to have stabilized at these temperatures.

Effect of A-stage on pulp yield

Pulp yield after acid hydrolysis decreased steadily as the temperature and reaction times of the A-stage increased (**Fig. 6**). Overall, there was approximately 2% decrease in yield as the temperature was increased from 95°C to 125°C. The decrease in pulp yield was also more pronounced at the higher temperature, with the pulps hydrolyzed at 95°C and 110°C showing no significant difference in yield.

DETERMINATION OF OPTIMUM CONDITIONS FOR A-STAGE

The parameters we used to decide on the optimum conditions for the A-stage were the conditions that resulted in (1) maximum removal of HexA, (2) maximum pulp yield after bleaching, (3) minimum chlorine dioxide consumption, and (4) minimum impact on pulp quality. In order to determine the optimum conditions that satisfied these requirements, three acid hydrolyzed pulps, containing varying amounts of HexA, were selected and bleached to 90% ISO bright-

Pulp Type	pH	Temp (°C)	Reaction Time (min)	Lignin (%)	HexA (μmol/g)
Oxygen delignified (control pulp)	--	--	--	1.68	61.2
Acid hydrolyzed	3.5	95	60	1.24	32.3
Acid hydrolyzed	3.5	95	180	1.14	16.1
Acid hydrolyzed	3.5	110	120	1.05	3.2

III. Selected acid hydrolyzed pulps containing varying amounts of HexA and lignin that were bleached to 90% ISO brightness using D_0ED_1 sequence. Oxygen delignified pulps that were not subjected to acid hydrolysis were used as controls.

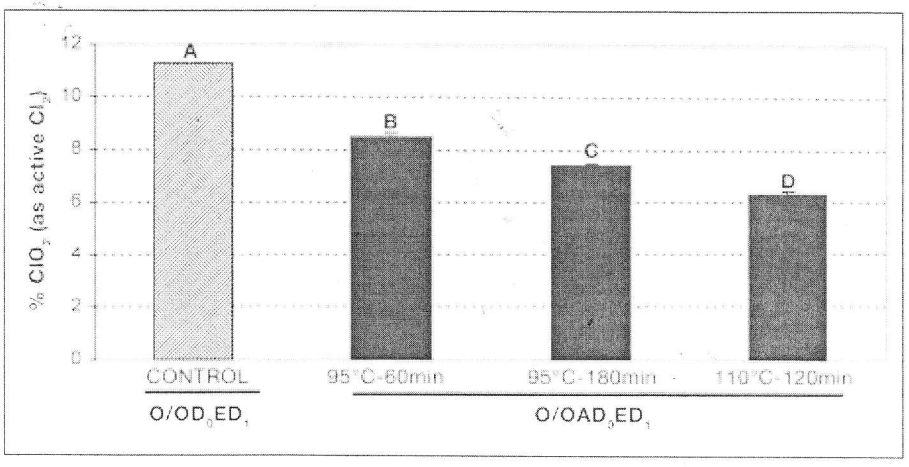
	CONTROL	95°C - 60min	95°C -180min	110°C -120min
D_0 stage*				
kappa number	11.0 (0.05)	8.64 (0.19)	7.16 (0.12)	6.12 (0.08)
ClO_2 charge (%)	8.09 (0.00)	6.05 (0.13)	5.26 (0.09)	4.50 (0.06)
ClO_2 consumed (%)	8.09 (0.00)	6.05 (0.13)	5.26 (0.09)	4.49 (0.06)
Final pH	2.33 (0.18)	2.24 (0.06)	2.22 (0.05)	2.22 (0.04)
E stage				
NaOH charge (%)	1.5	1.5	1.5	1.5
Final pH	12.0 (0.09)	12.0 (0.04)	12.1 (0.02)	12.0 (0.02)
D_1 stage*				
ClO_2 charge (%)	3.47 (0.00)	2.59 (0.06)	2.26 (0.04)	1.93 (0.02)
ClO_2 consumed (%)	3.21 (0.03)	2.44 (0.03)	2.13 (0.02)	1.84 (0.03)
Final pH	4.11 (0.10)	3.84 (0.19)	4.07 (0.06)	4.00 (0.05)

* ClO_2 charge expressed as active Cl_2

IV. Chemical dosage and consumption for acid hydrolyzed and control pulps that were bleached to 90% ISO brightness using D_0ED_1 sequence. All bleaching experiments were carried out in triplicate and the values within parentheses denote the standard deviation.

ness using a D_0ED_1 sequence (full bleaching sequence was O/OAD_0ED_1). These samples are listed in **Table III**.

An oxygen delignified pulp that was not subjected to acid hydrolysis, and which contained the maximum amount of HexA, was also bleached to 90% ISO brightness (full bleaching sequence was O/OD_0ED_1). We used this pulp as a control in our study. The pulps hydrolyzed at 110°C-120 min were chosen as the upper limit for acid hydrolysis because any further increase in temperature and/or reaction time of the A-stage beyond this point did not result in a further significant reduction in the concentration of HexA in the pulps (see Fig. 1). We carried out all bleaching experiments in triplicate and the amounts of chemicals applied and/or consumed in the bleaching stages are shown in **Table IV**.



7. Consumption of ClO_2, expressed as active Cl_2, for acid hydrolyzed and control pulps to reach 90% ISO brightness. Common letters indicate no significant differences among the mean values, at 95% confidence levels.

Fig. 7 shows that, compared to the control pulps, the consumption of ClO_2 decreased significantly for the pulps

	CONTROL	95°C-60min	95°C-180min	110°C-120min
Glucose (% in wood)	37.1(1.0) (A)	36.2(0.8) (A)	37.1(0.8) (A)	37.0(0.2) (A)
Xylose (% in wood)	6.1(0.22) (A)	5.1(0.3) (B)	5.4(0.2) (B)	5.5(0.2) (B)
Viscosity (cps)	66.8(0.8) (A)	54.6(2.3) (B)	53.9(1.9) (B)	46.1(3.0) (C)
Pulp yield (%)	97.3(0.9) (A)	97.1(0.6) (A)	98.5(0.8) (A)	98.0(1.2) (A)

Full bleaching sequence for control pulps: O/OD_0ED_1

Full bleaching sequence for acid hydrolyzed pulps: O/OAD_0ED_1

V. Properties of acid hydrolyzed and control pulps that were bleached to 90% ISO brightness. Values within parentheses denote the standard deviation, and common letters within parentheses denote no significant differences among the mean values of a specific property, at 95% confidence levels.

	CONTROL	95°C-60min	95°C-180min	110°C-120 min
Burst index at 400CSF (MN/kg)	5.8(0.4) (A)	6.0(0.3) (A)	6.2(0.4) (A)	6.0(0.2) (A)
Tear index at 400CSF (Nm^2/kg)	9.6(0.6) (A)	9.8(0.4) (A)	9.4(0.2) (AB)	8.8(0.0) (B)
Tensile index at 400CSF (kNm/kg)	78(6.7) (A)	82(4.8) (A)	84(1.3) (A)	81(2.8) (A)
Zero-span tensile index at 400CSF (kNm/kg)	34(1.9) (A)	35(0.9) (A)	34(3.1) (A)	41(0.8) (B)
Bending resistance at 400CSF (mN)	41(1.9) (A)	44(1.2) (AB)	46(3.6) (B)	46(1.2) (B)
Opacity at 400CSF (%ISO)	74.9(1.6) (A)	72.2(0.7) (B)	73.1(1.0) (AB)	73.6(0.5) (AB)
Brightness reversion (%ISO)	4.2(0.5) (A)	3.8(0.5) (A)	3.3(0.5) (B)	2.4(0.3) (C)

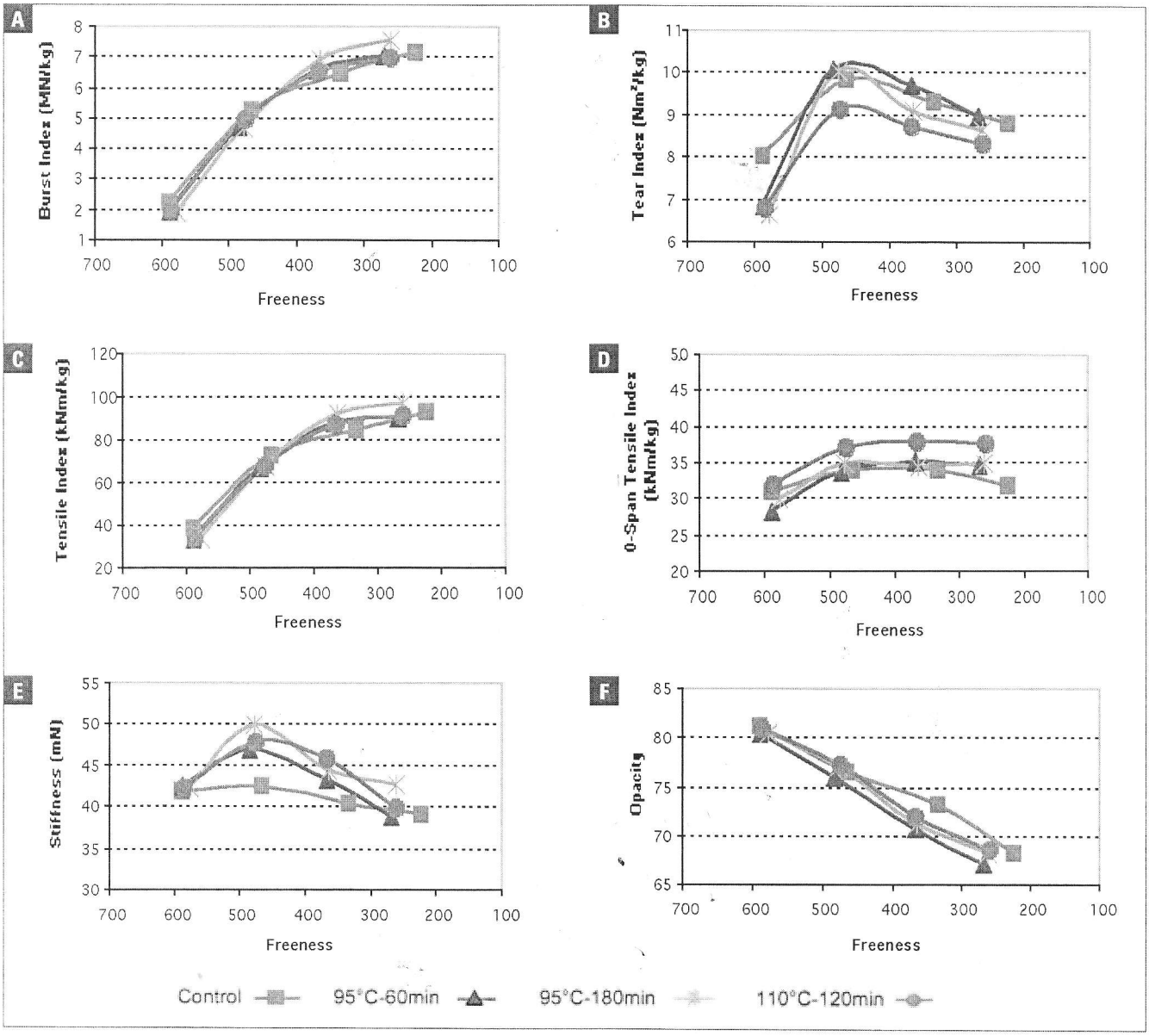
Full bleaching sequence for control pulps: O/OD_0ED_1

Full bleaching sequence for acid hydrolyzed pulps: O/OAD_0ED_1

VI. Comparison of properties between acid hydrolyzed and control pulps bleached to 90% ISO brightness. Numerical values within parentheses denote the standard deviation and common letters within parentheses denote no significant differences among the mean values of a specific property, at a 95% confidence level.

that were acid-hydrolyzed before bleaching as the conditions of the A-stage increased. According to Table III, the control pulps contained maximum HexA, and this concentration decreased significantly as the temperature and/or the reaction time of the A-stage increased. Hexenuronic acid belongs to a class of compounds that contain enol ether or unsaturated carboxylic acid groups which are the targets of both electrophilic and nucleophilic attack. As a result, chlorine dioxide reacts with HexA groups [4-5,16,21] and is partially consumed during this reaction, resulting in increased consumption of chlorine dioxide. Figure 7 shows that the inclusion of the A-stage prior to bleaching was effective in the removal of HexA, as well as lignin, thereby resulting in significant chemical savings of up to 44% using the conditions 110°C, 120min, pH 3.5 for the A-stage. Vuorinen, *et al.*, [5] reported chemical savings of up to 35% using less severe conditions for the A-stage (110°C, 60min, pH 3.5), while Furtado, *et al.*, [10] reported savings up to 25% using even milder conditions (90°C, 120min, pH 3.5).

Table V shows the chemical composition, pulp viscosity and yield of the bleached pulps. The results show that inclusion of the A-stage in the bleaching sequence had no significant impact on the glucose content, but xylose appeared to be more sensitive to the acid treatment. Compared to the control pulps that did not undergo acid hydrolysis prior to bleaching, the acid hydrolyzed pulps showed a significant reduction in xylose content. However, among the acid hydrolyzed pulps, the temperature and reaction time of the acid



8. Development of pulp properties with beating. Comparison between acid hydrolyzed and control pulps that were bleached to 90% ISO brightness.

treatment was found to have no further impact on the xylose content of the bleached pulps.

The fully bleached pulps showed significantly lower viscosity for the acid hydrolyzed pulps, compared to the control pulps. The temperature of the A-stage appeared to play a significant role in the viscosity reduction: a three-fold increase in the reaction time at 95°C had only a slight effect on viscosity, but at 110°C, the impact was more significant.

We found that pulp yield after bleaching was unaffected by the inclusion of the A-stage in the bleaching sequence. Acid hydrolysis carried out at 95°C-180 min and 110°C-120 min showed slight improvements in yields compared to the control pulps, but the increase was not significant.

We plotted, as a function of freeness, the physical properties (burst, tear, tensile, zero-span tensile, bending resistance and opacity) of the fully bleached pulps that underwent acid hydrolysis prior to bleaching (**Fig. 8A-F**). We then interpolated the values of the specific properties at a constant freeness of 400CSF from the respective property-freeness curves and were compared to the control pulps at the same level of freeness (**Table VI**). One-way analysis of variance and Duncan's multiple range tests were then used to test for significant differences among the means of each property at constant freeness and at a 0.05% level of error. The results of brightness reversion tests, which were only measured on the unbeaten pulps, are also included in Table VI.

As in Table VI, comparisons made at constant freeness (400CSF) showed that the inclusion of the A-stage in the bleaching sequence had no impact on the burst and tensile indices of the fully bleached acid-hydrolyzed pulps. Tear

index also appeared unaffected by the A-stage carried out at the lower temperature (95°C). However, acid hydrolysis carried out at 110°C significantly reduced the tear strength of the fully bleached pulps compared to the control pulps that did not undergo acid hydrolysis prior to bleaching. The high temperature used during acid hydrolysis seemed to have a positive effect on the bending resistance (stiffness) and zero-span tensile index, which showed significantly higher values, compared to the control pulps. Opacity was significantly lower for the pulps hydrolyzed at 95°C-60 min compared to the control pulps, but then improved to similar values as the control pulps when the reaction time of the A-stage was increased at 95°C or when the temperature was increased to 110°C.

Brightness reversion of the fully bleached pulps decreased significantly for the pulps that were acid-hydrolyzed prior to bleaching. Acid hydrolysis carried out at 110°C-120min reduced reversion by as much as 43% compared to the control pulps that did not undergo acid hydrolysis prior to bleaching. The results we obtained indicate a strong correlation between the removal of HexA during acid hydrolysis and the observed reduction in brightness reversion. Besides the removal of HexA, according to Table V, the lower xylose content in the bleached acid hydrolyzed pulps (between 0.6% and 1.0%) compared to the bleached control pulps, could offer another explanation for the reduced brightness reversion. The xylans could contain lignin-carbohydrate complexes [22] and so removal of xylose during acid hydrolysis could improve brightness stability by removing these complexes.

In deciding on the optimum set of conditions for acid hydrolysis, a compromise between the efficiency of HexA removal, the resulting bleached pulp quality, and practical considerations for implementation of the A-stage in industry was required. The choice for the optimum conditions was therefore between 95°C-180 min and 110°C-120 min, mainly because of the lower HexA and lignin concentration, and as a result, the higher kappa number reduction and lower ClO_2 consumption required to bleach to 90% ISO brightness. Both sets of conditions resulted in bleached pulps with strength properties and pulp yields comparable to the control pulps that did not undergo acid hydrolysis prior to bleaching. However, acid hydrolysis carried out at 110°C-120 min did result in pulps with a significantly lower viscosity and tear strength, and due to the higher operating temperature, the 95°C-180 min acid hydrolysis conditions were considered to be the more attractive option.

CONCLUSIONS

Our study showed that pulps produced from South African eucalypt clones contain significant amounts of HexA that contribute several units to the kappa number of the pulp. The A-stage was found to be effective in the removal of HexA, with the efficiency of removal increasing as the temperature and reaction times of the A-stage increased. However, at elevated temperatures, pulp yields and viscosity were found to be negatively affected, while glucose and xylose content of the pulp appeared to be relatively unaffected by the acid hydrolysis treatment over the temperature range we studied. In addition to the removal of HexA from the pulp, acid hydrolysis also removed lignin. Due to the concomitant removal of both HexA and lignin, the amount of chlorine dioxide required to reach 90% ISO brightness using a D_0ED_1 sequence was lowered by as much as 44%, depending on the temperature and reaction times used during acid hydrolysis. Bleached pulp yields and glucose contents were unaffected by including the A-stage in the bleaching sequence, while bleached pulp viscosity and xylose contents were significantly reduced. Most of the strength properties of the pulps were unaffected by the acid treatments, and in some instances showed improvements for the pulps that were acid hydrolyzed prior to bleaching. The exception was tear strength, which was significantly lower compared to control pulps that were not subjected to acid hydrolysis prior to bleaching. Based on these findings, the optimum conditions found for the A-stage that resulted in minimal impact on the physical and chemical properties of the bleached pulps were: pH 3.5; temperature 95°C and reaction time 180 min. **TJ**

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INSIGHTS FROM THE AUTHORS

We chose this area of research because, as we noted in the background section of our paper, it is common practice in South Africa to adopt and run, usually at less-than-optimal levels, pulp technologies that were developed in other countries for overseas tree species. Because of the considerable variability of hardwood resources, both morphologically and chemically, and their varying responses to pulping and bleaching processes, it is important to understand the response of our locally grown wood resources to these processes.

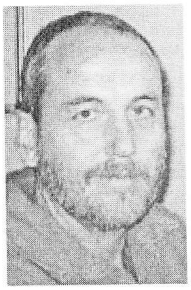
This study is a continuation of some of our earlier work. Although the A-stage is effective in the removal of HexA, we saw a need to examine its effects on other pulp properties. Our study differs from some earlier research in that, in addition to providing data on Hex-A, it also includes data on carbohydrate content, klason lignin and kappa number.

A significant amount of ClO_2 can be saved by removing HexA from pulp. In addition to the obvious savings in operating costs, other benefits include the potentially lower effects on the environment from producing bleached pulp. Because of HexA, kappa numbers have previously been measured incorrectly. Pulp quality and yield can now be improved or optimized by varying delignification during pulping and pulping to higher kappa numbers.

Although the A-stage has been proven effective in the removal of HexA, it may require a significant amount of capital investment as a stand-alone stage, and it does not lead to an improvement in pulp brightness. The next research steps will include looking at other options for removing HexA, such as D_{HT}, Z and A/D stages.


Andrew


Grzeskowiak


Kerr

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