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Scion's core funded experiments on thermal modification of *Eucalyptus nitens*.

Report to the Speciality Wood Products research partnership

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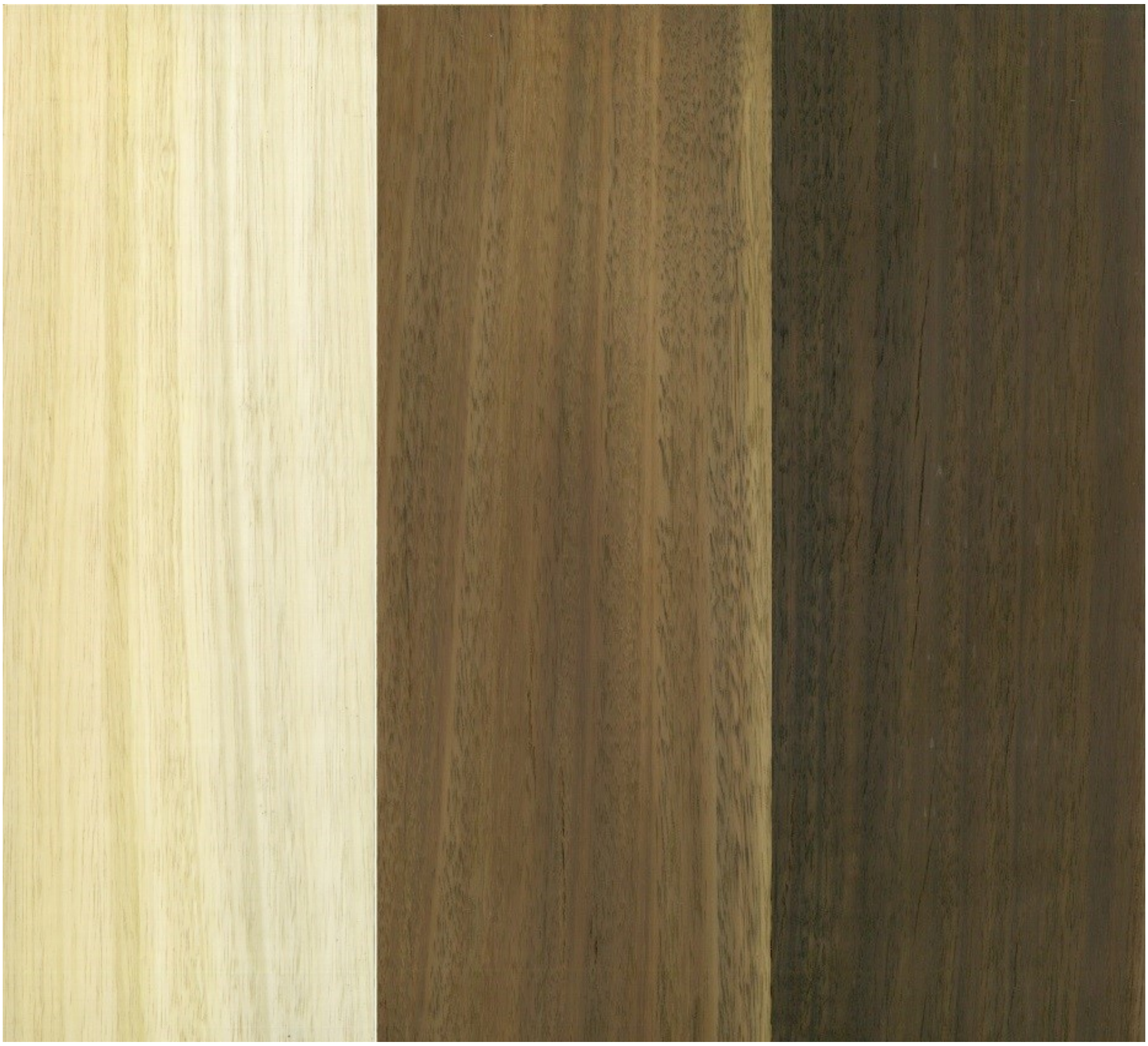
Report Number: SWP-T021



Report information sheet

Report title	Report to the Specialty Wood Products Partnership on Scion's core funded experiments on thermal modification of *Eucalyptus nitens.*
Authors	Rosie Sargent, Bruce Davy, Elizabeth Dunningham Scion
Client	Specialty Wood Products Partnership
Client contract number	
MBIE contract number	
SIDNEY output number	
Signed off by	
Date	
Confidentiality requirement	Confidential (for client use only)
Intellectual property	
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Published by: Scion, 49 Sala Street, Private Bag 3020, Rotorua 3046, New Zealand. www.scionresearch.com

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Executive summary

The problem

The objective of this work was to replicate successful lab scale thermal modifications of *Eucalyptus nitens* at a larger scale. Lab scale thermal modification has been shown to improve dimensional stability and durability of eucalyptus nitens while darkening the wood colour. Pilot scale modifications also allow further property testing, such as evaluating the effect of thermal modification on the strength of knots, and allowing more in depth testing of durability and dimensional stability. Lab scale modifications have had excessive levels of between ring checking after modification, and attempts are being made to reduce this.

Key results

Properties of the pilot scale modifications were similar to those of the lab scale, but were often more variable (e.g. Anti shrink efficiency). The strength of knots relative to clear timber was not affected by thermal modification. Dimensional stability in humid air environments is significantly improved by thermal modification at 210°C (185°C was not tested). Between-ring checking was not reduced at the pilot scale, but subsequent lab scale modifications have significantly reduced levels of checking.

Further work

For thermal modification of E. nitens to be successful at a commercial scale, issues of within-charge variability and levels of between-ring checking need to be solved.

Introduction

Eucalyptus nitens (Shining gum) is a plantation species that has been grown in small quantities in New Zealand for many years. *E. nitens* is not well utilised as a sawn timber resource for a variety of reasons; difficulty in sawing and drying, as well as dimensional instability and an undesirable pale, uneven colour. Following on from successful lab-scale trials it was hoped that thermal modification would be able to improve the dimensional stability and colour evenness of 2.4m lengths of *E. nitens* without compromising the mechanical properties of the timber, or exacerbating known drying defects such as checking. Producing longer lengths of modified timber also mean that more in-depth tests are possible; e.g. long term dimensional stability, fungus cellar durability testing, and mechanical testing to determine the effect of modification on the strength of knots. *E. nitens* is not routinely pruned and contains numerous small knots, so it is important to understand the effect that the thermal modification process has on knots.

Thermal modification at Scion is based on a ThermoWood-style process (Finnish ThermoWood Association, 2003), where steam is used to create an oxygen-free atmosphere during the thermal modification stage, to prevent the wood igniting. Scion has two kilns capable of thermal modification, one 0.1m3 (wood capacity) wood drying kiln to enable thermal modification of 600mm lengths of wood and one 2m3 kiln able to modify 2.4m lengths of wood. Both kilns use schedules and conditions similar to those used on industrial scale kilns. Being able to control the kiln humidity during the early and late phases of the modification process, and effectively excluding oxygen during the high temperature phase should reduce drying defects.

Approach

Pilot scale trials were carried out on kiln dried *E. nitens.* This was sourced from Specialty Timber Solutions, and the trees originated from a farm forest in the North Canterbury area. Replication was fifty boards per modification temperature, cut to 2.4m long.

Using the pilot-scale Scion thermal modification kiln, two modification schedules were used, replicating the lab-scale work done in 2015. With one schedule, the wood was heated to 185°C and held for 2 hours; with a second, the wood was heated to 210°C and held for 2 hours. A third schedule was to hold wood as an unheated control. These two schedules are the same as those used previously in the lab scale work.

Changes in wood colour, short- and long term stability, durability and the strength of knots were assessed using standard methods. More specifically durability was assessed using an in-house accelerated decay test. Drying defects (checking and collapse) were subjectively assessed to decide if they would be acceptable for use in an appearance grade product or not.

Results

Colour

Thermal modification turned the light-coloured timber dark brown, with the 210°C modification giving a darker brown than the 185°C modification (Figure 1). The colours were similar to those seen in the lab scale modifications.

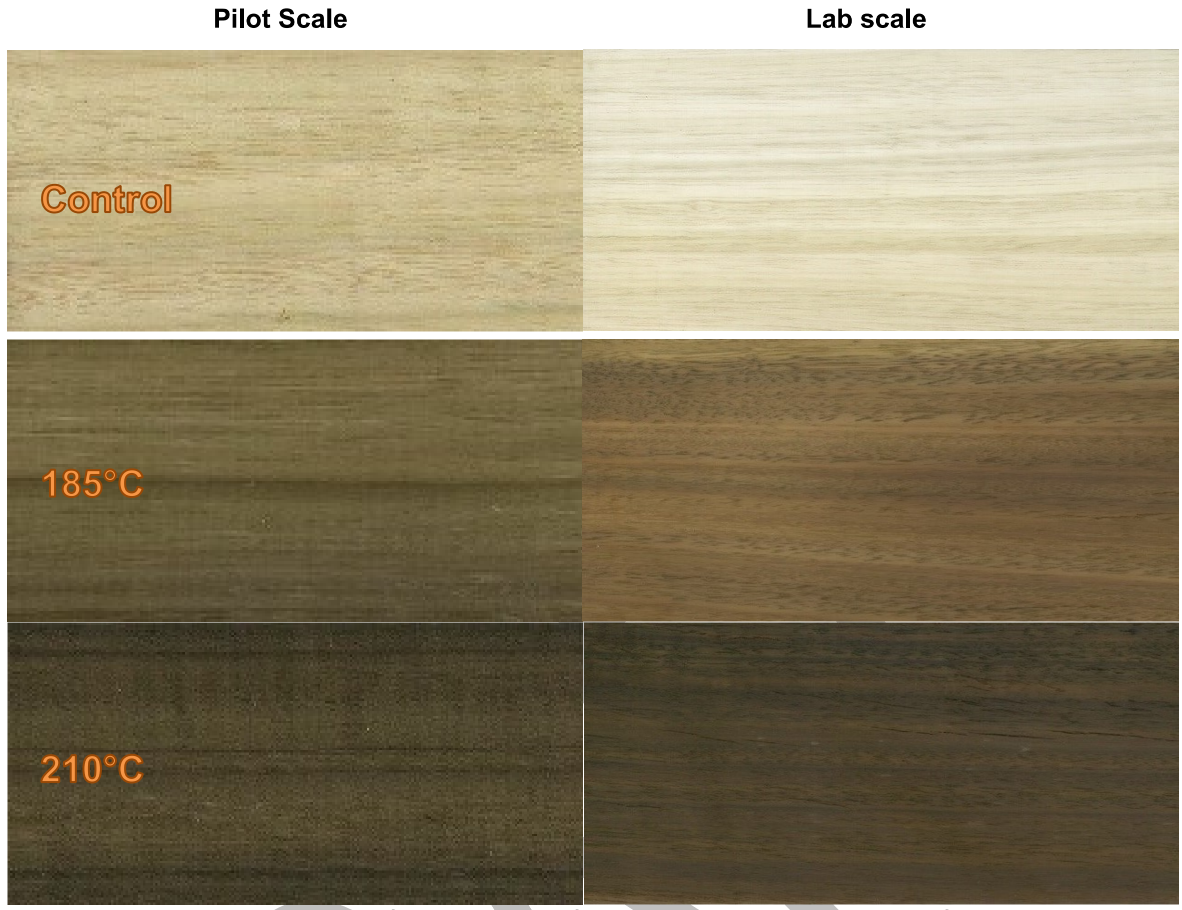

Figure 1. Representative boards from each modification, comparing the colour of the pilot and lab scale modifications.

The L* value of the L*a*b* colour space represents lightness, with white having an L* value of 100 and black having an L* value of 0. The L* values for each modification (both pilot and lab scale) are shown in Figure 2. Interestingly the two sets of control samples (labelled as “0” in the graph) are slightly different colours, with the pilot scale controls being significantly darker coloured. There is no significant difference in colour between the lab and pilot scale samples at 185°C, but the 210° pilot scale samples are significantly lighter coloured than the lab scale samples.

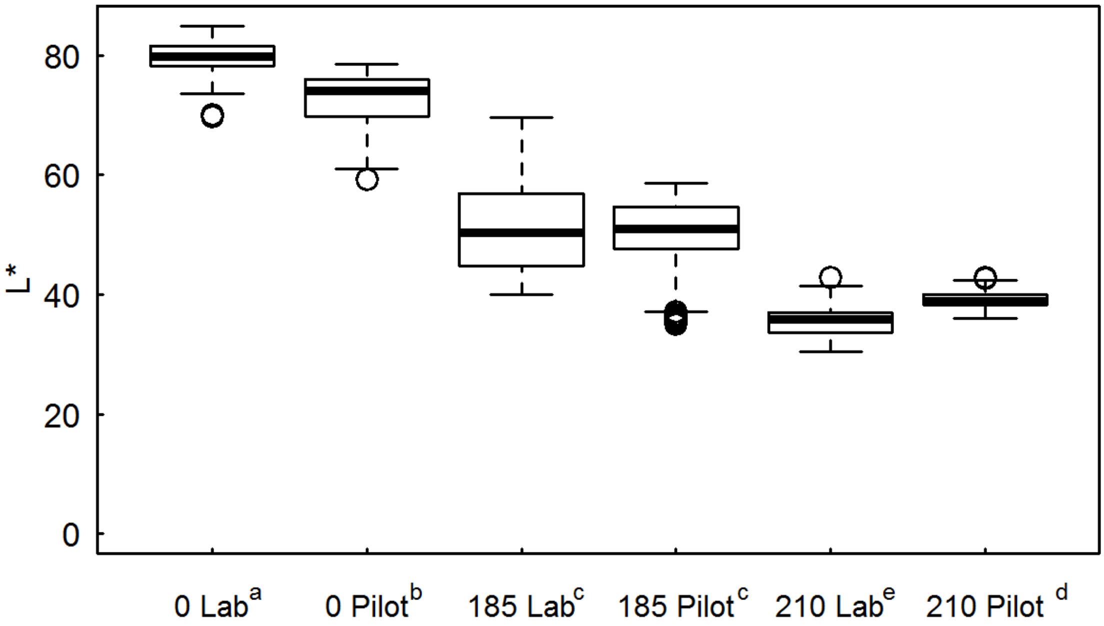

Figure 2. L* (lightness) values for each modification. Control samples are Superscript letters indicate treatments that are significantly different to each other (95% confidence level).

Stability

Short-term (Anti shrink efficiency)

Anti-shrink efficiency is a measure of how much wood resists swelling when in contact with liquid water. A higher ASE value indicates that the wood shrinks and swells less than it would have prior to modification. ASE values for both the pilot and lab scale modifications are given in Figure 3. For the pilot scale modifications, the median ASE values are similar to the equivalent lab scale modifications, but the pilot scale modifications have a much greater spread of ASE values. This suggests that the pilot scale modification was more variable, possibly due to variations in conditions within the stack leading to differences in the final level of modification.

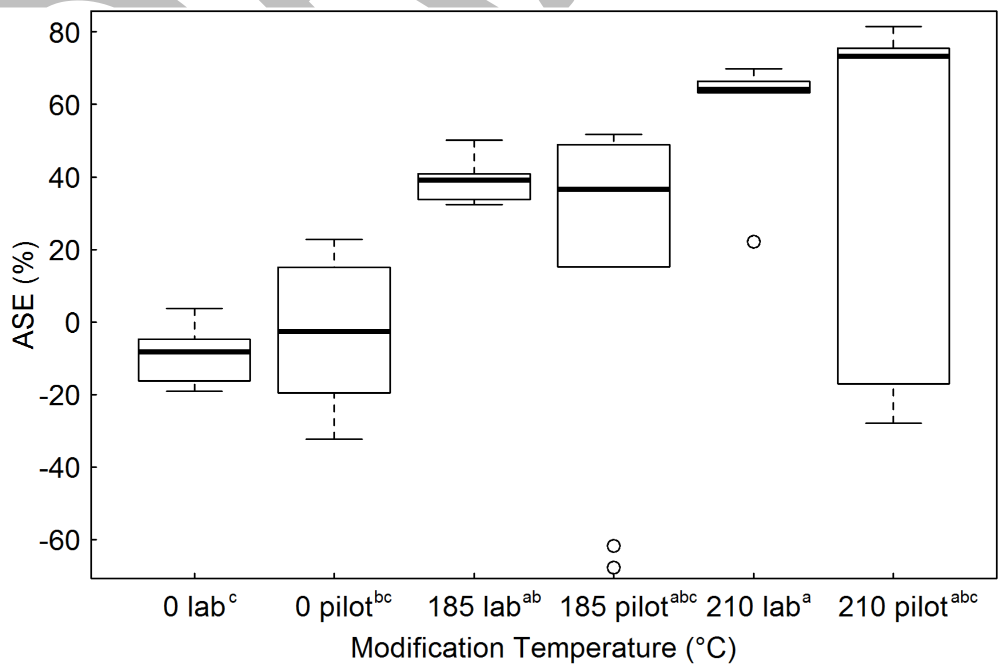

Figure 3. Anti shrink efficiency for each modification at both the lab and pilot scale Superscript letters indicate treatments that are significantly different to each other (95% confidence level).

Long-term (humidity cycling)

This test measures the amount that wood shrinks and swells when the humidity of the surrounding air changes. Dimensional stability was quantified as the amount the radial and tangential dimensions shrink or swell for every 1% change in air humidity. A higher value indicates less dimensional stability (because the wood is shrinking and swelling more for every 1% change in air humidity). As this test is more labour intensive than the anti shrink efficiency test above, it has only be done on two treatments - pilot scale controls and the pilot scale 210°C modification. This test is scheduled to be complete in late 2017, so interim results are given here. As can be seen in Figure 4 the modified samples were significantly more stable than the unmodified controls.

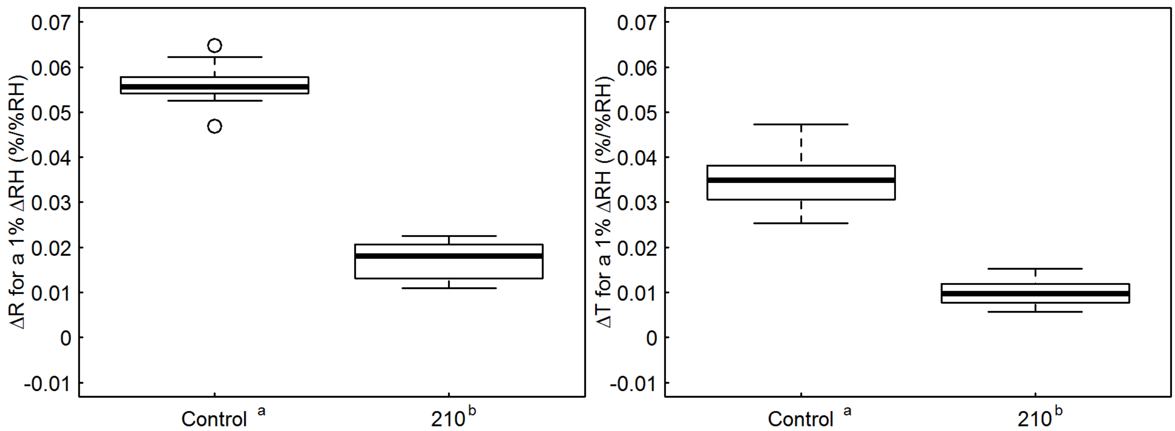

Figure 4. Dimensional stability of the pilot scale 210°C modification compared to unmodified controls. Superscript letters indicate treatments that are significantly different to each other (95% confidence level).

Mechanical Properties

Mechanical properties are shown in Table 1. MOE (stiffness) is not changed by the modification, but MOR (strength) is significantly reduced. This is in line with what we would expect for thermal modifications at these temperatures. The same mechanical tests had previously been performed on the lab scale boards, so direct comparisons can be made about the mechanical properties at the two scales. For each modification temperature there were no significant differences in MOE or MOR between the lab scale and pilot scale modifications (i.e. lab-scale modification to 185°C gave the same MOR as pilot-scale modification at the same temperature).

Table 1: Average Mechanical Properties for each schedule. Superscript letters indicate values that are significantly different (95% confidence).

Modification Temp (°C)	MOE (GPa)		MOR (MPa)	
	mean	% reduction	mean	% reduction
0	12.7[a]	-	115.3[a]	-
185	10.4[a]	17.8	81.5[b]	29.4
210	9.6[a]	24.1	53.5[c]	53.6

Superscript letters indicate groupings that are not significantly different to each other (95% confidence

Strength of knots

The strength (MOR) of thermally modified timber containing knots was compared to the strength of a length of clear timber within the same board. As seen in Table 1, thermal modification decreases the MOR of timber. The presence of knots also decreases the MOR (even in unmodified timber). A linear model was used to determine if interactions between the level of modification and the size of knots (knot area ratio) had a significant effect on the MOR. No significant interactions were found, showing that thermal modification reduces the MOR of knotty timber to the same degree as it does for clear timber. This is a good result for nitens, as it often contains knots.

Drying defects

Previous work at Scion has found that numerous between-ring checks appear during thermal modification of nitens. These types of checks tend to occur late in the drying process, so it is reasonable to assume that they could be caused by thermal modification. Levels of checking were classed as either being ‘acceptable’ or ‘unacceptable’ in each board. For each modification the proportions of boards being classed as acceptable and unacceptable are shown in Figure 5. For both modifications, levels of checking are unacceptably high and as the modification temperature increases, the numbers of unacceptable boards increase. For the pilot scale modification the boards were heated at a slightly slower rate than the lab scale, to try and reduce levels of checking, but this was not successful.

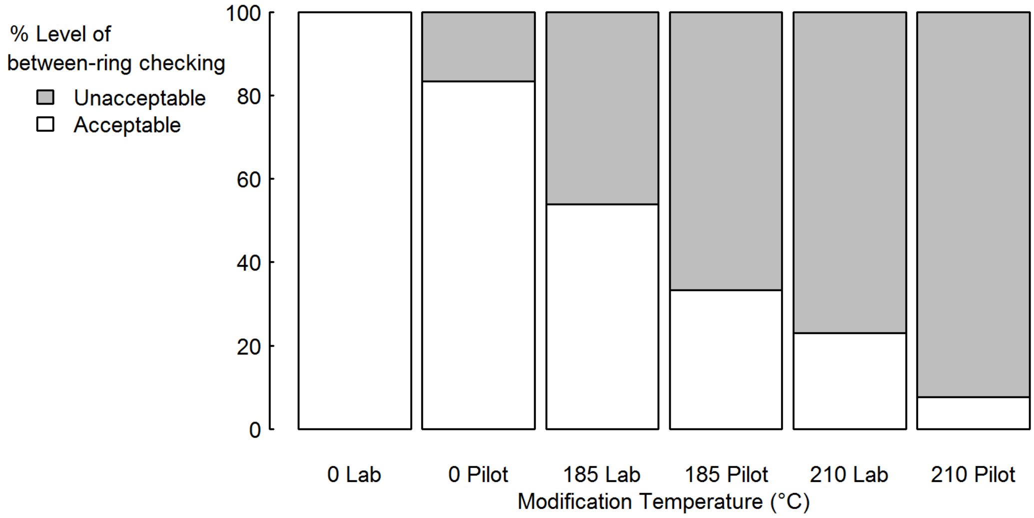

Figure 5. Proportion of boards with unacceptable between-ring checking following thermal modification.

An additional lab scale modification was done at 210°, heating the wood at a very slow rate compared to the previous modifications. This had significantly lower levels of checking (Figure 6). While this is a good result, 60% of boards were still affected by between-ring checking which is unacceptably high. Future work will look at ways of reducing levels of checking further.

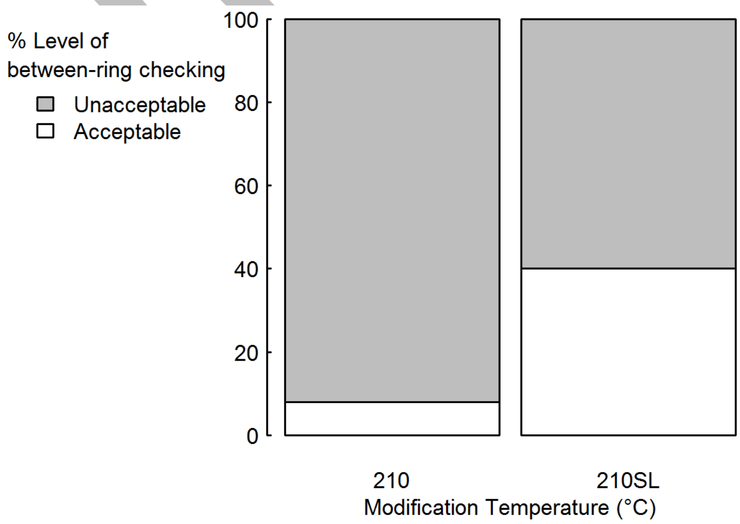

Figure 6. Levels of between ring checking in the pilot scale (left) and slow-heated lab scale modifications. The differences in levels of checking are statistically significant (95% confidence)

Durability

The accelerated durability (fungus cellar) testing takes two years to complete and full results are expected in September 2018. Interim results from the 9 month assessment are due in June and will be included in this report as soon as they are available.

Recommendations and conclusions

Overall the properties of the pilot scale modifications were similar to those of the previous lab scale modifications, but were more variable. This may be due to higher variability in the initial wood properties, or variation in the conditions in the kiln stack, leading to different levels of modification in different parts of the stack.

The modification does not appear to affect the strength of knots relative to that of clear timber. As nitens tends to be a knotty timber, this is a good result, as it means that no special consideration needs to be given to knots, other than taking into account the relative difference in strength between knotted and clear timber in the unmodified wood.

Dimensional stability in humid air environments was improved, with the 210°C modified samples changing dimension and weight less than the unmodified controls when exposed to changes in atmospheric humidity.

Attempts to reduce between ring internal checking were not successful at the pilot scale, but subsequent lab scale trials have managed to reduce levels of checking. While these schedules could be trialled at the pilot scale, the best schedule still had 60% of boards with unacceptable checking, so further reductions in checking would be required to give a commercially viable process.

Acknowledgements

This work was funded by the Ministry of Business, Innovation and Employment, through Crown Research Institute (CRI) Core Funding to Scion.
Timber was sourced from John Fairweather at Specialty Wood Solutions in North Canterbury. Steve Riley, Steve Chapman and Jamie Agnew assisted with preparing and drying the timber. Ian Simpson and Jackie van der Waals did the fungus cellar testing. Maxine Smith did the equilibrium humidity cycling. Gavin Durbin and Maxine Smith did the ASE testing.