Final Report
Project NT046

Minimising market-limiting discolouration in appearance Tasmanian hardwood

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Minimising market-limiting discolouration in appearance Tasmanian hardwood

Prepared for

National Institute for Forest Products Innovation

Launceston

by

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Introduction

This is a summary report for the National Institute for Forest Products Innovation's (NIPFI) project: *NT046 / NIF107 Minimising market-limiting discolouration in appearance Tasmanian hardwood.* The project's objective is to reduce the economic impacts of market-limiting discolouration in dry appearance grade boards of key Tasmanian species.

Production-induced board discolouration such as stain and 'sticker mark' can occur regularly in appearance hardwood production. Currently, market-limiting discolouration of appearance boards can lead to an industry-estimated loss of up to $1m per annum to the Tasmanian native hardwood value chain. If continuing, stain evident at project commencement in plantation hardwood had the potential to reduce the value of Tasmanian public managed plantation estate significantly. Discolouration agents are diverse, and varying management approaches are required. Agents such as a form of 'blue stain' fungus, are well understood and effective management techniques are available. Agents that lead to other discolouration such as sticker mark are more complex and reliable management options are less clear.

This is the first of two technical reports and a PhD thesis for this project. This report provides a summary of the project and its findings. Technical report TR-1 details the methodology and results of the biotic and chemical laboratory testing. The PhD thesis of the higher degree research student associated with the project, Mr David Rhys Tanton, is due in early 2024.

Project overview

This project's objective was to reduce the economic impacts of market-limiting discolouration in dry appearance grade boards of key Tasmanian species. It aimed to identify the causes and where possible generate management tools to address the impacts of market-limiting, process-induced discolouration of appearance Tasmanian hardwood boards, particularly 'tyre track' in appearance plantation Shining gum (Eucalyptus. nitens) board and *'sticker mark'* in Tasmanian Blackwood (*Acacia melanoxylon*) Project deliverables included:

- Best practice guidance on management and processing options for avoiding or controlling market-limiting discolouration in appearance quality boards.
- A scientific explanation of market-limiting wood discolouration and its causes.

Definitions

In this project, *process-induced discolouration* is unacceptable discolouration in the wood that results from agents or process that can be controlled during log storage and breakdown or subsequent drying and milling of recovered boards. It excludes discolouration caused by processes in the standing tree. *Market-limiting discolouration* is discolouration at a level that makes the board unacceptable or grade-limited in the market.

Sticker mark is unacceptable light or dark stripes across boards that correspond with the position of rack sticks. See Figure 1. They can occasionally appear like a shadow of the rack stick, with darker strips either side of a lighter strip. While there are regularly marks across dry rough sawn boards, this results from weathering of the exposed surfaces and generally planes out easily. *Sticker mark* discolouration often occurs some distance into the wood and may be difficult to plane out.

Tyre-track is a form of blue-stain that appears as a regular greyish mark on parts of the board. Unlike sticker mark that appears directly around the rack stick position, tyre track impacts broader areas of the board's surface. Only some racks (or parts of racks) are affected. See Figure 2.

Figure 1: Sticker mark

Figure 2: Tyre track

Methodology

The project’s methodology covers appearance quality sawn board recovered from native forest Blackwood and plantation E. nitens logs. Its stages include:

- **Discolouration Audit.** This was to define the level of market-limiting, production-induced discolouration evident in dry board and estimate its economic impact.
- **Assessment of discolouration’s causes.** While discolouration is production-induced, this is to determine the actions and conditions that may contribute to the discolouration process.
- **Avoiding discolouration.** This is to confirm processes to avoid or minimise the discolouration process.
- **Develop best practice guidance.** This is to convert the results of the audit, material testing and replication trials into industry best-practice guidance.

These stages progressed in two parallel streams reported separately below and in the associated technical reports. These are:

- Audit and assessment of material in production.
- Biotic and chemical assessment of discoloured and control samples recovered from production.

Audit and assessment of material in production

The level of market-limiting, production-induced discolouration evident in dry board and estimates of its economic impact were defined through production and product audits of plantation Shining gum and native forest Blackwood boards.

Several types of process-induced discolouration are evident, and these occur due to agents and processes such as exposure to light, biotic or chemical action alone or in combination, and other climate and location dependant factors. Given this, surveys of its occurrence at board, rack and site level provides important clues as to its causes and potential management approaches.

Shining gum audit and assessment

Appearance plantation Shining gum (E. nitens) board is milled and dried for research and commercial purposes at several location around the states, including Smithton, Launceston, Hobart and the Huon Valley. *Tyre-tract* stain was first noticed during a large scale milling trial at Britton Timbers at Smithton in 2018 and impacted a significant portion of the material. As plantation Shining gum is an economic importance resource for the future of the Tasmanian hardwood sector, this audit sought to determine if this discolouration was an isolated problem or likely to be an on-going quality issue. Auditing discolouration in E. nitens is relatively simple. Milled Shining gum boards are generally an even pale straw colour while affected timber has grey-brown marks visible the planed surface. Discolouration is visible and present, or it is not.

Methodology

To determine the extent of discolouration, audits were conducted of CSAW's research stock of E. nitens board and sawn E. nitens material was monitored in industry facilities during regular site visit, quality audits and processing trials.

Results

Tyre track (or blue stain) is uncommon in Shining gum board. It was only found in two occurrences: in the Britton Timbers milling trial in 2018 and one batch of CSAW research material. It was not visible in the remainder of CSAW's dressed research stock or reported in subsequent milling at Britton Timbers.

In the 2018 trial, the incidence of stain was extensive and suppressed market recovery considerably. It occurred at differing levels through all drying treatments, board sizes and grades. As reported below, biotic assessment of the affected material attributed the stain to blue stain fungus, and this likely occurred due to very wet conditions at the mill during drying. The timber was milled in April 2018, and as shown in Figure 19, the autumn and winter rainfall in Smithton in that year appears abnormally high.

The occurrence of blue stain in the CSAW research material was uncovered when boards milled and dried as part of a characterisation trial where milled as part of a later machining trials in 2022. A review of this material's handling during processing indicated that the green boards had been stored in plastic and exposed to the elements for some time over summer, creating conditions conducive to mould ground. Blue stain was not observed in similar E. nitens processed at the same time but racked in normal production timelines.

Conclusion

Plantation E. nitens appears to be is susceptible to blue stain fungi if stored in damp conditions during the early stages of drying. Given the timber's pale straw colour, blue stain's impact on the material's planed surface is readily apparent and market limiting.

Recommendations

Blue stain management should become a part of normal operating procedures in E. nitens processing facilities.

Tyre-track and blue stain can be avoided by:

- Racking the timber as soon as possible after milling and storing it in favourable drying conditions in normal production timelines.
    - Avoid storing appearance board in green packs for extended periods generally. Particularly avoid storing it in plastic in exposed locations.
- Maintain mould-limiting practices and hygiene on site.
    - Store unseasoned timber clear of the ground, limit standing water, remove green waste material, and ensure adequate air flow under packs, especially in autumn and winter.
    - Anti-sap stain dips may be required on site with poor ventilation or hygiene characteristics.

Blackwood audit and assessment

Sticker mark in Tasmania primarily affects Blackwood (*A. melanoxylon*), one of state's major special species timbers. While these marks can occur in eucalypt hardwood, their occurrence in Tasmanian mills is rare and not reported during the study. However, in Blackwood, *sticker mark* is a persistent and ongoing problem. It affects a significant portion of boards in most production runs and results in considerable economic loss. Boards with *sticker mark* have to be reworked into an acceptable product, reducing effective volume and increasing production cost, or sold at a discount in the market.

Effective audit and assessment of Blackwood discolouration is significantly more complicated than similar auditing of Shining gum. Blackwood is a richly coloured timber with significant natural tonal variation between boards and between earlywood and latewood bands within boards. The visual impact of individual sticker marks varies in intensity.

This stage aimed to quantify the volume of affected material, and determine any patterns to the size, shape, location or production history of affected boards during drying, and to collect representative examples of affected boards for other testing.

Methodology

This stage focused on auditing *sticker mark* in the output of representative production runs at Britton Timber's Smithton mill. Britton Timbers is the state's major Blackwood producer, sawing, and drying material at two sites: Smithton and Somerset, and dry milling and grading boards at their Smithton site. Generally, green sawn boards are racked and air-dried at the site in which they are sawn, and racks are not moved once they are placed in stacks in the drying yard until they are taken for further processing.

The Somerset drying yard has one relatively small air-drying area. As shown in Figure 3, the Smithton site has three discrete drying areas: the green mill *Smithton East* yard and the *Smithton West* around the dry mill to the west of the green mill site and the *Smithton drying shed*. In the Smithton yards, racks are stacked in rows oriented east – west.

Figure 3: Britton Smithton mill (Mark up locations)

The Blackwood audit and assessment methodology included:

- Definition of market limiting discolouration in Blackwood.
- Auditing production racks at breakdown over four seasons of input and output.
- Determining the production history of audited racks.
- Assessment of the results.

Definition of market limiting discolouration in Blackwood and E. nitens

To successfully audit discolouration, a *discolouration characterisation system* is required based on a survey of features found in dry, planed stock. This was developed through: initial interaction with industry graders; collection of representative samples of recognised discolouration types and levels; analysis of the collected samples; the development of a system of discolouration types, intensities and likely 'acceptance' boundaries; and then testing and refining this system with graders in further production.

Auditing production racks at breakdown over four seasons of input and output.

As discussed above, discolouration of different types in Blackwood appears to be season and location dependent. To quantify the amount of discolouration by season and drying location, a survey of production racks assessed the amount and types of discolouration in individual boards, the location of the discolouration in the rack, and the rack's production history.

After a literature review, a detailed methodology was established for the Blackwood rack surveys in the second half of 2020 and used in data collection during the December 2020 production run. It was subsequently revised before re-use in six production runs in March, May, June, August, October, and December 2021. As Britton Timbers saw and dry mill Blackwood in discrete runs, this breadth of dates provided sufficient information to cover seasonal variation in both sawing and racking, and in dry milling.

Prior to rack breakdown, each row and boards in the row were numbered and lettered as shown in Figure 4. This provided a location for each board in the rack. Discolouration was assessed at the individual board level and the number of lineal meters of all and grade-limiting discolouration was assessed and tallied.

Table 1 lists the data recorded during the evaluation and assessed for stain volume and type and location against rack history and other site factors.

Figure 4: Board numbering in preparation for rack breakdown and data collection

Figure 5: Blackwood rack breakdown

Table 1: Data collected

Item	Item
Rack Number.	Board dimensions.
Maximum alphanumeric board number.	Date the timber was racked.
Evaluation date and time.	Board length.
Amount of board affected by discolouration, (recorded as quartiles).	Alphanumeric board number (where present).
Type of observed discolouration.	Board orientation in the rack.
Severity of discolouration.	

Other information obtained where possible about the rack's production history included:

- For logs: the date the logs were harvested and milled. These establish the log storage period.
- For racks: the total linear meters of timber in each rack; rack location within each yard; rack location within each stack; and rack orientation in the yard.

The data from the audits was entered into spreadsheets manually. These contain information on each discoloured board. This data is interrogated using Python programming language using several plugins that add database, plotting and statistical functionality.

Results

Definition of market limiting discolouration in Blackwood

A discolouration classification system was developed as part of the December 2020 survey and refined during the March 2021 survey. See Figure 6. This classification includes:

- Light sticker mark 1: Shallow discolouration that can be planed out.
- Light sticker mark 2: Light bands in darker stain ’pools”, observed in weathered packs.
- Dark sticker mark 1: Dark sticker mark that appear to penetrate through the timber and cannot be planed out.
- Dark sticker mark 2: Black marks at the location of the stickers that occur irregularly through the pack.
- Red sticker mark: A variant common in some racks but entirely absent in others.

Figure 6: Blackwood sticker mark types

The classifications were then used in the assessment of production runs.

Assessed discolouration rate

Racks surveyed by factors influencing the average discolouration rate

Primary factors likely to influence the discolouration rate include:

- The air-drying location. Material from four separate drying locations were identified and tracked through the audit sessions. These were: 1a - Smithton East; 1b - Smithton West; 1c - Smithton Shed; and 2 - Somerset.
- The board thickness. Racks of 25, 35 and 50 mm thick material of various width were accessed
- The season the logs were sawn and racked. Seasons were aligned with Bureau of Meteorology (BOM) definitions: Spring from September 1 to November 30; summer from December 1 to February 28; autumn from March 1 to May 31, and winter from June 1 to August 31.
- The drying duration - the length of exposure in the yard.

The grade-limiting discolouration rate is the percentage of lineal meters of unacceptable discoloured board in a rack, and indicates likely value loss.

152 racks were surveyed from across these locations. See Table 2 and Figure 7. Of these, 30% were 25 mm thick board, 42% were 38 mm thick, and 28% were 50 mm thick board. Figure 8 shows the spread of board dimensions between the surveyed. For these locations, 28% were racking in summer, 21% in autumn, 27% in winter and 24% in spring. See Table 3 and Figure 9. The surveyed racks contained 30,156 boards with a total of 139,400 lineal metres of timber. See Table 4.

Table 2: No. of assessed racks by drying location and thickness.

Drying location	All racks	25 mm	38 mm	50mm
All locations	152	46	64	42
1a - Smithton East	92	38	24	30
1b - Smithton West	14	0	2	12
1c - Smithton Shed	14	0	14	0
2 - Somerset	32	8	24	0

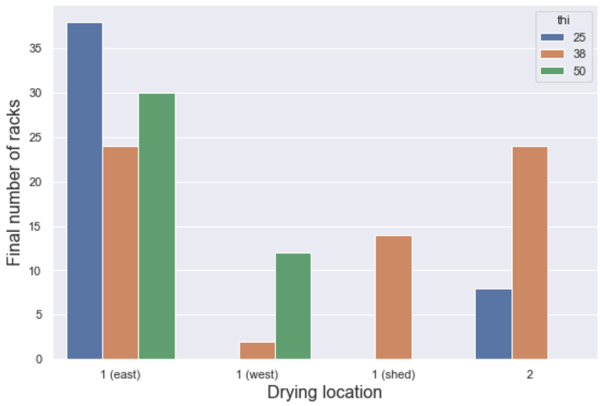

Figure 7: Assessed racks by drying location and thickness.

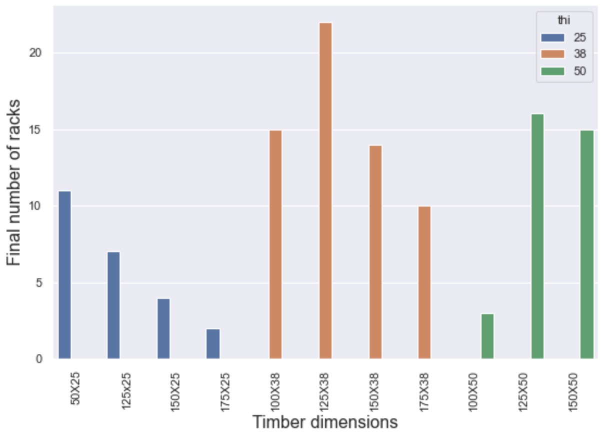

Figure 8: Assessed racks by board dimension.

Table 3: No. of assessed racks by drying location and milling season.

Drying location	Summer	Autumn	Winter	Spring
All locations	83	30	28	11
1a - Smithton East	65	17	9	1
1b - Smithton West	2	3	9	0
1c - Smithton Shed	14	0	0	0
2 - Somerset	2	10	10	10

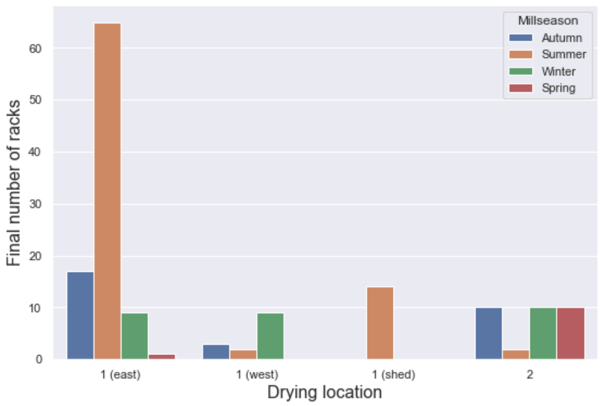

Figure 9: Assessed racks by drying location and milling season.

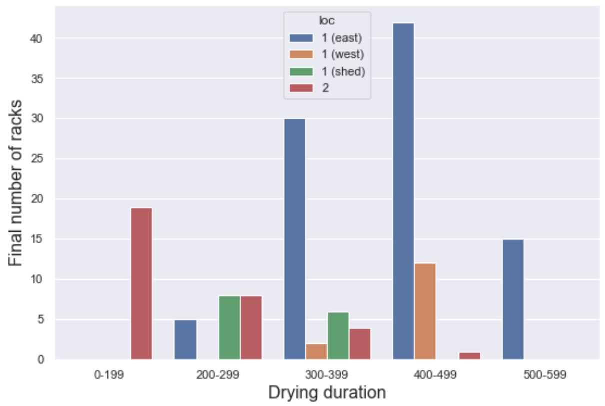

Figure 10: Assessed racks by drying location and drying duration

Table 4: Length, number and thickness of assessed boards.

Board dimension	Linear meters	% meterage	No. of boards	% board
25	64,833	47%	12,389	41%
38	47,438	34%	11,508	38%
50	27,132	19%	6,259	21%
Totals	139,403	100%	30,156	100%

For these locations, drying duration varied considerably. See Table 5 and Figure 10. The shortest average drying duration was in Somerset while the standing time in the Smithton East and West drying yards was of similar average duration.

Table 5: No. of assessed racks by drying location and drying duration.

Drying location	0-199 days	200-299 days	300-399 days	400-499 days	500-599 days
All locations	19	21	42	55	15
1a - Smithton East	0	5	30	42	15
1b - Smithton West	0	0	2	12	0
1c - Smithton Shed	0	8	6	0	0
2 - Somerset	19	8	4	1	0

Grade-limiting discolouration rate by location and board thickness

Table 6 and Figure 11 show the average discolouration rate in audited racks by site and by board thickness. In all, 22.9% of the assessed board length had grade-limiting discolouration. This represents nominally 32,000 lineal meters of discoloured bards. The discolouration rate is:

- 19.5% on average for 25 mm thick, or 12,640 lineal metres of board.
- 27.4% for 38 mm thick, or 13,000 lineal metres.
- 19.8% for 50 mm thick board, or 5,400 lineal metres.

The highest discolouration rate is for 38 mm material dried in Smithton east and west.

Table 6: Racks by location, thickness and average rate of grade-limiting discolouration.

Drying location	Average rate of grade-limiting discolouration (%)			
	All racks	25 mm	38 mm	50mm
All	22.9	19.5	27.4	19.8
1a - Smithton East	25.0	20.2	36.9	21.4
1b - Smithton West	18.3	n/a	33.3	15.8
1c - Smithton Shed	20.8	n/a	20.8	n/a
2 - Somerset	19.9	16.1	21.2	n/a

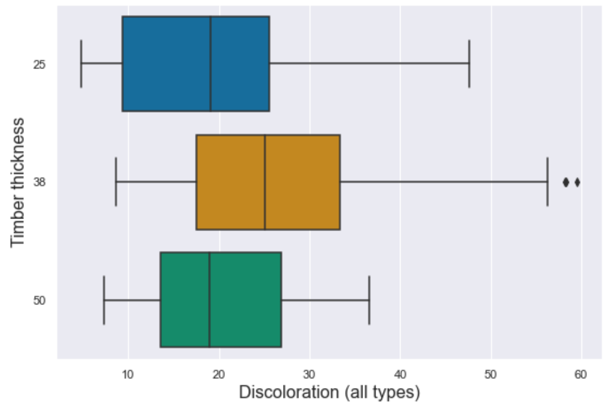

Figure 11: Racks thickness and average rate of grade-limiting discolouration.

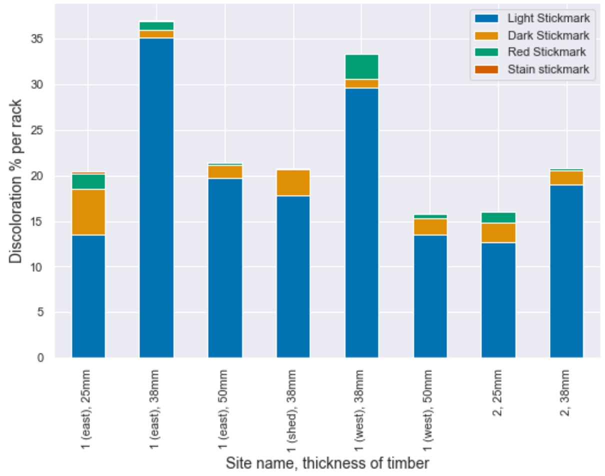

Figure 12: Racks by location, thickness, rate of grade-limiting discolouration and type.

Proporition of grade-limiting discolouration by variant

Sticker marks occur in three grade-limiting variants: Light, Dark and Red, plus a rare stain. Individual racks can contain each of these variants and the occurrence rate varies between racks. Table 7 and Figure 12 shows that light sticker mark is the dominant sticker mark type at all sites, particularly in 38 mm material.

Table 7: Drying site and average rate of grade-limiting discolouration by type.

Drying location	Average rate of grade-limiting discolouration (%)			
	Light	Dark	Red	Stain
1a - Smithton East	21.19	2.74	1.02	0.10
1b - Smithton West	15.77	1.76	0.78	0.03
1c - Smithton Shed	17.85	2.82	0.14	0.00
2 - Somerset	17.40	1.72	0.49	0.03

Grade-limiting discolouration rate by location, milling season, and drying duration

As outlined above, the breadth of audit dates provided sufficient information to cover seasonal variation in both sawing and racking, and in dry milling. However, some care is required in assessing seasonal factors on discolouration rate as the board's production history involves:

- The sawn green board being racked and exposed to the elements in the drying yard.
- A drying period where the board dries first to its fibre-saturation point (FSP). At this point, it can progress to further processing, or be held to an air-dry state, in equilibrium with ambient conditions.
- A storage period where the air-dry timber is held in rack in the yard until scheduled for the next stages of production and milling.
- The board being reconditioned, kiln dried and dry milled.

While the racking and dry-milling date are known, the drying and storage periods of each rack are difficult to estimate. The drying period varies with at least the ambient climatic conditions and the board's thickness, while the storage period begins when the board reaches FSP and ends at the date when it progresses for final drying. Market demand for specific dimension and grade of boards and other production factors will often influence this.

Table 8 and Figure 13 show the average discolouration rate in audited boards by drying location and the season of sawing and racking. In all, 24.2% of boards racked in summer, 16.6% racked in autumn, 17.3% racked in winter, and 26.5% racked in spring were discoloured. The highest discolouration rate was Summer milled material dried at Smithton west. The lowest was in Winter milled material dried at Smithton East, and Somerset material milled in Summer and Autumn.

Table 8: Racks by location, milling season and average rate of grade-limiting discolouration.

Drying location	Average rate of grade-limiting discolouration			
	Summer	Autumn	Winter	Spring
All	24.2	16.6	17.3	26.5
1a - Smithton East	26.3	23.5	15.3	28
1b - Smithton West	33.3	9.9	17.8	no data
1c - Smithton Shed	20.8	no data	no data	no data
2 - Somerset	16.5	16.4	18.9	25

Table 9 and Figure 14 show the average discolouration rate in audited boards by drying location and nominally drying duration. The highest discolouration rate was for Smithton East material, particularly held for a 200 – 299 day duration.

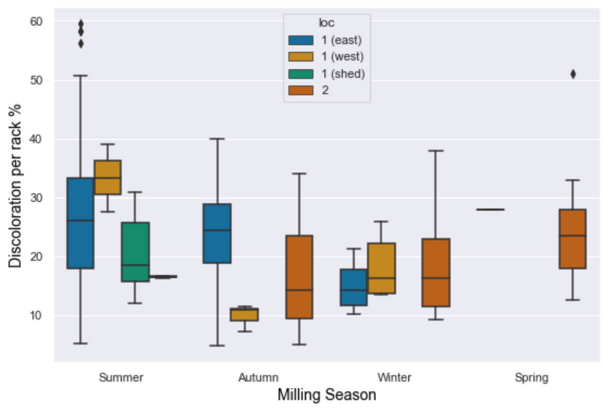

Figure 13: Racks by location, milling season and average rate of grade-limiting discolouration.

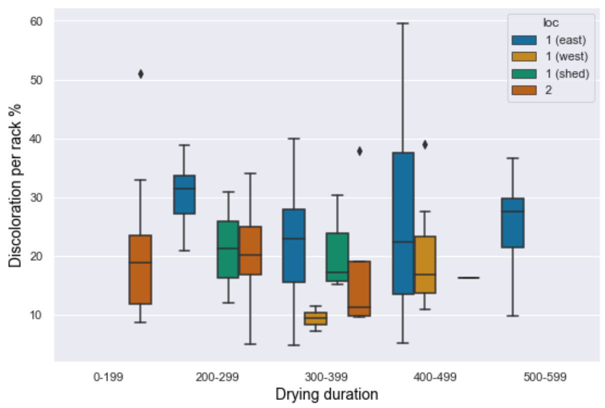

Figure 14: Racks by location, drying duration and average rate of grade-limiting discolouration.

Table 9: Racks by location, drying duration and average rate of grade-limiting discolouration.

Drying location	0-199 days	200-299 days	300-399 days	400-499 days	500-599 days
1a - Smithton East	0.0	30.4	24.5	25.2	
1b - Smithton West	0.0	0.0	18.3	0.0	
1c - Smithton Shed	0.0	21.2	20.3	0.0	
2 - Somerset	20.4	20.4	17.3	0.0	

Grade-limiting discolouration rate by board thickness, milling season, and drying duration

Table 10 and Figure 15 show the average discolouration rate in audited boards by thickness and the season of sawing and racking. The highest discolouration rate was in 38 mm material milled in Summer

Table 10: Racks by board thickness, milling season and average rate of grade-limiting discolouration.

Board thickness	Average rate of grade-limiting discolouration			
	Summer	Autumn	Winter	Spring
25 mm	17.9	23.4	17.3	17.7
38 mm	30.5	17.6	19.3	28.3
50 mm	25.2	15.9	16.6	28.0

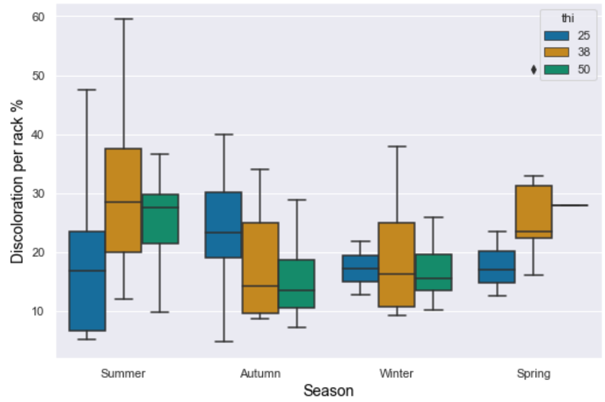

Figure 15: Racks by board thickness, milling season and average rate of grade-limiting discolouration.

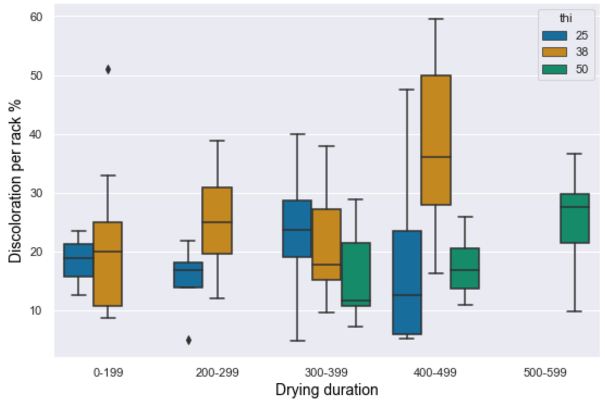

Figure 16: Racks by board thickness, drying duration and average rate of grade-limiting discolouration.

Table 11 and Figure 16 show the average discolouration rate in audited boards by board thickness, drying location and nominally drying duration. The highest discolouration rate was for 38 mm material with a 400-499 drying duration.

Table 11: Racks by board thickness, drying duration and average rate of grade-limiting discolouration.

Drying location	Average rate of grade-limiting discolouration				
	0-199 days	200-299 days	300-399 days	400-499 days	500-599 days
25 mm	18.4	15.1	23.5	16.7	0.0
38 mm	20.8	25.0	21.2	38.2	0.0
50 mm	0.0	0.0	16.1	17.2	25.2

Grade-limiting discolouration rate by board thickness and date of sawing and racking

While seasonal variations are likely to influence the discolouration rate, the actual conditions that batches of material experienced will vary with the date of sawing and racking. Table 12 and Figure 17 show the average discolouration rate in audited boards by board thickness and the date of milling.

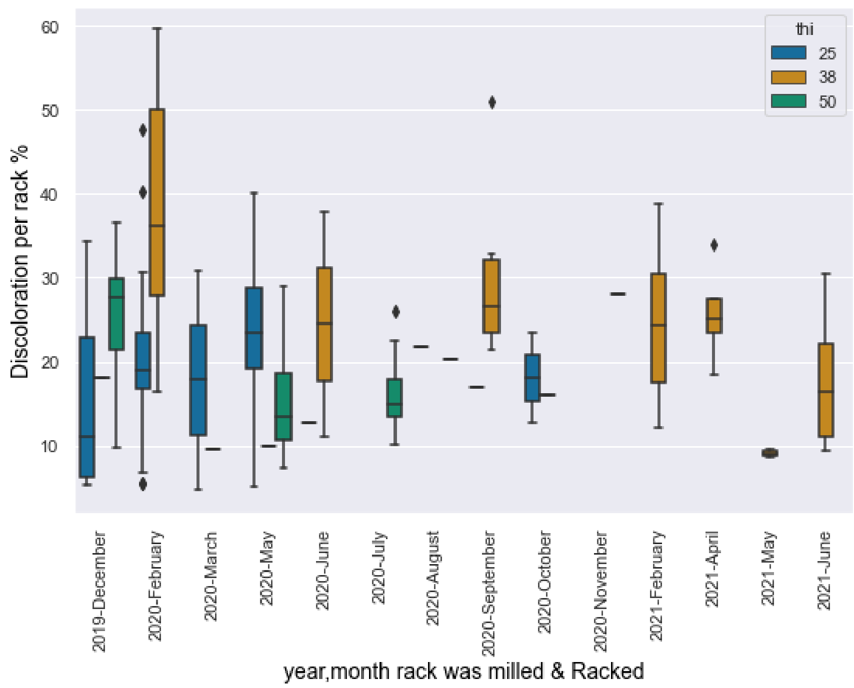

Figure 17: Assessed racks by date of sawing and racking, thickness and grade limiting discolouration rate.

Table 12: Racks by date of sawing and racking, thickness and grade limiting discolouration rate.

Month of sawing and racking.	Average rate of grade-limiting discolouration		
	25 mm	38 mm	50mm
2019-December	14.7	18.0	25.2
2020-February	21.3	38.2	0.0
2020-March	17.8	9.6	0.0
2020-May	24.3	10.0	15.9
2020-June	12.8	24.5	0.0
2020-July	0.0	0.0	16.4
2020-August	21.8	0.0	20.2
2020-September	17.0	30.3	0.0
2020-October	18.1	16.1	0.0
2020-November	0.0	0.0	28.0
2021-February	0.0	23.9	0.0
2021-April	0.0	25.7	0.0
2021-May	0.0	9.1	0.0
2021-June	0.0	17.6	0.0

Characteristics of 38 mm material with high grade-limiting discolouration rate

Two apparent groups of material have significantly higher average discolouration rates and an investigation of their processing may provide indicators of means to limit discolouration. These are:

- The 38.2% discolouration rate for 38 mm material milled in February 2020 from Table 12.
- The 38.2% discolouration rate for 38 mm material with a 400-499 drying duration from Table 11.

The audit information indicates that the two groups are the same racks of timber from a block of 31 racks of Blackwood milled at Britton Timbers at Smithton in runs between February 3 and March 6, 2020. Four additional racks were milled in the same period at Somerset, and all had low or average discolouration rates.

A subset of 20 Smithton-milled racks had a discoloration rate above 25%. Their characteristics were:

- Sixteen of the highly discoloured racks were 38mm thick and four were 25mm thick timber. Six racks were100 mm wide boards, 10 racks were 125mm wide, and 4 racks were 150mm wide material.
- The average log age for material into the discoloured racks (the duration the log had been stored in the log yard prior to milling) was 567 days, with a high of 668 days.
- Their average drying time for the racks was 415 days, with a maximum of 426 days and a minimum of 408 days.
- Eighteen of the racks were dried at site 1a (east) while two were dried at site 1b (west). Of the site 1a (east) racks, all were dried between rows 9 and 16. See Figure 18. 14 were stacked on the southern side of the double rows.
- Six racks were on the bottom of their respective stacks with the remaining 14 placed as the second rack. There is no noticeable difference in discolouration between the bottom and second rack is this subset. None of the 35 racks of this block were dried any higher than the second rack.
- The ratio of discoloration types appears similar to the average rack results. The high discoloration level is the main distinguishing factor.

By comparison. the characteristics of the 11 low discolouration racks milled in this block at Smithton were:

- Four were thin 50x25 mm boards.
- The average log age was 527 days, similar to the highly discoloured material.
- All were dried at site 1a (east). Nine were dried on the northern side of the double row.

Climate may have contributed to the high discolouration rate. The period immediately after milling in late summer and autumn 2020 had particularly high rainfall. This is evident in the BOM data charted in Figure 19.

Figure 18: Drying area for the highly discoloured racks in Site 1a (east)

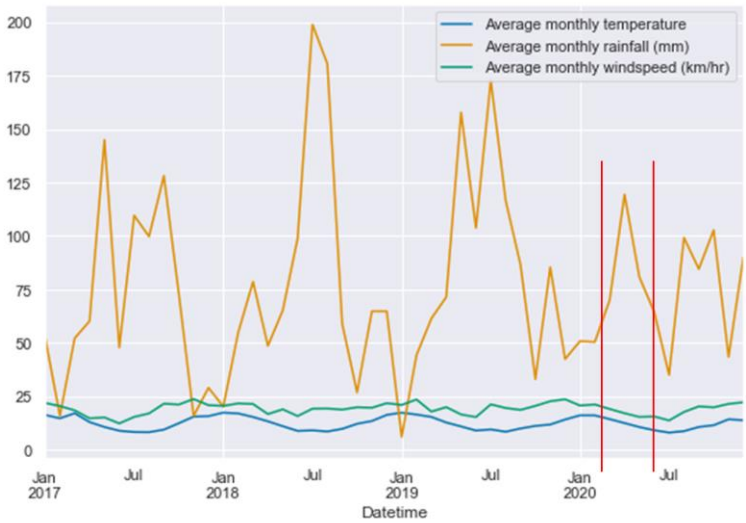

Figure 19: Summary BOM climate data for Smithton

Economic impacts

In Blackwood, *sticker mark* is a persistent and ongoing problem. It affects a significant portion of boards in most production runs and results in considerable economic loss.

Industry indicates two economic effects from discolouration. Material discoloured with sticker mark is downgraded from Select to Standard grade product, and discounted by approximately \$2,000 /m^3. Alternatively, material discoloured with sticker mark can be re-worked, accepting a 20% loss in volume, and then sold at the higher price. However, a portion will still be downgraded and receive the discounted price.

The audit surveyed approximately 580 m^3 of board. Given the measured discolouration rate averaged 22.9%, 133 m^3 of the surveyed material had grade-limiting discolouration. If 75% of that material was sold at a discounted grade, and 25% reworked to a smaller size, with 20% of the reworked material still being sold at a discounted grade, the economic loss on the surveyed racks due to grade-limiting sticker mark is approximately \$240,000.

If the Tasmanian industry produces approximately 25,000 m^3 of Blackwood per annum and the overall discolouration rate is consistent with the survey results, the total annual economic loss from Blackwood discolouration is approximately \$1.05 million per annum.

Discussion

Discolouration in Blackwood is detected in dry boards when their surface is dressed. Prior to this, the board progresses through a production process where:

- It is sawn from logs of varying age. They may come from straight off the truck or be stored for up to 700 days in the log yard.
- It is racked and positioned into one of several air-drying yard, dried and then often stored in the open air for total periods from 200 but regularly up to 450 days.
- It is subject to the ambient drying conditions during this period as the timber progresses from green to being stored air-dry for further production.

Each of these stages introduces numerous variables that may contribution to grade-limiting changes in the wood's colour. As it is not possible to assess board discolouration in racks during the production process, a discolouration audit was conducted across seven processing runs from December 2020 to December 2021. It aimed to collect sufficient information about the timber and the production processes across seasons to indicate potential causes for grade-limiting discolouration.

As part of this audit, a discolouration classification system was developed and shown in Figure 6. The grade limiting types of sticker mark in this classification including: light sticker mark 2; dark sticker mark 1; dark sticker mark 2; and red sticker mark.

The audit surveyed 152 racks contained 30,156 boards with a total of 139,400 lineal metres of timber. In all, 22.9% of the assessed board length had grade-limiting discolouration. This represents nominally 32,000 lineal meters or 133 m^3 of discoloured boards

Four primary factors likely to influence the discolouration rate were explored in this report: air-drying location; the board thickness; the season the logs were sawn and racked; and the drying duration. These assessments showed that each of these factors did have impacts.

- Generally, discolouration rates appear lower at the Somerset site compared to the Smithton sites.
- 38 mm thick material dried at Smithton outside of the shed has a particularly high discolouration, as does 38 mm material milled in summer.

However, the general scatter in the results indicate that it is highly unlikely that any of these factors in isolation is determining the discolouration rate. The characteristic of the 38 mm material with high grade-limiting discolouration rate discussed above indicates that potential factors may include the climate during initial drying, the rows in which the racks are positioned (sunny side or shaded side), and potentially the average drying time. Even given this information, it is equally possible that discolouration mechanisms could have impacted the timber:

- In shaded location during the high-rain period during its initial drying in late summer of 2020
- At some later time during the 400 days that the timber sat in the shaded racks.

To progress this, the project's higher degree research (HDR) student, Mr Rhys Tanton, is reviewing the audit results using multivariable assessment techniques. The results of this will be reported in publication during his candidature and in his thesis.

Biotic & chemical assessment of board discolouration

Chemical or biological features can contribute to sticker mark and tyre track. *Tyre-track* is a form of blue-stain that appears as a regular greyish mark on parts of the board. Sticker mark may result from a mobilisation of water soluble extractives in the wood and their concentration (or depletion) at or near rack sticks, or the oxidation due to contact with the air or local climatic conditions. Biological agents may also occur with these concentrations. In combination, these features change the colour of the affected areas to an unacceptable extent.

Biotic testing

This component aimed to determine if any correlation could be drawn between the stain symptoms and the presence of fungal or bacterial species in boards from plantation Shining gum and native forest Tasmanian Blackwood. It followed supply of discoloured and controlled sample of plantation hardwood to an external wood scientist, Dr Jugo Ilic and his identification of blue stain fungus as the cause of the 'tyre track' discolouration.

Methodology

Samples of discoloured and control material were collected as part of the development of the discolouration characterisation system detailed above. From this material set, representative samples of known origin and location were prepared for biotic and chemical testing.

Fungi and bacteria associated with discoloured and unstained wood were detected without isolation by extracting DNA from samples with and without the staining followed by amplification and sequencing of barcode genes for fungi and bacteria.

DNA was extracted from 23 samples with a range of stain defects and from control (unstained) samples. DNA barcode regions for fungi (rDNA ITS) and bacteria (18S rDNA) were amplified and sequenced on an Illumina Miseq at the Australian Genomics Research Facility. Illumina reads were grouped into operational taxonomic units (OTUs) based on sequence similarity and the number of reads for each OTU recorded.

Results

The number of reads per sample ranged from 47,070 to 138,001 for bacteria and from 1 to 68,489 for fungi. Nine of the 23 wood samples had an unacceptably low number of fungal reads (1-11), eleven samples had a low but acceptable number of reads (1,866 - 9,745) while the remaining three samples produced a minimum of 20,000 reads. Unacceptably low read numbers occurred in all defect classes except for the grey discolouration on the dressed face of *E. nitens*.

Fungal Species

The two tree species supported different fungal communities, with 61 fungal species in *E. nitens* and only 24 in Blackwood, of which only six had relative abundances over 1%.

The fungal species detected in *E. nitens* were dominated by members of the Eurotiales, a group of filamentous fungi that includes well-known and ubiquitous mould genera such as *Aspergillus, Penicillium* and *Byssochlamys*. Of the 21 fungal species that constituted at least 1% of the reads in any sample, 17 were members of the Eurotiales. The exceptions included two basidiomycetous yeasts; *Malassezia restricta* occurred in two of four samples with grey discolouration on the dressed face (Nitens_TT_2 and Nitens_TT_Shed_S1) and *Sporobolomyces johnsonii* was a minor component (1.6% of reads) in one sample with yellow stain (Nitens_YS_4).

Byssochlamys spectabilis was detected as a major component of the fungal community in approximately half of the *E. nitens* samples, with or without defect, though the relative abundance was higher in stained samples (77-99%) than in the control sample (16%). This species is an endophyte, previously isolated from grapevines, and capable of producing pigmented secondary metabolites including viridins (Lopez-Fernandez et al., 2020). Other members of the Eurotiales produce a range of pigmented secondary metabolites, including ochratoxin, melanin and citrinin. Thus, though there is no clear association of one particular fungal species with the stain defects, it does not exclude the possibility that there may be a suite of fungi involved and production of the pigmented compounds is triggered by certain environmental conditions.

Bacterial species

The number of bacterial species was greater than fungal species with 241 overall, 106 in Blackwood and 149 in *E. nitens*. Despite the low percentage of bacterial species that occurred in both Blackwood and E. nitens, the three most abundant species were the same in both timbers. The most abundant, a species of *Blastococcus*, was detected in all samples. The second most abundant, *Bradyrhizobium elkanii,* was detected in all bar one of the Blackwood samples and all bar one of the E. nitens samples. The third most abundant bacterial species, *Cutibacterium* sp., was detected in all of the Blackwood samples with pale sticker marks (13.9 to 21.4% of reads) and also in one of the control samples, between dark sticker marks (10.6% of reads). In *E. nitens, Cutibacterium* sp. occurred in one of the control samples, two samples with yellow stain and two with grey discolouration on the dressed face. Most of the remaining bacterial species were each detected in a single sample.

Discussion

Results were inconclusive and recommendations included:

- No clear association of any fungal species with the stain defects has been identified, though conclusions are constrained by the low read count from nine of the samples.
- A potential association between Eurotiales and staining of E. nitens and A potential association between *Cutibacterium* sp. and discolouration in Blackwood could be explored further.

Chemical testing

Wood is generally composed of four broad chemical components: cellulose, hemicellulose, lignin and extractives. Extractives can be divided into three major subgroups according to their chemical composition: aromatic phenolic compounds, aliphatic compounds (fats and waxes), and terpenoids. The phenolic compounds can be sub-divided into four groups: lignans, stilbenes, flavonoids and tannins. Flavonoids and tannins are responsible for the colour, fragrance, and flavour characteristics of the wood.

Wood components can be readily degraded by a combination of processes with interactions between UV-visible light, moisture, temperature, oxygen and air pollutants. Specifically, oxidation of flavonoids yields compounds such as O-quinones and coupling (polymerisation) products such as condensed tannins, which are usually coloured compounds.

In this component, chemical assessment was undertaken in identifying chemical anomalies within the surface of the Blackwood *(Acacia melanoxylon*) with sticker marks with the deployed methodology developing as results were achieved and analysed. As a result, three study were undertaken, namely:

- Study 1. Identification of chemical differences in Blackwood board and sticker marks using GC-MS
- Study 2. Confirmation of mome-inositol role in Blackwood board and sticker marks using GC-MS
- Study 3. Phenolic extractives of Blackwood board

Study 1. Identification of chemical differences in Blackwood board and sticker marks using GC-MS

This initial study sought to develop appropriate and robust small-scale sampling / extractive techniques for exploring the chemical anomalies within the Blackwood samples' surface. This was completed and a novel, small scale sampling/extraction approach/protocol was established, which when applied, demonstrated that three dominant compounds were consistently extracted in ethanol, and could be separated by GC-MS from the tested Blackwood samples. From their mass spectra, the three compounds were identified as mome inositol (sugar/polyalcohol) and derivatives of stigmasterol and ergosterol (phytosterols).

From multiple extractions of a wide variety of sticker mark affected Blackwood boards, qualitative assessment of GC-MS chromatograms obtained has demonstrated that mome inositol peaks were consistently and significantly smaller from extracts of sticker mark affected areas, compared to the adjacent face region (n=12), whereas minimal variation was observed in the peaks associated with phytosterols.

Methodology

Microscopy has previously shown accumulation of darker material in the grain of the surface, planed face regions, when compared to the grain of sticker mark regions of Blackwood. Targeted sampling of these grain regions using a needlestick, allowed collection of 30 mg of sample be obtained and subsequently extracted in small volume of ethanol using the developed method, sonicated and filtered prior to instrumental analysis (GC-MS).

Results and Discussion

Mome inositol is a common plant constituent, reported in water and ethanol extracts from seed, leaves and stems. Qualitative analysis of chromatograms indicates that mome inositol peaks are consistently greater in the face region compared to the sticker mark from the same board (n=12 pairs of samples). From these results, there would appear to be a clear 'cause and effect', which is consistently observed, indicating this molecule could act as a chemical proxy for sticker mark.

Table 13 shows a summary of chemical compounds in ethanol extracts determined by GC-MS

Table 13: Chemical compounds detected by GC-MS in ethanol extracts of Blackwood

Peak number	Compound	Formula	Molecular weight (g/mol)	Retention time (min)
1	Mome inositol	$C_7H_{14}O_6$	194.18	25-27.5
2	Stigmasterol	$C_{29}H_{48}O$	412.69	53
3	Ergosterol	$C_{28}H_{46}O$	396.65	54

Comparison chromatograms of extracts from sticker mark and adjacent face regions revealed smaller peaks of mome inositol in the sticker mark regions. See Figure 20 and Figure 21.

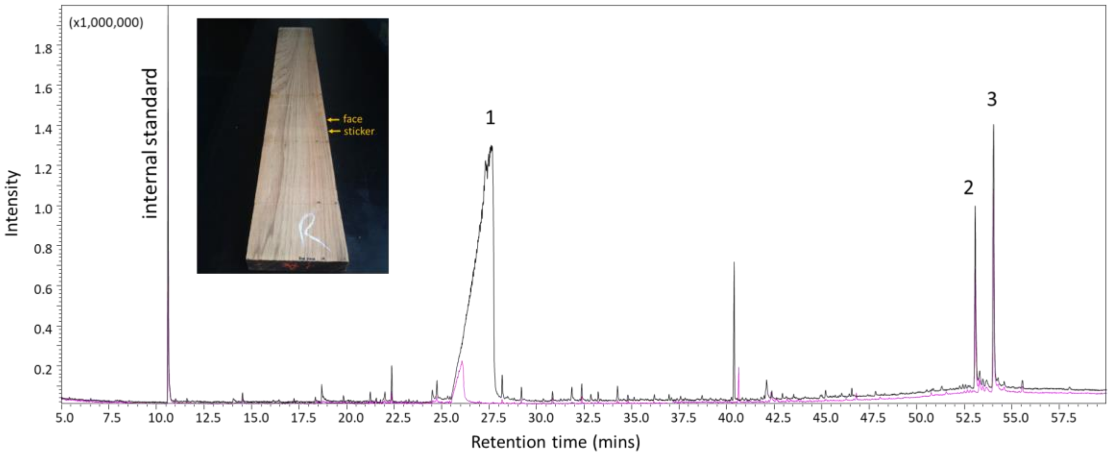

Figure 20: Comparative chromatograms of extracts samples from face (black) and sticker (pink) regions (inset Board 1A(iii) described as pale sticker marks)

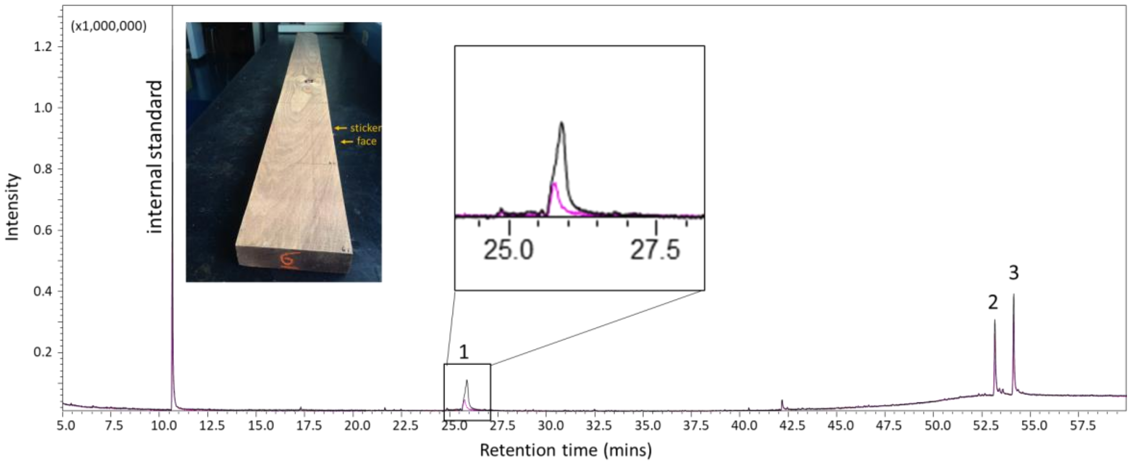

Figure 21: Comparative chromatograms of extracts from face (black) and sticker (pink) (inset Board 6(v) described as 'dark' sticker)

A separate confirmatory analysis of water extract of Blackwood (LC-MS with sugar selective column) also identified a single compound of Mwt 194.12, $C_7H_{14}O_6$ in support of mome inositol identification.

Conclusions

There appeared to be an association between the general amount of mome inositol in the face and the extent (or contrast) of discolouration. For example, the Blackwood described with 'pale stickers', with greater contrast in discolouration between face and sticker appeared to have greater mome-inositol in the face region, whereas the Blackwood described with 'dark stickers', and less 'discoloured' appearance had less mome-inositol in general.

Study 2. Confirmation of mome-inositol role in Blackwood board and sticker marks using GC-MS

Briefly, the results of Study 1 indicated that different chemical processes were occurring in face and sticker regions delivering different extractable concentrations of the above chemical species. However, the technique of sampling material from boards used in those initial studies needed optimisation, and further analysis to evaluate the significance (if any) of mome-inositol in the discolouration process was required. However, a direct relationship between different colouration of the face and sticker regions vs specific chemical markers detected by GC-MS couldn't be achieved.

Methodology

An alternative Blackwood sampling technique was developed where visible sticker marks were demarcated from the face regions using a blade before shaving with a hand plane (N° 12). Sample thickness of shavings was approximately 100 µm.

Samples (30 mg) were shaved, extracted in 2 mL of ethanol, sonicated and filtered prior to instrumental analysis (GC-MS). Blackwood specimens with 'pale' sticker marks were selected, and sticker marks and adjacent face regions (total 9 pairs in Figure 22) were analysed in duplicate (total number of tests n = 36).

Figure 22: Pale sticker marks on Blackwood boards. Samples were shaved from sticker mark and face regions

The density and moisture content (MC) of boards not suited to sampling with needle stick (Board 4 and 6) were determined in duplicate using Australian Standard (AS) 1080.1:1997. A board that was amenable to the needle technique (i.e., Board 3) was included for comparison (Table 14).

Table 14: Physical properties of Blackwood boards designated 'pale' sticker marks

Specimen	Density (kg/m$^{3)}$	Moisture content (%)	General Colour appearance
Board 3	380 ± 0.1	6.7 ± 0.1	Brown and blonde
Board 4	600 ± 20	6.9 ± 0.1	Reddish
Board 6	502 ± 0.6	7.6 ± 0.1	Reddish

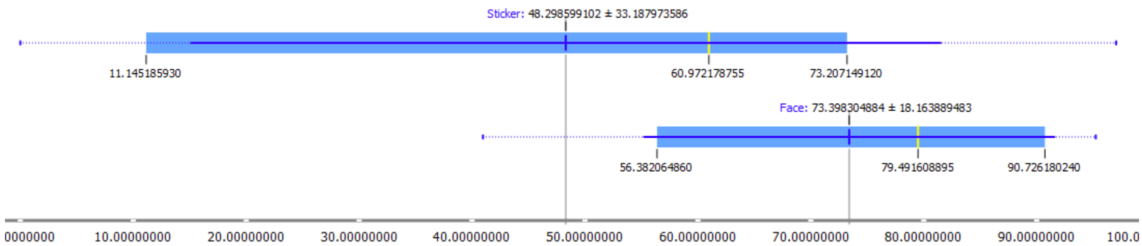

Figure 23: Box plot of area % of mome-inositol of sticker mark vs face regions (n = 36)

Results and Discussion

Peak areas from mome-inositol and two phytosterols derivatives (phytosterol[a] and phytosterol[b]) were obtained from GC-MS chromatograms and assessed using Orange Mindat software. The relative peak area (%) for each compound was determined and sticker mark and face region pairs compared. The box plots (Figure 23) show the median peak area (%) of mome-inositol to be smaller in the sticker mark compared to the face region, i.e., 61.0 and 79.5 %, respectively. The mome-inositol mean relative peak area (%) was also smaller in the sticker mark (48.3 ± 33.2 %) compared to the face region (73 ± 18.2 %), however the mean standard deviations were substantial and thus requires further assessment to confirm the statistical relevance of the differences identified.

Conclusions

The lack of complete clarity in the correlation between mome-inositol and sticker mark discolouration may be due to several reasons. Firstly, the alternate sampling method does not target the material contained in the grain of the wood. Physical properties of the wood itself, particularly density, and variation of grain orientation were found to be important factors in sampling technique given the small amounts excised for the instrumental techniques used here within. Secondly, the number of compounds which can be detected by GC-MS is typically limited to low polarity, low molecular mass compounds. Lastly, mome-inositol is a ubiquitous compound reported in major abundances in aqueous, ethanol and methanol extracts in seed, stem and leaf of various species in pharmacological context. Little, if any, information on regarding the structure or degradation products of mome-inositol in oxidation processes relevant to Blackwood discolouration processes is reported in the literature.

Study 3. Phenolic extractives in Blackwood board

This third study investigated alternative chemical markers, namely flavonoids, which could be related with changes in wood surface colour and which were not detectable using the GC-MS methodology. Three different analytical techniques, i.e., spectrophotometric analysis, liquid chromatography coupled with UV-vis and mass spectrometry detection (LC-DAD-MS) and high resolution-accurate Orbitrap mass spectrometry (HRAM-Orbitrap-MS), were applied to the wood extract samples. The results of this final study demonstrated several clear relationships between the concentration of certain chemical species identified and the sampled area (face or sticker mark) of the board.

Methodology

Additional Blackwood specimens were obtained to carry out this study. The specimens received contained sapwood and were considerably darker and redder in colour appearance compared to previous specimens. When received, dark sticker marks were apparent on 2 of the 10 boards (16th May 2022). Ten days later, the boards developed lighter colouration and sticker marks were apparent on an additional 4 boards. A total 8 sticker marks and face regions pair (total of 16 samples) were sampled. See Figure 24.

The density and MC of boards were determined using AS 1080.1:1997. Wood samples (30 mg) were shaved from the boards and placed in a glass vial. Deionized water (DIW, 2 mL) was then added to the vial and extraction was performed using an orbital shaker for 19 hours with light excluded.

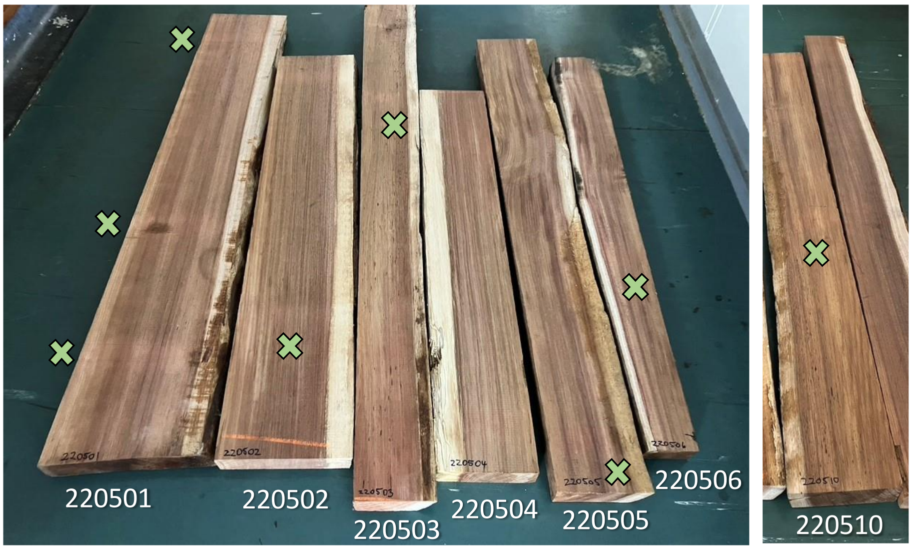

Figure 24: Dark sticker marks on Blackwood boards. Samples were shaved from sticker mark and face regions marked by green cross

After extraction, spectrophotometric analysis of the filtered water extracts was carried out to obtain the UV-vis absorbance spectra between 380 to 600 nm, where coloured compounds typically exhibit maximum absorbance. The main focus of this study was the analysis of the water extracts using liquid chromatography (LC) coupled with spectrophotometry and mass spectrometry detectors, namely a diode array detector (DAD) and a single quadruple mass spectrometer (SQ), respectively. LC was used to separate the mixture of compounds extracted from the wood samples based on the different retention times of each compound on the chromatographic column. Each separated compound was then analysed using the DAD, which provided the UV-vis spectrum of each individual compound connected in series with the SQ mass spectrometer, which provided the mass spectrum for each compound.

Selected samples were further analysed using high resolution accurate mass-Orbitrap-mass spectrometry (HRAM-Orbitrap-MS). For each compound detected, the complementary analytical information of retention time, UV-vis spectrum, mass spectrum, molecular formula and MS/MS data was obtained. Evaluating and comparing this analytical information with available literature, the identification or tentative identification of the compounds present in the water extracts from wood samples was undertaken. LC-DAD-SQ and HRAM-Orbitrap-MS methods used in this study targeted medium polarity compounds with molecular mass under 1500 Da, such as flavonoids and their oxidation/degradation products. However, condensed tannins or other high-molecular compounds, such as photodegradation products from lignin, could not be detected

The 16 water extracts were stored in the dark at 4 °C for 85 days. These 'aged' samples were re-analysed using the same techniques and results compared with those obtained for the 'fresh' extracts.

Results and Discussion

The sampled Blackwood density ranged from 443 – 591 kg/m^3 with MC ranging from 7.6% to 9.0 %.

Spectrophotometric analysis of samples extracts

The water extracted from the face region shavings was consistently darker or deeper yellow coloured compared to the sticker mark. Spectral scans confirmed greater absorbance in the yellow-brown region (380-500 nm) in the extracts from the face region compared to the sticker marks See Figure 25. This trend between face and sticker mark was consistent in 'aged' water extracts (Figure 26). These results indicated a higher presence of these coloured compounds in face extracts than in stickers extracts, which is highly reflective of differential rates of chemical oxidation between the more exposed face and the sticker regions of the wood. The darker colour for 'aged' extracts indicated that the oxidation processes continue over time, generating a higher amount of differently coloured (and colourless) oxidised products.

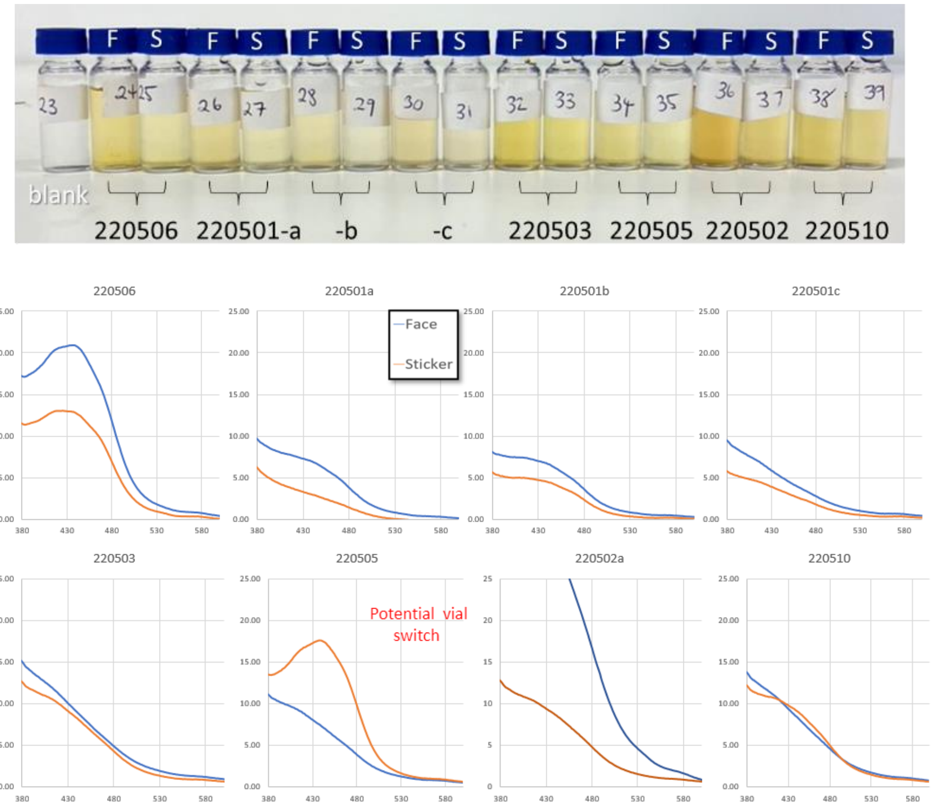

Figure 25: Above: Numbered vials for LC-MS analysis containing water extracts of face and sticker mark pairs. Each sample pair has extract of the face (F) on the left, and sticker mark (S) on the right. Below: corresponding spectral absorbance between 380 and 600nm of Blackwood water extracts.

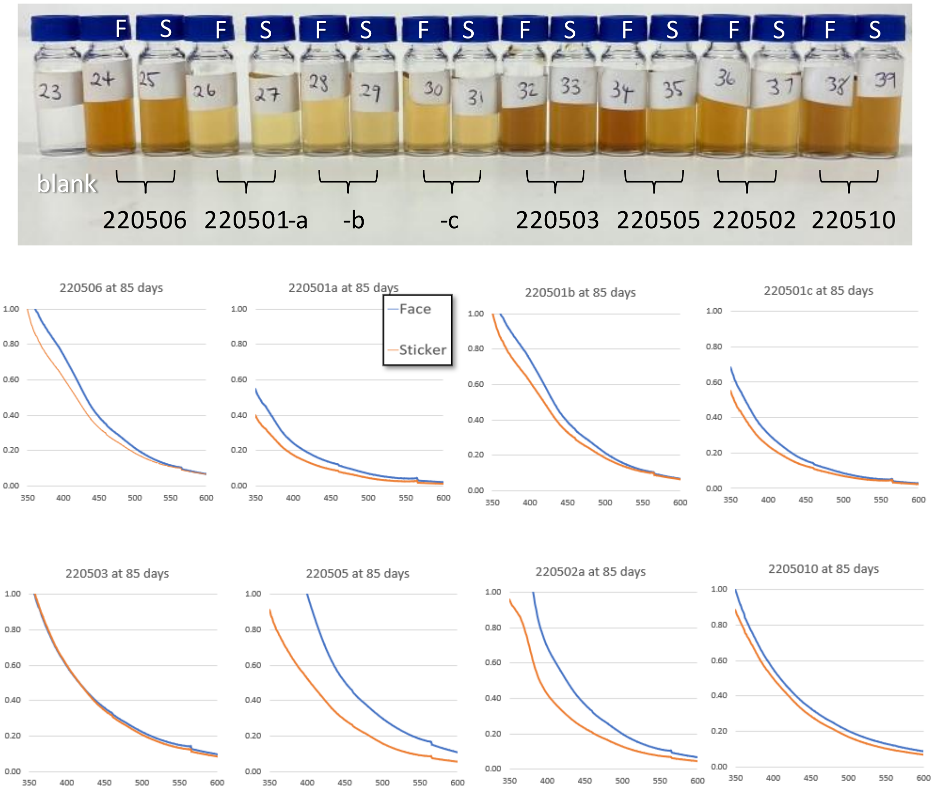

Figure 26: Above: Oxidised water extracts of face and sticker mark pairs after 85 days. Each sample pair has extract of the face (F) on the left, and sticker mark (S) on the right. Below: corresponding spectral absorbance between 380 and 600nm of Blackwood water extracts after 85 days

LC-DAD-SQ and HRAM-Orbitrap-MS analysis

Analysis of the water extract of the 16 wood samples using LC-DAD-SQ and HRAM-Orbitrap-MS detected 39 major compounds, indicative of the complex chemical nature of the samples. From those, 29 were identified or tentatively identified, while the identity of 10 of them remained unknown (UNK).Table 15 summarises some basic information for those 39 compounds.

Almost all compounds identified or tentatively identified were flavonoids, many of which have been typically found in *Acacia* species. The main compounds identified in extracts from all samples were melacacidin (14a) and its isomer, isomelacacidin (14b), as previously reported for *Acacia melanoxylon*, although these compounds can be also found in other species of *Acacia*. Likewise, many of the identified compounds are melacacidin-related compounds such as melacacidin oxidation products (e.g., (10), (11)), melacacidin dimers (e.g., (25)), melacacidin derivatives (e.g., (18) or melacacidin condensed with other flavonoids/glycosides ((28), (30)) or with dihydroxybenzoic acid (e.g. (21)). Melacacidin (14a), teracacidin (9) and a hexahydroxyflavonone (19) show the backbone structures from which the rest of the compounds can be derived through oxidation and/or condensation processes. Some of the detected compounds were colourless and others exhibited absorbance reflecting coloured compounds ranging from light yellow to reddish (350-550 nm).

Only four compounds were found to show increased amounts in 'aged' samples. Since the spectrophotometric analysis of the 'aged' extracts showed a clear darker colour than the 'fresh' extracts and this visual information was supported by an absorbance typical for brownish-orangish compounds, some of the compounds responsible for the colour must be polymeric compounds, such as condensed tannins, not detectable by the analytical method applied in this study.

Combining all the information about the 39 compounds detected and their abundances (See Figure 27), it was observed that:

- ~32% of the compounds were found in higher amounts in face samples than in sticker samples; of those ~15% were coloured compounds.

- ~24% of the compounds were found in higher amounts in sticker than in face samples; of those ~12% were coloured compounds.
- ~44 % of the compounds were found in similar amount in face and in stickers and ~29% of those compounds were coloured. This high percentage of similar amount in both type of samples can be due to the heterogeneity in face and sticker sampling region.
- ~62 % of the detected compounds were coloured. Of those, ~33% were more abundant in face samples, ~19% in sticker samples and ~48% were present in similar amounts in face and sticker samples. Overall, face samples contained more coloured compounds than sticker samples.
- Many compounds are responsible for the colour and spectral absorbance of extracts.

Table 15: Identified and tentatively identified compounds in water extracts of *Acacia melanoxylon*

N°	Code	Molecular mass (Da)	Formula	Name	UV-vis	Face	Sticker	Aged
1	1	138	$C_7H_6O_3$	4-Hydroxybenzoic acid		75		UP
	2	154	$C_7H_6O_4$	3,4-Dihydroxybenzoic acid		x	x	n.a.
2	3	192	$C_6H_7O_7$	UNK-191 carbohydrate?			75	UP
3	4	196	$C_6H_{12}O_7$	UNK-195 carbohydrate?		75		DOWN
4	5	224	$C_7H_{12}O_8$	UNK-223 carbohydrate? or Quinic acid?		100		UP/DOWN
5	6a, 6b	272	$C_{15}H_{12}O_5$	7,3',4'-Trihydroxyflavanone or Tetrahydroxychalcone		50	50	DOWN
6	7	288	$C_{15}H_{12}O_6$	7,8,3',4'-Tetrahydroxyflavanone		62.5		DOWN
7	8a	288	$C_{15}H_{12}O_6$	Okanin		75		DOWN
8	8b	288	$C_{15}H_{12}O_6$	Keto-teracacidin			62.5	DOWN
9	9	290	$C_{15}H_{14}O_6$	Teracacidin		50		DOWN
10	10	302	$C_{15}H_{10}O_7$	Melanoxetin		50	50	DOWN
11	11a	304	$C_{15}H_{12}O_7$	Melacacidin B-ring O-quinone intermediate		50	50	UP
12	11b			(±)7,8,3',4'-tetrahydroxydihydroflavonol				UP
13	11c			Taxifolin			100	DOWN
14	12	304	$C_{16}H_{16}O_6$	Methyl-Teracacidin		50	50	n.a.
15	13	304	$C_{12}H_{16}O_9$	UNK-303.07		50	50	n.a.
16	14a	306	$C_{15}H_{14}O_7$	Melacacidin		75		DOWN
17	14b	306	$C_{15}H_{14}O_7$	Isomelacacidin		50	50	DOWN
18	14c	306	$C_{15}H_{14}O_7$	Melacacidin isomer		50	50	DOWN
19	14d	306	$C_{15}H_{14}O_7$	Melacacidin isomer		50	50	DOWN
20	15	316	$C_{16}H_{12}O_7$	Transilitin		87.5		DOWN
21	16	318	$C_{16}H_{14}O_7$	Methyl-taxifolin		50	50	DOWN
22	17	318	$C_{15}H_{10}O_8$	hexahydroxyflavone		50	50	DOWN
23	18	320	$C_{16}H_{16}O_7$	8-O- or 4-O- Methylmelacacidin			62.5	n.a.
24	19	320	$C_{15}H_{12}O_8$	Hexahydroxyflavanone				n.a.
25	20	338	$C_{19}H_{30}O_5$	UNK-337			75	DOWN
26	21	438	$C_{22}H_{14}O_{10}$	Melanoxetin+dihydroxybenzoic acid?			62.5	DOWN
27	22	442	$C_{22}H_{18}O_{10}$	Melacacidin+dihydroxybenzoic acid?		50	50	DOWN
28	23	486	$C_{18}H_{30}O_{15}$	UNK-487 SciFinder 217817-66-8?		50	50	DOWN
29	24a	514	$C_{26}H_{26}O_{11}$	UNK-513a and UNK-513b: 2",6"-O-Diacetyloninin			75	DOWN
30	24b			7-Hydroxy-4'-methoxyisoflavone 7-O-(2",6"-diacetylglucoside)?			62.5	DOWN
31	25a	594	$C_{30}H_{26}O_{13}$	Melacacidin dimer and isomers		50	50	DOWN
32	25b					50	50	DOWN
33	25c					75		DOWN
34	26	638	$C_{35}H_{26}O_{12}$	UNK-637 Four options in SciFinder				n.a.
35	27	644	$C_{24}H_{35}O_{20}$	UNK-643 SciFinder 199527-72-5		87.5		DOWN
36	28	792	$C_{33}H_{44}O_{22}$	Melacacidin trissacharide				n.a.
37	29	950	$C_{39}H_{50}O_{27}$	Melanoxetin tetrassacharide				n.a.
38	30a	610	$C_{30}H_{26}O_{14}$	Melacacidin+$C_{15}H_{12}O_8$ dimer?		50	50	DOWN
39	30b					75		DOWN

Notes: X= 3,4-dihydroxybenzoic acid was found only as a fragment from another compounds. n.a= not available

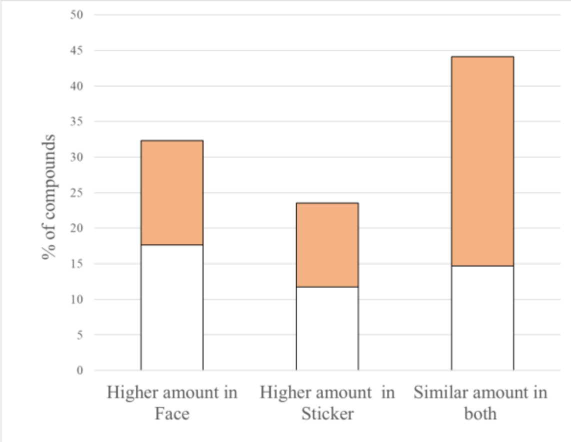

Figure 27: Percentage (%) of compounds found in a bigger amount in face samples, in a bigger amount in sticker samples or in equal amount in both type of samples. In orange: percentage (%) of coloured compounds within each case.

Conclusions

The production of degradation products of flavonoids (together with similar processes for other wood components, such as lignin) is driven by the combination of absorption of UV-vis light, moisture content, temperature and interaction with oxygen. The study results clearly suggest the observed chemical differences are a result of differential rates of chemical oxidation of the wood over time. By using stickers, the protection of the wood in localised regions from UV exposure, oxygen access and differential exposure to moisture is highly likely to slow the local rate of chemical oxidation, which would result in visible differences in colouration from different concentrations of coloured oxidation products. Since the main flavonoid present in Blackwood (*Acacia melanoxylon*) is melacacidin, most of the compounds detected were melacacidin oxidation products or melacacidin-related compounds.

To address these differences in appearance through the surface boards, as far as possible, similar ambient conditions should be applied by using alternative storage methods for the boards (including open sticker designs) or by applying photo stabilisers to the board surface, which retard the photodegradation of wood products. Fortunately, photo stabilisers can be naturally derived products from plants which are biocompatibility and less chemically hazardous than synthetic photo stabilisers.

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Conclusions and recommendations

Discolouration in Shining gum (*E. nitens*)

Tyre-track is a form of blue-stain that appears as a regular greyish mark across the face of affected Shining gum boards. Fortunately, it is uncommon in industry. It was only found in two occurrences: in the Britton Timbers milling trial in 2018 and one batch of CSAW research material. It was not visible in the remainder of CSAW's dressed research stock or reported in subsequent milling at Britton Timbers. However, plantation E. nitens appears to be is susceptible to blue stain fungi if stored in damp conditions during the early stages of drying. Given the timber's pale straw colour, blue stain's impact on the material's planed surface is readily apparent and market limiting.

Management approaches

Blue stain management should become a part of normal operating procedures in E. nitens processing facilities. Tyre-track and blue stain can be avoided by:

- Racking the timber as soon as possible after milling and storing it in favourable drying conditions in normal production timelines.
- Maintain mould-limiting practices and hygiene on site.

Discolouration in Blackwood (*Acacia melanoxylon*)

While *sticker mark* can occur in eucalypt hardwood, its occurrence in Tasmanian mills primarily affects Blackwood (*A. melanoxylon)* where it is a persistent and ongoing problem. It affects approximately 20% of boards in most production runs and results in economic loss of up to $1 million per annum.

Effective audit and assessment of Blackwood discolouration is significantly more complicated than similar auditing of Shining gum. Blackwood is a richly coloured timber with significant natural tonal variation between boards and between earlywood and latewood bands within boards. The visual impact of individual sticker marks varies in intensity.

The biotic and chemical assessment conducted as part of this project broadly concluded that sticker mark in Blackwood results from the differential rates of oxidation of coloured chemical compounds between the more exposed face and the covered sticker regions of the wood. This presence of the sticker over the wood during drying may accelerate or retard chemical oxidation and results in grade-limiting discolouration. The test results also indicated that the oxidation processes continue over time, generating a higher amount of differently coloured (and colourless) oxidised products. However, the natural tonal and chemical variation in and between boards means that the exact oxidation pathway in any discolouration event is difficult to determine and may not provide a commercially relevant result. It is likely that several oxidation pathways exist that lead to grade-limiting discolouration and their impact varies with the characteristics of the timber, and the ambient conditions in which it is dried and stored prior to milling.

Reviewing the initial Blackwood audit results from this perspective, it appears that:

- Blackwood is susceptible to a commercially unavoidable background level of discolouration-generating oxidation.
- Ambient conditions can increase the oxidation impact by exposing different parts of the board to varied influences.
- Individual factors such air-drying location; board thickness (or surface area); racking season; log age and drying duration contribute to the rate of discolouration-generating oxidation. However, these factors act more significantly in combination the impact of which remain to be identified.

Management approaches

The results of the project's HDR student are connected to the development of useful management approaches. This work is ongoing. It is intended that his interaction with industry continue during his candidature and that his results link back to industry practice.