ACIAR FST/2009/062 Development of advanced veneer and other products from coconut wood to enhance livelihoods in South Pacific communities

DAF Report - Coconut palm stem veneer processing

Trial 4

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Queensland Government

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Summary

A coconut stem rotary veneer processing trial (Trial 4) was undertaken at the Valebasoga Tropikboards Ltd. (VTB) commercial plywood mill located in Labasa, Fiji. The trial was designed to further advance processing protocols developed within earlier research and semi-industrial scale processing trials, and apply them within an industrial environment. A supply of coconut palm logs believed to be about 60 years-old were sourced from a planting near the Naidi Village, Savusavu on Vanua Levu, Fiji.

A total of 153 coconut palm billets (25.1 m^3) were processed into rotary veneer. Resulting veneer was dried through a commercial jet box drier using a modified drying schedule to a target dry veneer moisture content of 6%. After drying, 12.5 m^3 of veneer was recovered reflecting a recovery rate of 49.8% (or 65.0% of rounded billet volume). This is similar to the recovery result achieved during trial 3 despite the upscaling in lathe capacity (i.e. 1300 mm lathe for trial 3 and 2600 mm for trial 4). When a trimming factor is applied to determine the volume of veneer recovered at a nominal standard length and width (edges trimmed square etc), 11.4m^3 of veneer was recovered reflecting a recovery rate of 45.4%.

The trial confirmed the need to adopt specific processing protocols (e.g. lathe settings and billet preconditioning temperatures) in order to successfully peel coconut veneer however when the processing conditions were within the target ranges, the coconut billets peeled with efficiency similar to that of traditional timber billets.

In the absence of a coconut veneer product grading standard and the unsuitability of existing industry standards developed for traditional forest resources, the grading method developed during processing trial 3 (McGavin 2015) was adopted (with minor improvement) to allow specific defects and characteristics to be quantified. The results showed significant improvement in many key veneer qualities compared to the previous processing trial (trial 3).

Veneer density and modulus of elasticity measurements further confirmed the wide spread of values recovered from coconut stems. The range in density that exists within a coconut log is potentially two to three times more than what would be experienced in traditional wood resources.

The veneer MoE results were generally low compared to most commercial wood species with a mean value of 5,352 MPa (16,883 MPa maximum, 1013 MPa minimum, 2,896 MPa standard deviation). These results indicate that the suitability of cocoveneer in the manufacture of structural based products may be challenging unless blended with other forest resources or specific markets can be identified that have low mechanical quality requirements (or at least low MoE) however demand other qualities that cocoveneer possess (e.g. aesthetic qualities). Another strategy may be increased product dimensions to compensate for the lack of mechanical performance. Further investigation is necessary to better understand the variable

veneer MoE results and the impact of veneer MoE on manufactured product mechanical properties.

Three nominal grade qualities are proposed to reflect superior quality (Grade 1), high quality (Grade 2) and standard grade (Grade 3). A grade recovery of 15%, 50% and 84% respectively was achieved when veneers were graded against each grade criteria. These grade scenarios are indicative only and more relevant grade rules will need to be determined when product and market information are better understood.

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1 Introduction

A coconut stem rotary veneer processing trial (Trial 4) was undertaken in June 2015 at the Valebasoga Tropikboards Ltd. (VTB) commercial plywood mill located in Labasa, Fiji. The trial was led by the Queensland Department of Agriculture and Fisheries (DAF) in collaboration with VTB, the University of Tasmania (UTAS), the Pacific Community (SPC), and the Fiji Ministry of Fisheries and Forests. The trial was part of the Australian Centre for International Agricultural Research (ACIAR) project, *FST/2009/062 Development of advanced veneer and other products from coconut wood to enhance livelihoods in South Pacific communities.*

The trial incorporated the following specific objectives:

- Provide demonstration and evidence of coconut palm stems processed into rotary veneer within an industrial environment using machinery settings and processing protocols developed during earlier project trials.
- Engage with a major rotary veneer and plywood producer in the South Pacific and further evaluate the commercial possibilities for coconut veneer or ‘cocoveneer’.
- Test and advance the processing protocols that were developed during smaller-scale processing trials using research and semi-industrial equipment.
- Produce sufficient quantity of cocoveneer to determine indicative recovery rates and veneer qualities from an industrial processing plant and to identify possible processing challenges.
- Supply a quantity of cocoveneer feedstock for preliminary product development activities.
- Deliver introductory training and exposure to key project staff on veneer processing equipment setup, operation and maintenance along with veneer processing trial R&D protocols and veneer drying.

2 Material and methods

2.1 Processing and veneer production

A supply of coconut palm logs were sourced from a planting at Graham Haynes Estate, near the Naidi Village, Savusavu on Vanua Levu, Fiji. The palms were believed to be about 60 years-old. Harvested trees were merchandised to provide a six metre log which was transported to VTB's plywood mill in Labasa, Fiji.

Prior to pre-conditioning, logs were docked to provide two billets for peeling that measured approximately 2700 mm in length. Pre-conditioning was performed in a water-steam chamber and targeted core log temperatures of around 80-90 degrees Celsius (Image 1). The pre-conditioning process aims to soften the billet to improve the peeling operation and the resulting veneer quality (McGavin *et al.* 2015). The requirements of pre-conditioning coconut palm stems prior to rotary peeling have been demonstrated in earlier processing trials (Bailleres *et al.* 2015, McGavin 2015) with temperatures above 80 degrees Celsius being necessary to gain the most benefit which includes reducing lathe cutting forces and improving veneer quality.

Image 1 – Water-steam chamber used to pre-condition coconut palm stem logs prior to peeling

Logs were 'de-barked' and rounded in a dedicated rounding lathe to remove the majority of the fibrous cortex layer along with the majority of any taper, sweep and bumps from the billet, to provide a billet that was close to cylindrical in preparation for peeling. A log diameter measurement was recorded prior to rounding and at the completion of rounding.

Rotary peeling was performed using a Chinese-built spindleless veneer lathe (Image 2). While the VTB staff had substantial knowledge and experience with lathe settings for commercial timber species, they had no experience with settings suited to coconut palm peeling. DAF experience in spindleless lathe operation combined with the learnings from previous project processing trials provided the base line initial settings and guided subsequent changes. The minimum residual or peeler core size was approximately 48 mm.

Image 2 –Spindleless veneer lathe used for peeling coconut stems

Peeled veneer was clipped targeting a sheet width of approximately 1,350 mm. Each veneer sheet was labelled with a unique identifier before being prepared for drying (Image 3). Veneer was dried using a commercial jet box drier using a modified drying schedule (Image 4). A target dry veneer moisture content of 6% was selected (Image 5). Dried veneers were packaged and forwarded to the DAF Salisbury Research Facility in Brisbane, Australia for further assessment.

Image 3 –Veneer sheets were labelled with an individual identifier immediately after clipping

Image 4 – Cocoveneer sheets exiting the jet box drier

Image 5 – Checking cocoveneer moisture content at the completion of drying.

2.2 Veneer visual quality

A randomly selected subset of veneers were graded for a range of natural and process induced qualities. In the absence of a coconut veneer product grading standard and the unsuitability of existing industry standards developed for traditional forest resources, the grading method developed during processing trial 3 (McGavin 2015) was adopted with minor improvement to allow specific defects and characteristics to be quantified.

The following attributes were assessed:

- Colour – measured using a colorimeter.
- Roughness – visual scoring system between 1 to 8, with 1 indicating a smooth surface and 8 indicating a very rough surface.
- Splits - scoring system between 1 and 10 based on veneer split measurements across the veneer width, with 1 indicating no splits and 10 indicating severe splitting.
- Brittleness - visual scoring system between 1 and 10, with 1 indicating robust veneer and 10 indicating a large proportion of the sheet affected by very fragile veneer.

- Collapse - visual scoring system between 1 and 10, with 1 indicating no collapse and 10 indicating a large proportion of the sheet affected by collapse.
- Decay - visual scoring system between 1 and 10, with 1 indicating no decay and 10 indicating a large proportion of the sheet affected by decay.
- Holes and tear-out - scoring system between 1 and 10, based on defect measurements across the veneer width, with 1 indicating no holes or tear-out and 10 indicating large and/or high frequency of holes and tear-out.
- Compression - visual scoring system between 1 and 4, with 1 indicating minimal/ no compression and 4 indicating severe compression.
- Handling splits - scoring system between 1 and 10, based on size and severity of splits caused through handing, with 1 indicating no splits and 10 indicating severe splitting.
- Wane - visual scoring system between 1 and 3, with 1 indicating no wane and 3 indicating excessive wane.
- Insect tracks - visual scoring system between 1 and 3, with 1 indicating no insect tracks and 3 indicating a high frequency of insect tracks.

The grading methods remained consistent to that reported by McGavin (2015) for processing trial 3 for all characteristics with the exception of brittleness and handling splits. For these characteristics, the grading thresholds were modified to better access their presence. As a result, a direct grade comparison is not possible between processing trial 3 and this trial for these two characteristics.

2.3 Veneer properties

2.3.1 Density

Density is the mass per unit volume of a material. In the wood industry, density is usually expressed in kilograms per cubic metre (kg/m^3), usually at a specified moisture content (MC) such as 12% (air-dry density). The inner core zone of coconut palm stems is characterised by very low density, between 100 and 400 kg/m^3 (McGavin *et al* 2015). The intermediate zone has medium density material usually between 400 and 600 kg/m^3 while the outer-wood has very high density, above 600 kg/m^3 and often between 800 and 1,170 kg/m^3 (McGavin *et al* 2015).

To better understand how the coconut stem density profile is recovered in veneer after processing, veneer air-dry density was measured on sampling strips removed from the veneer sheets used for grading. The sampling strip measured 150 mm (parallel to the grain) by approximately 1,200 mm long. The sampling strips were conditioned to 12% MC prior to veneer dimensions (length, width and thickness) and weight being measured, allowing density to be calculated.

2.3.2 Modulus of elasticity

A sampling strip was removed from the veneer sheets used for grading to measure veneer modulus of elasticity (MoE). This same sampling strip was used to measure veneer density (see 2.3.1). Veneer MoE was measured using an acoustic natural-vibration method as described by Brancheriau and Bailleres (2002) (Image 6).

Image 6 – Modulus of elasticity measurement on cocoveneer sampling strips.

2.4 Veneer grade recovery

It is common practise in the forest products industry to segregate feedstock (e.g. sawn timber, rotary veneer) based on the visual characteristics. The segregation not only reflects quality and therefore suitability for particular products or end-uses, but is also used to assign value with higher quality material (e.g. less defects) usually able to attract a premium price at the market. For most commercial forest product feedstocks, grading standards have been established either as industry-wide standards, or specific standards established in partnerships between the producer and the customer. Established grading standards provide confidence to stakeholders that the supply of graded feedstock meets their manufacturing and quality requirements. While many veneer grading systems exist which have been developed for traditional forest resources, a new or modified veneer grading system will be necessary to suit the uniqueness of cocoveneer.

The product suitability and market acceptability of the size and frequency of specific defects and characteristics along with product performance expectations will need to be determined when target end-products are more accurately defined. This will then guide the development of a grading standard that will segregate veneer qualities within specific grades.

In the absence of a suitable established grading system for coconut veneer as well as a lack of comprehensive market information, three nominal grade qualities are proposed to reflect superior quality (Grade 1), high quality (Grade 2) and standard grade (Grade 3). These nominal grades and the grade classifications provide an indicative spread of qualities when all veneer characteristics are evaluated. These indicative grades may provide a useful benchmark for the future development of a grading standard for cocoveneer. The grade criteria for each nominal grade is outlined in Table 1.

Table 1. Minimal grade scores for three nominal grade scenarios

Veneer Characteristic	Grade 1	Grade 2	Grade 3
Density	≥600 kgm^3	≥450 kgm^3	No restriction
Roughness	≤score 3	≤score 5	≤score 7
Splits	≤score 3	≤score 6	≤score 6
Brittleness	≤score 2	≤score 3	≤score 7
Collapse	≤score 3	≤score 4	≤score 6
Decay	score 1	≤score 5	≤score 7
Holes and tear-out	≤score 2	≤score 4	≤score 7
Compression	score 1	≤score 2	≤score 4
Handling splits	≤score 4	≤score 7	≤score 9
Wane	score 1	≤score 2	≤score 2
Insect tracks	≤score 2	≤score 2	≤score 3

3 Results

3.1 Processing

A failed preliminary attempt by VTB to rotary peel several coconut billets in the days prior to the trial commencing confirmed the difficulties and non-traditional protocols required to peel coconut palms. Applying some modified lathe settings (including knife position, nose bar compression etc.) and processing protocols made immediate improvements which were further improved throughout the trial.

The high loading on the rounding lathe and peeling lathe was obvious, especially when the processing conditions drifted from the target range (e.g. inadequate pre-conditioning). Several mechanical failures were experienced throughout the trial providing further evidence that suitable equipment and protocols are critical to successfully rotary peel coconut palm stems. However, when the processing conditions were within the target ranges, the coconut billets peeled with efficiency similar to that of traditional timber billets.

A total of 153 coconut palm billets (25.1 m^3) were processed into rotary veneer. The average billet diameter was 27.6 cm (Fig. 1). The rounding process accounted for a billet volume loss of 23%. This is higher than would be expected when rounding traditional forest resources however is explained by the fibrous ‘bark’ cortex being included in the initial billet volume. The bark on traditional forest billets would usually be excluded from billet volume calculations.

After drying, 12.5 m^3 of veneer (Image 7) was recovered reflecting a recovery rate of 49.8% (or 65.0% of rounded billet volume). This is similar to the recovery reported during trial 3 despite the difference in lathe capacity (i.e. 1300 mm lathe for trial 3 and 2600 mm for trial 4). When a trimming factor is applied (similar to that reported by McGavin *et al.* 2014) to determine the volume of veneer recovered at a nominal standard length and width (edges trimmed square etc.), 11.4m^3 of veneer was recovered reflecting a recovery rate of 45.4%.

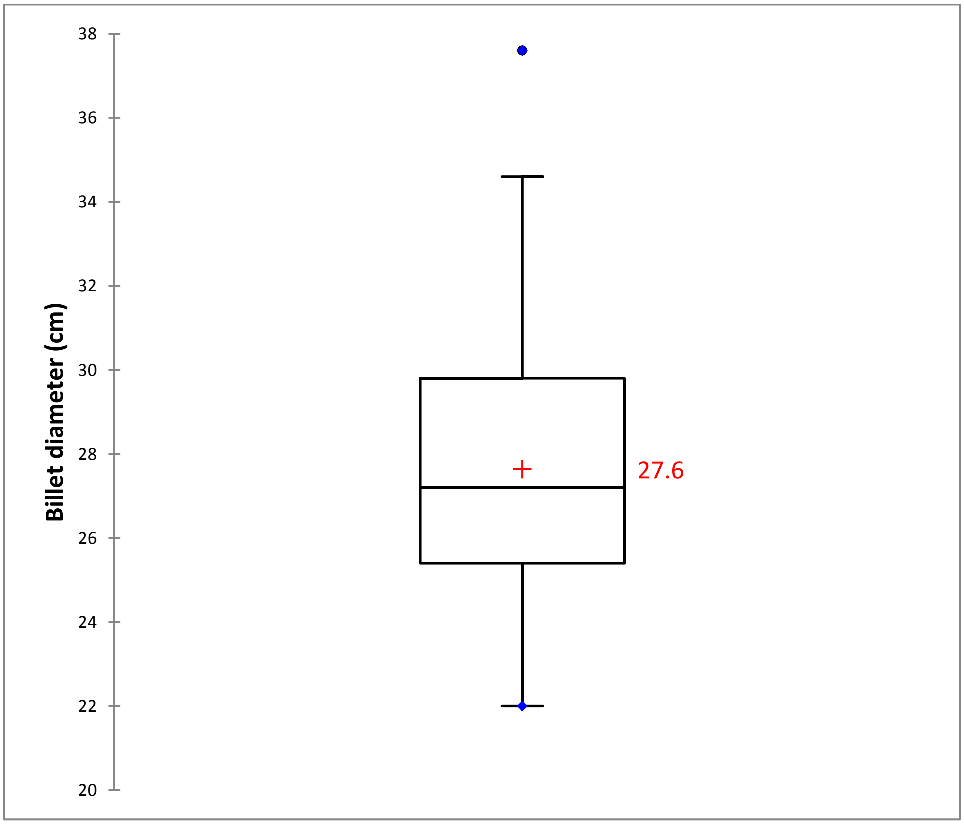

Figure 1 – Coconut palm billet diameter.

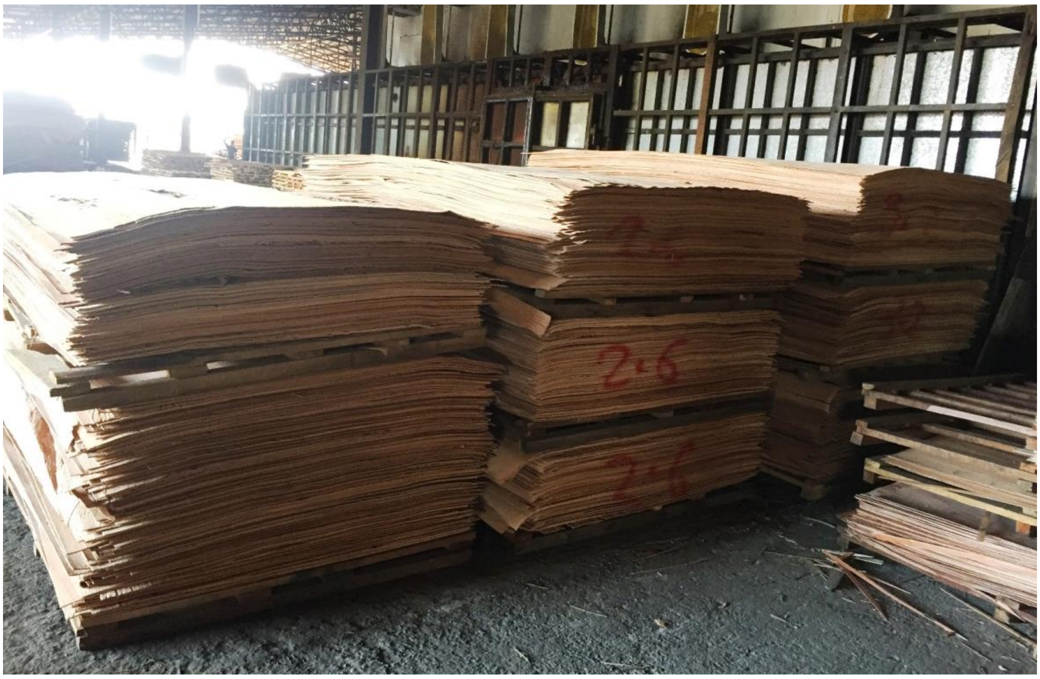

Image 7 – Cocoveneer produced during the trial

3.2 Veneer visual quality

A total of 393 veneer sheets were randomly selected to determine the range of natural and process induced qualities contained in the veneers.

3.2.1 Colour

The veneer colour was measured using a portable spectro colorimeter. This instrument uses a xenon flash lamp to illuminate the sample. The reflected light is then separated in its components and expressed in the Commision Internationale d'Eclairage (CIE) L*a*b*-scale (also called CIELAB). This scale is an expression of a three dimensional measurement with an L*-value (100 = perfect white, 0 = black), a*-value (describes redness when positive, grey when zero and greenness when negative) and b*-value (describes yellowness when positive, grey when zero and blueness when negative).

The colour readings 'a' and 'b' are similar to the results of trial 3, however unlike trial 3, trial 4 veneers show a clear decrease in colour reading 'L' (i.e. darkening) as veneer density increases (Fig. 2).

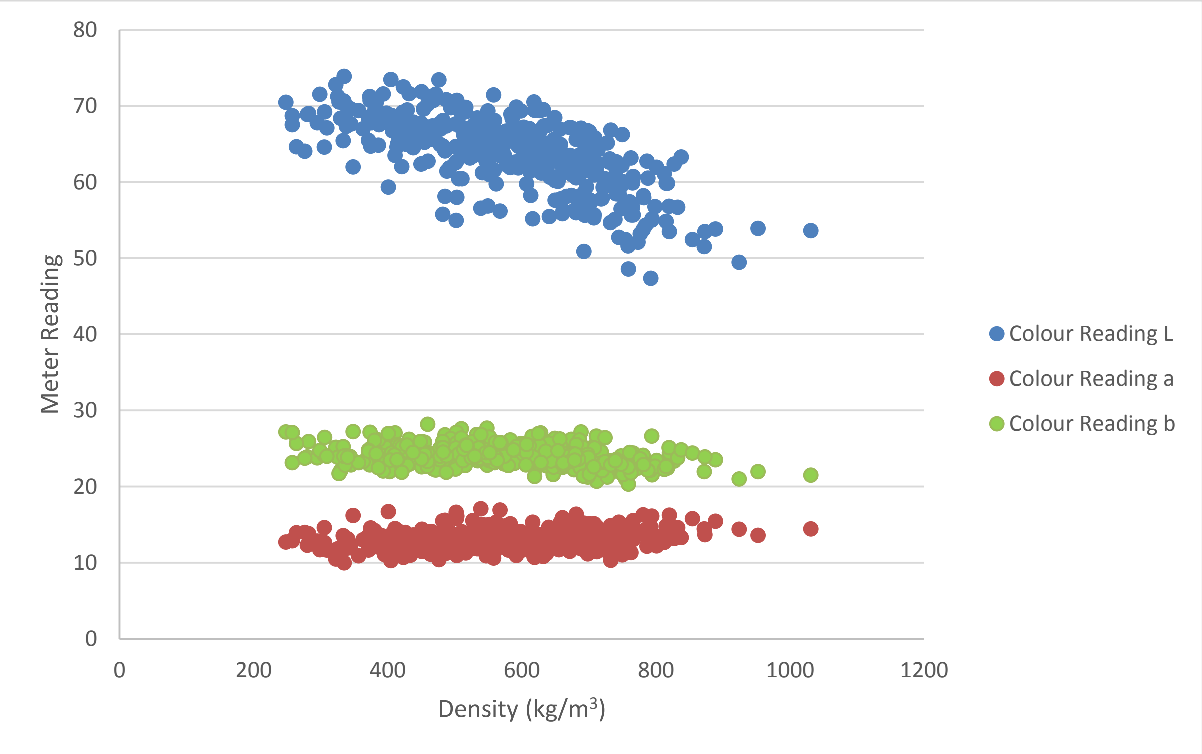

Figure 2 – Cocoveneer colour assessment.

Note: L*=darkness/brightness, a*=redness/greenness, b*=yellowness/blueness

3.2.2 Roughness

The assessment of veneer roughness provides a good indication of the appropriateness of the process settings, the suitability of the veneer for particular product manufacturing techniques and also guidance towards potential target end products.

The veneer produced from coconut stems was expected to have a rougher surface than what is generally produced in the traditional wood veneer processing industry. This is a result of the unique structure of the coconut stem as described by Bailleres *et al.* (2010).

The trial veneer produced a wide range of veneer roughness qualities with score distributions very similar to that reported for trial 3 (McGavin 2015). As per trial 3, no veneer was considered ‘smooth’ (score 1) and a roughness score of 3 dominated the assessment indicating that the veneers would be expected to be made smooth after moderate sanding (Fig. 3). While sanding may provide a potential solution, this process can usually only be performed practically on the final product meaning the roughness must be managed through the product manufacturing process. Excessive roughness can be particularly challenging for achieving reliable and efficient glue bonds during product manufacture.

While the coconut stem structure presents considerable challenges to producing smooth veneer, further optimisation of the veneering process would be expected to improve the quality. Increased control of log pre-conditioning followed by further optimised lathe settings would be expected to contribute to the most gains in roughness quality.

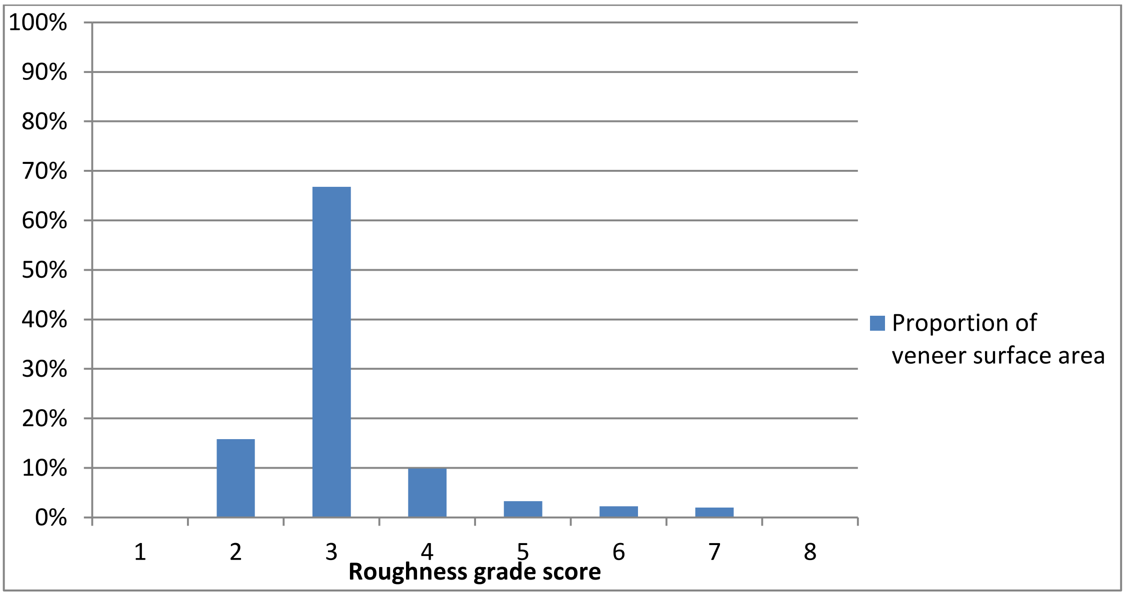

Figure 3 – Distribution of veneer roughness scores

3.2.3 Splits

This assessment focused on splits that were believed to be a result of veneer compression, shrinkage or other stress releases (Image 8). Splits believed to have resulted from handling were not included in this assessment (see section 3.2.9) although it is acknowledged that accurately identifying the source of the splits is difficult. Figure 4 displays the distribution of split grade scores. Over 60% of the veneer produced during the trial achieved a split grade score of 1. This is a significant improvement from the results of trial 3 and is reflective of the improved protocols adopted during this trial, especially during drying. Splits can have quite negative implications for the successful manufacture of end products, particularly those which demand high aesthetic qualities.

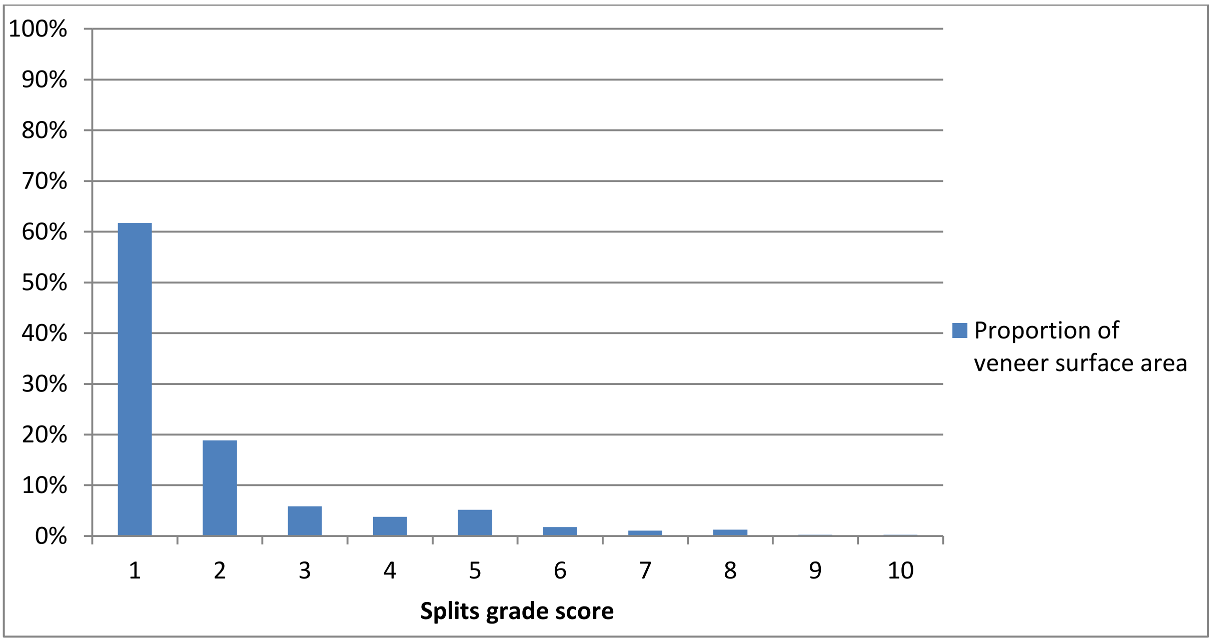

Figure 4 – Distribution of split scores

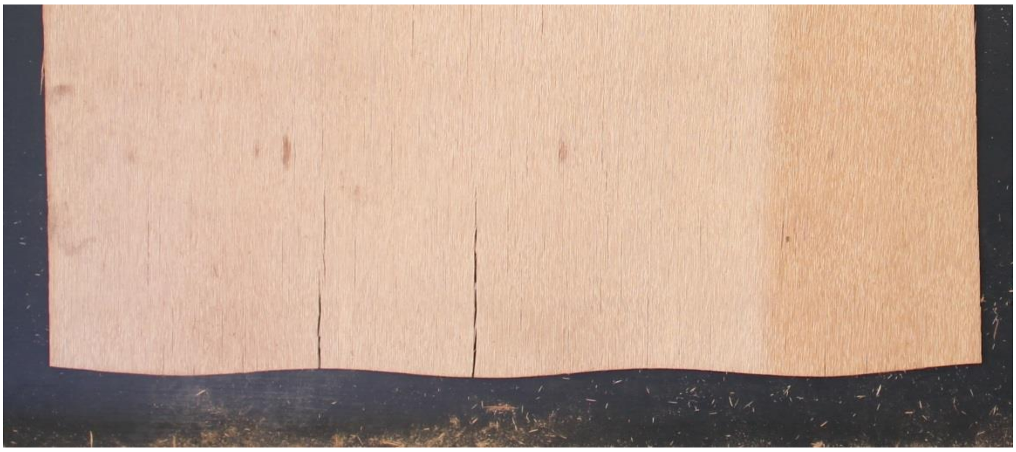

Image 8 – Example of veneer splits

3.2.4 Brittleness

The brittleness of veneer can make handling during stacking, drying and grading difficult. Brittleness can also negatively impact the utilisation of the veneer during product manufacture.

Over 90% of the veneer recorded a brittleness grade score of 3 or better (Fig. 5). McGavin (2015) highlighted brittleness in processing trial 3 as a veneer characteristic requiring targeted improvement in future trials. As explained in section 2.2, a modified grading method was used to assess veneer brittleness compared to that reported by McGavin (2015) for processing trial 3. While this prevents a direct comparison to the previous trial, it is reasonable to note that the veneer brittleness was significantly improved in this trial. This is a direct result of improved processing protocols adopted during this trial.

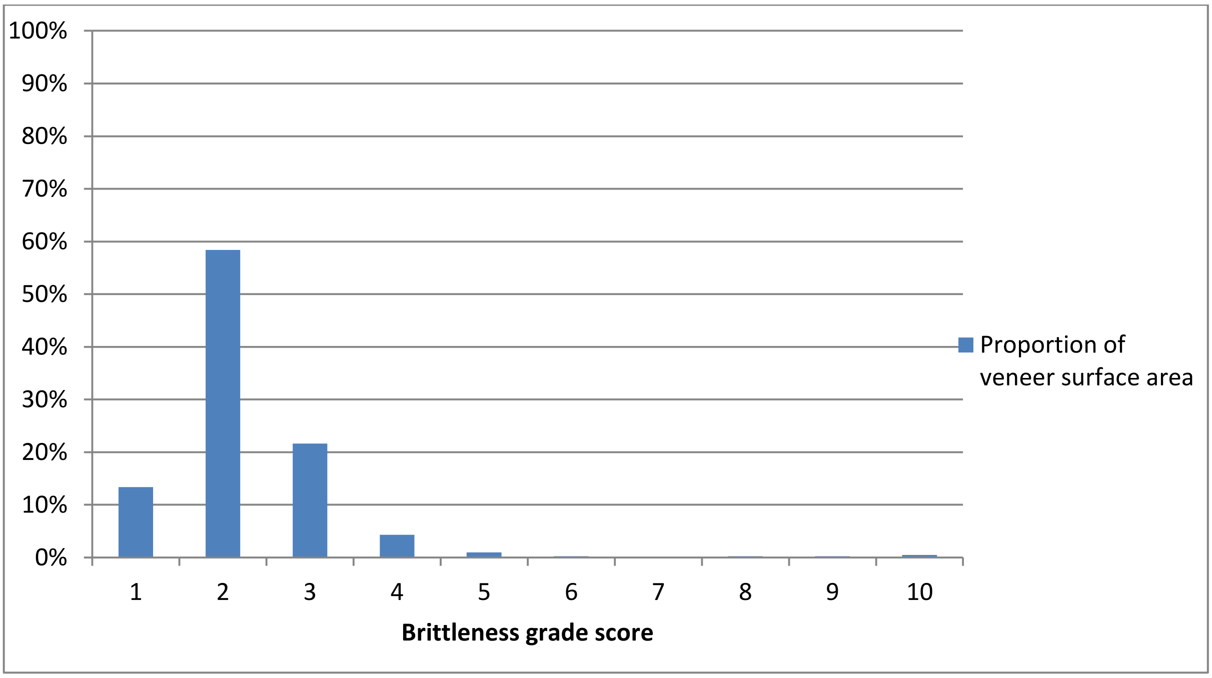

Figure 5 – Distribution of brittleness scores

3.2.5 Collapse

The severity of collapse in veneers from this trial was improved substantially compared to the veneers produced during trial 3. Over 90% of the veneers recorded a collapse grade score of 3 or better (Fig. 6). This is a significant improvement from the results of trial 3 where it was recommended that the reduction in this defect type be a primary focus of future trials. The improved result is reflective of the improved protocols adopted during this trial, especially during drying. Collapse can have quite negative implications for the successful manufacture of end products, particularly those which demand high aesthetic qualities.

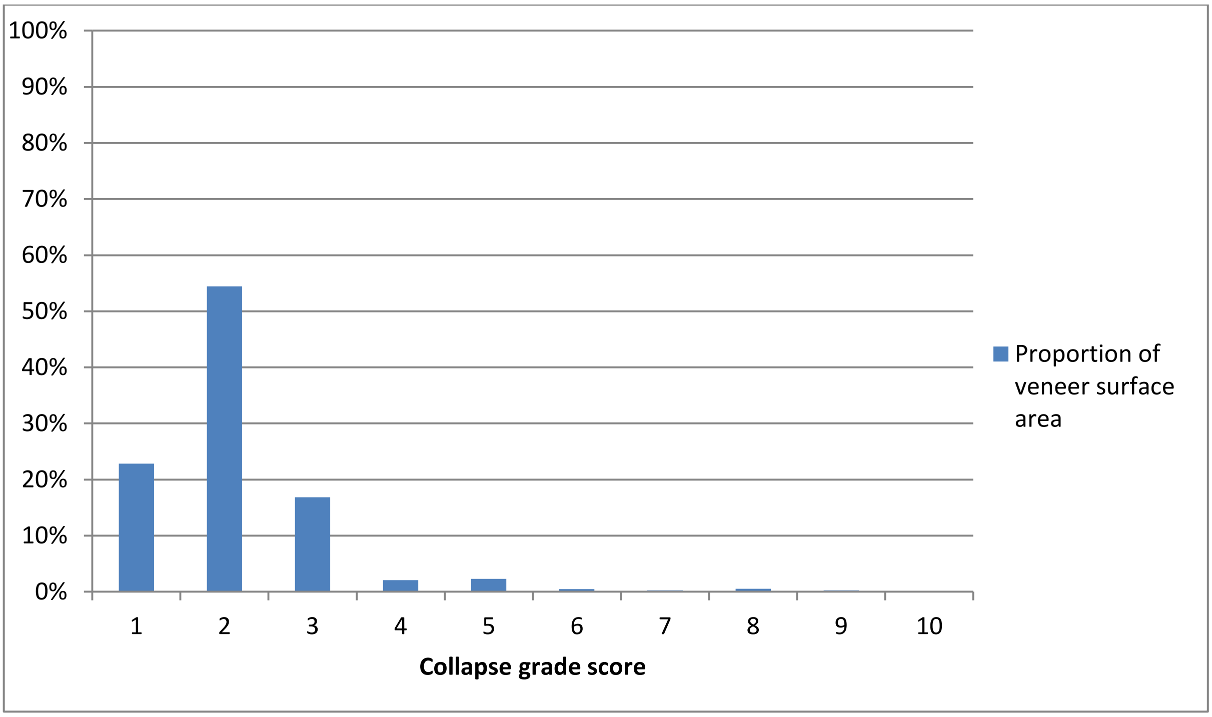

Figure 6 – Distribution of collapse scores

3.2.6 Decay

Decay was present in 10% of veneer (Fig. 7). Any management strategy to reduce the presence of decay in cocoveneer can only be made as part of palm selection, harvesting and/or log storage procedures and would only be considered once target products, market expectation and product performance criteria are better understood.

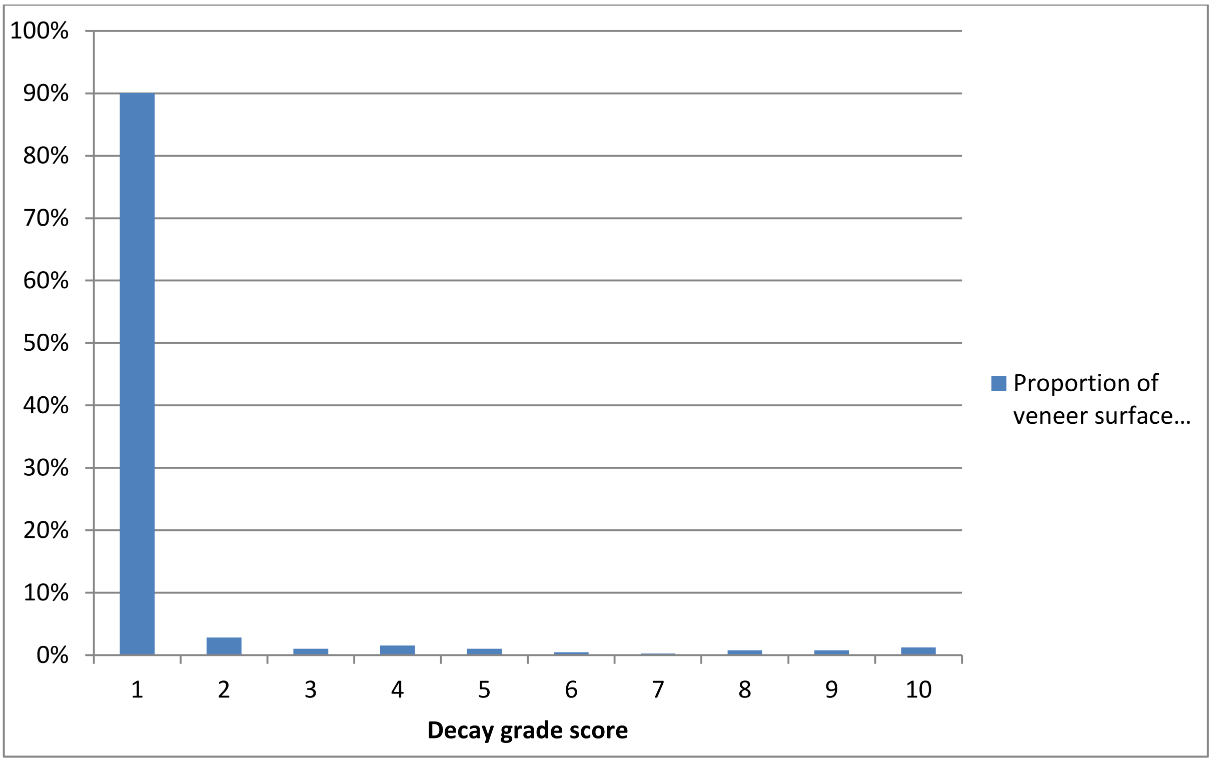

Figure 7 – Distribution of decay scores

3.2.7 Holes and tear-out

The severity of holes and tear-out in veneers from this trial was improved compared to the veneers produced during trial 3. The presence of holes and tear-out negatively affected 14% of trial veneer (Fig. 8) compared with over 20% in trial 3. The cause of this defect could be influenced by a range of factors including decay, undersized veneer thickness and mechanical damage on the log. Many of the causes of this defect would be expected to be relatively easily managed through optimised processing protocols and log quality control systems.

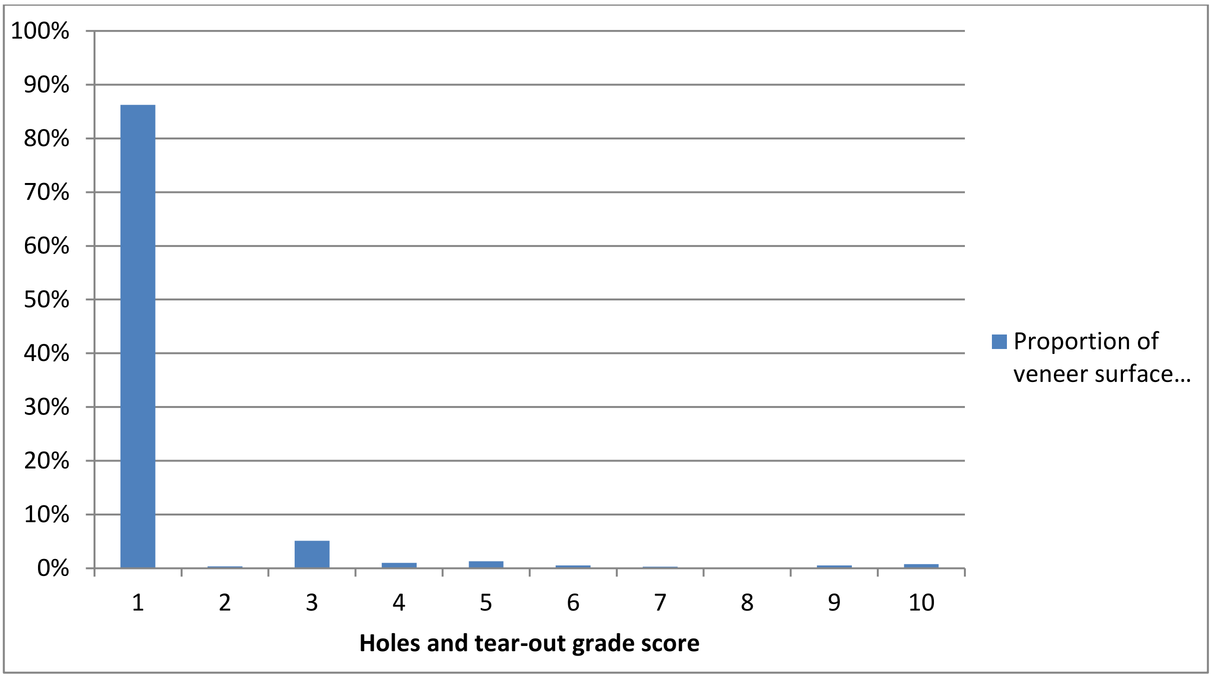

Figure 8 – Distribution of holes and tear-out scores

3.2.8 Compression

The occurrence of compression in veneer is quickly identified by the level of flatness or waviness of the veneer. In its most severe form, the veneer waviness prevents the veneer from being able to be pressed flat during product manufacture and reduces the effectiveness of the glue bond during pressing. The causes of compression can be resource-related (e.g. reaction wood) or process induced (e.g. poor log pre-conditioning and/or incorrect lathe settings). Over 97% of the trial veneer achieved a grade score 1 for compression compared with trial 3 where less than 80% achieved a grade score of 1 (Fig. 9).

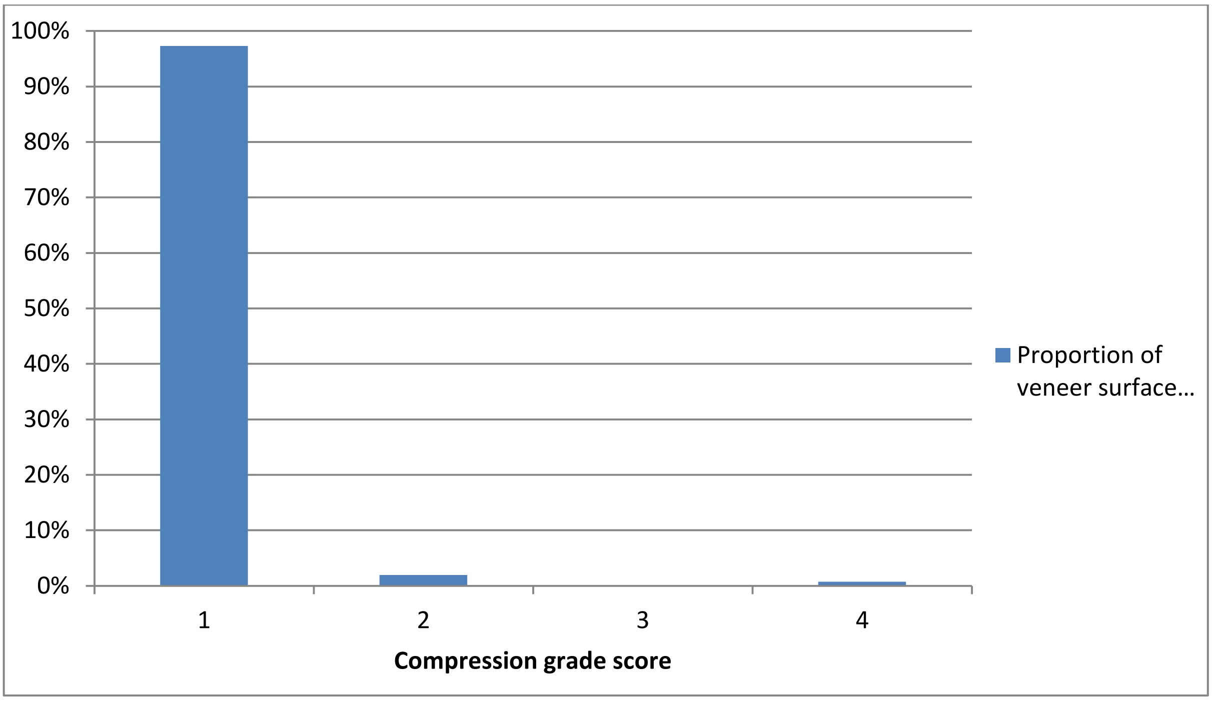

Figure 9 – Distribution of compression scores

3.2.9 Handling splits

The assessment of handling splits focused on splits that were believed to be a result of veneer handling as opposed to splits that result from compression, shrinkage or other stress releases (see Section 3.2.3). It would be expected that handling splits do not result in an overlap or gap between the two separated edges when the veneers are laid flat and therefore have less impact on the manufactured product by comparison. Despite this, their presence is not desirable as they can make the veneer sheets difficult to handle and can cause problems during the product manufacturing process (e.g. jamming in the glue spreader).

The resulting spread of handling split grade scores are presented in Figure 10. As explained in section 2.2, a modified grading method was used to access veneer handling splits compared to that reported by McGavin (2015) for processing trial 3. While this prevents a direct comparison to the previous trial, it is reasonable to note that the handling splits were significantly improved in this trial. This is a result of better veneer clipping and handling infrastructure and protocols adopted during this trial.

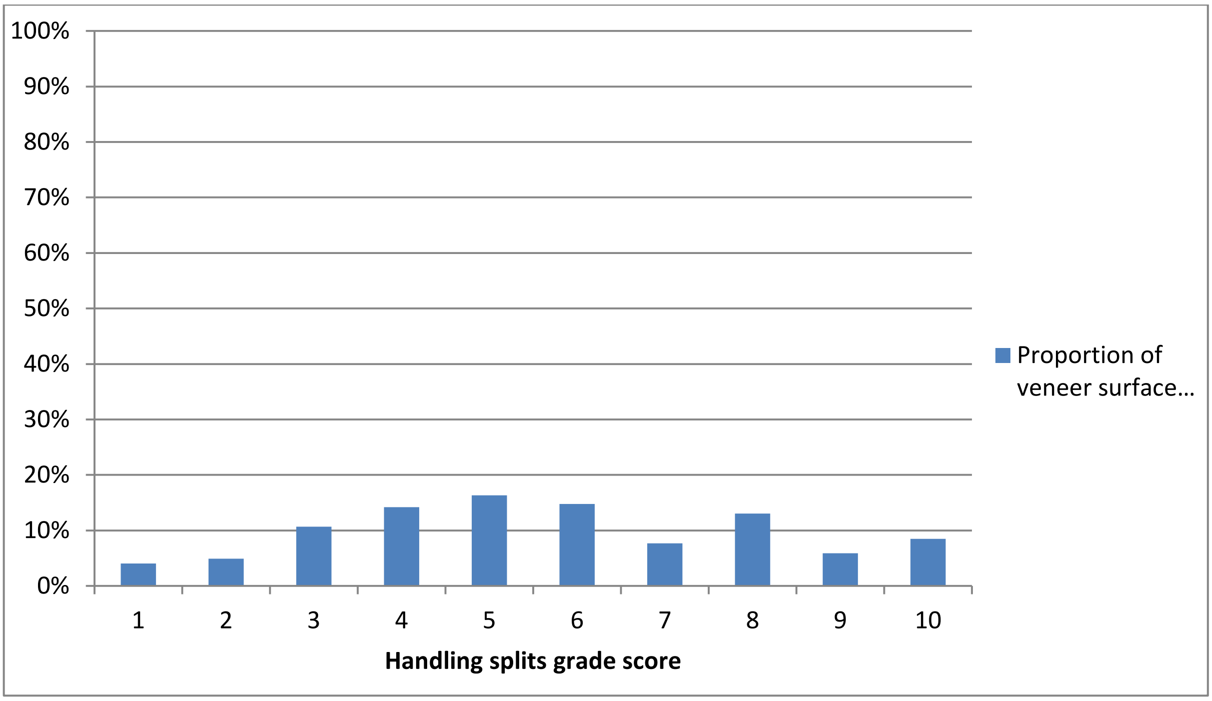

Figure 10 – Distribution of handling splits scores

3.2.10 Wane

Wane on veneer is a direct result of insufficient log rounding before veneer is recovered meaning that sections of the log's natural edge remain in the veneer. Management of this defect is often a balance between maximising the recovery of veneer versus maximising the grade recovery from the peeled veneer volume. Wane will increasingly affect recovery and veneer quality as the log quality is reduced (i.e. sweep, taper and ovality increase). Of the veneer produced during the trial, 94% contained no wane, 4% contained small quantities considered manageable for product manufacture and only 2% of veneers contained wane severe enough to require rejection or major trimming of the veneer sheet before being considered usable (Fig. 11 and Image 9).

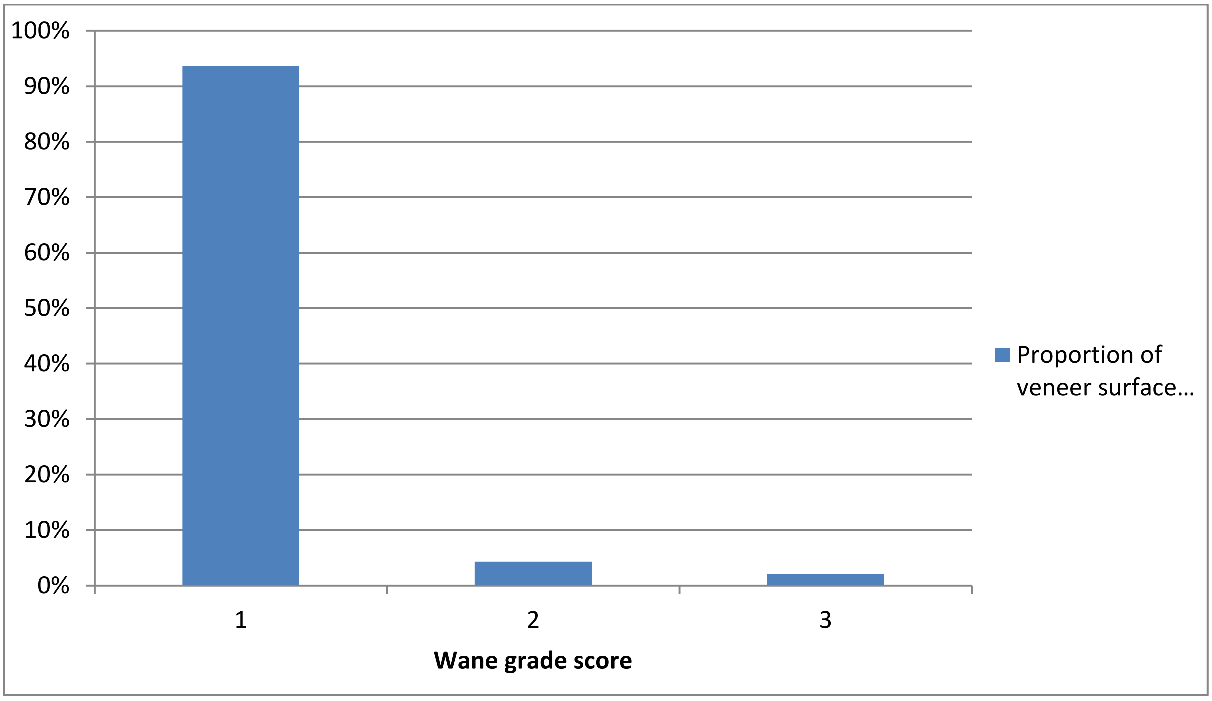

Figure 11 – Distribution of wane scores

Image 9 – Example of wane in cocoveneer

3.2.11 Insect tracks

Insect tracks were identified on 75% of veneers (Fig. 12), however the size and frequency were noted as being small. This is a much higher presence than in trial 3 veneers where only 32% of veneers were noted to have insect tracks. The impact of insect tracks on veneer usability (and value) would be very dependent on the target end product.

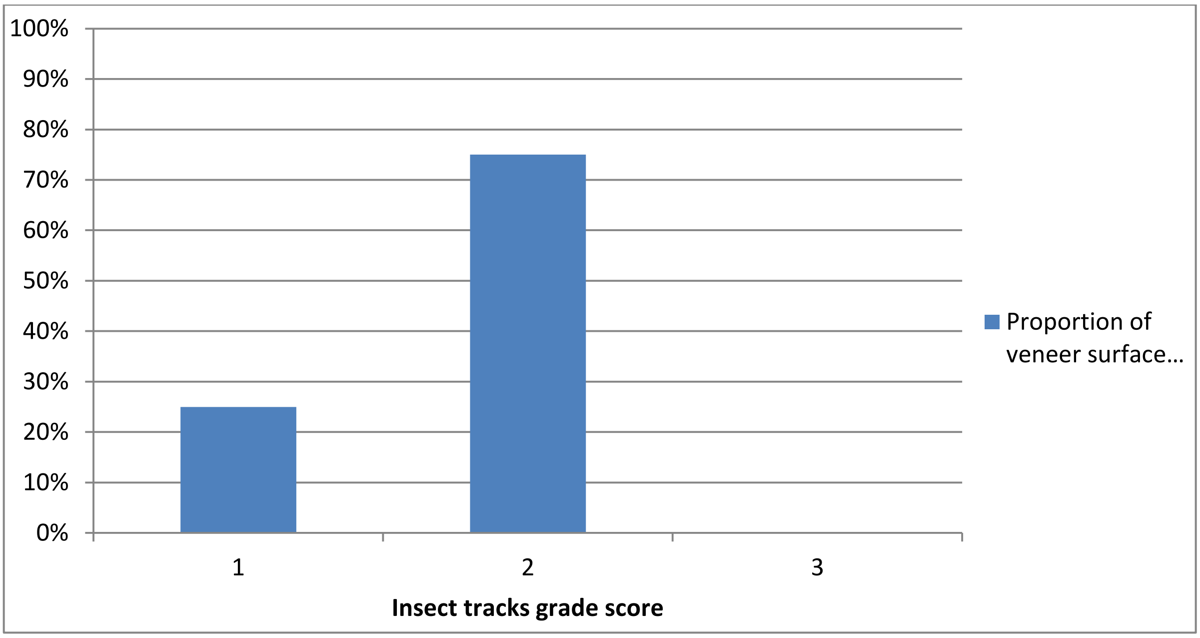

Figure 12 – Distribution of insect track scores

3.3 Veneer properties

3.3.1 Density

The distribution of veneer air-dry density is presented in Figures 13 and 14. The distribution is very similar to that reported in processing trial 3 with densities between 400 to 700 kg/m^3 dominating and accounted for around 70% of the veneer produced. As with trial 3, only 4% of veneers contained densities above 800 kg/m^3.

As reported by McGavin (2015), the density increased from the veneer recovered from towards the centre of the log to the veneers recovered from the periphery of the log. The range in density that exists within a coconut log is potentially two to three times more than what would be experienced in traditional wood resources and highlights one of the challenges with utilising the coconut resource. The wide range of densities certainly presents challenges for billet processing, veneer quality segregation systems and target product manufacture.

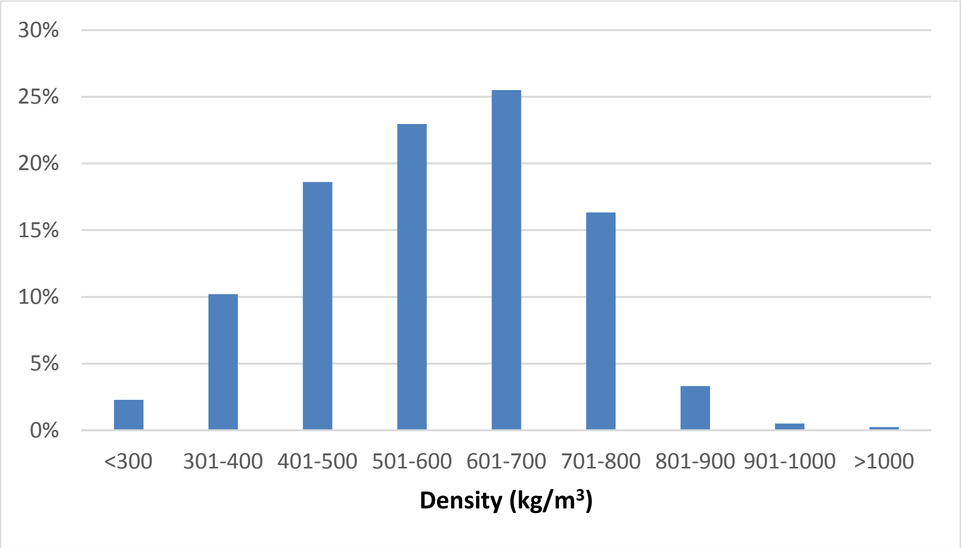

Figure 13 – Distribution of veneer air-dry density

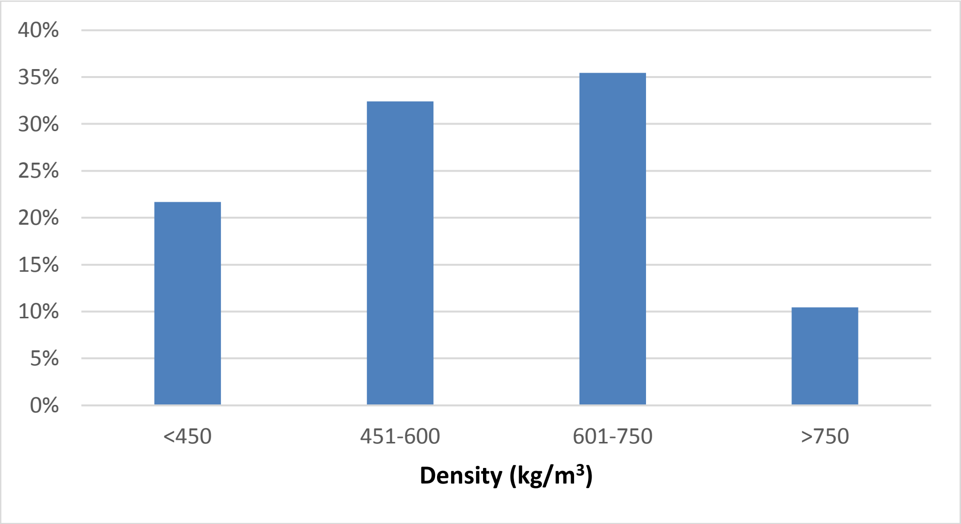

Figure 14 – Distribution of veneer air-dry density

3.3.2 Modulus of elasticity

A total of 247 samples were used to measure the veneer modulus of elasticity (MoE). The measurements resulted in an average MoE of 5,352 MPa (16,883 MPa maximum, 1,013 MPa minimum, 2,896 MPa standard deviation) (Figure 15). While the minimum and mean values were similar to the results of processing trial 3, trial 4 recovered a larger spread of higher MoE veneers compared with trial 3 (which recorded a maximum MoE value of 11,936 MPa). McGavin (2015) reported that some improvements in MoE might be possible through improved processing protocols however these gains would be expected to be marginal. The slight gains in this this trial compared to trial 3 may be a reflection of the improved protocols adopted during this trial.

The veneer MoE results are low compared to most commercial wood species. As a guide, market demand for wood-based structural products with MoE values below 10,000 MPa are limited with a low value often resulting. While veneer MoE is not the only important mechanical quality, it provides a very useful indicator of the veneer suitability for a range of structural products. These results indicate that the suitability of cocoveneer in the manufacture of structural based products may be challenging unless blended with other forest resources or specific markets can be identified that have low mechanical quality requirements (or at least low MoE) however demand other qualities that cocoveneer possess (e.g. aesthetic qualities). Another strategy may be increased product dimensions to compensate for the lack of mechanical performance.

Figure 16 shows a positive but surprisingly weak correlation between density and MoE. This reason for such a weak relationship between MoE and density is unclear and warrants further investigation, especially to determine the veneer MoE influence on manufactured product mechanical properties.

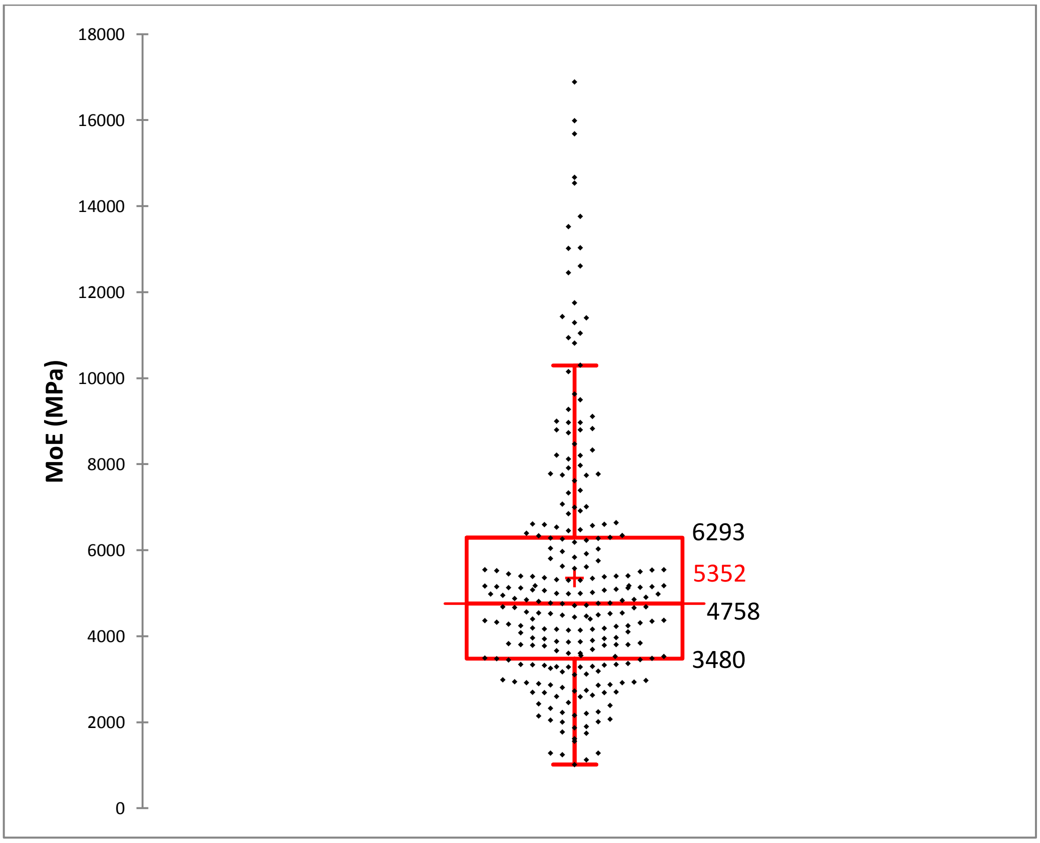

Figure 15 – Veneer MoE

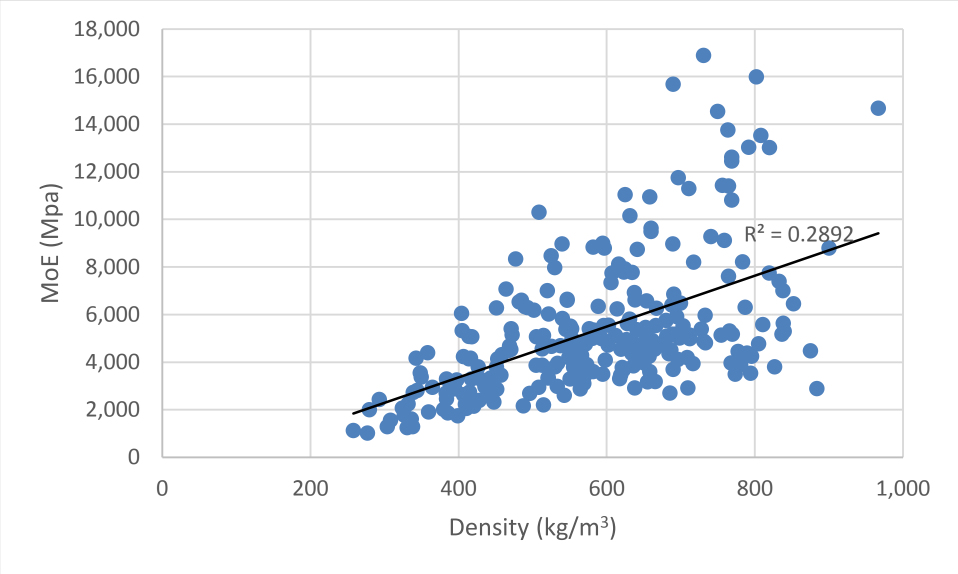

Figure 16 – Correlation between veneer MoE and density

3.4 Veneer grade recovery

As noted in section 3.1, after drying, 12.5 m^3 of veneer was recovered reflecting a recovery rate of 49.8% (or 65.0% of rounded billet volume). When a trimming factor is applied (similar to that reported by McGavin *et al.* 2014) to determine the volume of veneer recovered at a nominal standard length and width (edges trimmed square etc.), 11.4m^3 of veneer was recovered reflecting a recovery of 45.4%. This volume and recovery however doesn't necessarily reflect the volume of usable or saleable veneer.

Veneer would normally be graded into specific grade qualities to reflect product suitability, market acceptability and product performance expectations. In the absence of critical market information, three nominal grade qualities are proposed to reflect superior quality (Grade 1), high quality (Grade 2) and standard grade (Grade 3). These nominal grades provide an indicative spread of qualities when all veneer characteristics are evaluated together. The grade recovery when veneers are graded to each grade criterial are outlined in Table 1. Note that these grade scenarios are indicative only and more relevant grade rules will need to be determined when product and market information are better understood.

Table 2. Veneer grade recovery for three nominal grade scenarios

	Grade 1	Grade 2	Grade 3
Grade recovery (% of total recovered veneer)	15	50	84

4 Discussion

The trial was successful in demonstrating that with appropriate processing protocols, coconut palms can be processed efficiently into rotary veneer within industrial facilities. Deviating outside the relatively narrow processing protocol target ranges does negatively impact veneer quality and increase machinery loading. The commercial scale veneer processing equipment performed satisfactorily however some mechanical failures demonstrated the need for robust rounding and peeling equipment if coconut palms are to be peeled in large volumes. Commercial veneer drying approaches dried the resulting veneer to a satisfactory standard.

Veneer recoveries were within the expected range for the processing approach, log dimensions and equipment limitations. As with earlier processing trials, the recovered veneer contained a range of defects and other characteristics. With modified processing protocols, significant quality gains were made with veneer splits, handling splits, brittleness, collapse and compression, when compared with processing trial 3 results.

The resulting veneer contained a range of properties that far exceeds the normal ranges recovered when processing traditional forest resources. While this presents some challenges, it highlights the need for effective grading systems to segregate the qualities that suit the target end products. In addition, several end-products may need to be pursued to ensure utilisation of all the recovered qualities.

While a veneer grade segregation system was proposed that separated veneer qualities into three nominal grades, more detailed grading rules need to be established in line with a thorough product and market assessment.

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