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 3

July 2015

Queensland Government

This publication has been compiled by Rob McGavin of Agri-Science Queensland, Department of Agriculture and Fisheries.

Summary

A coconut stem rotary veneer processing trial was undertaken using newly installed experimental veneer processing equipment at the Fiji Ministry of Fisheries and Forests, Timber Utilisation and Research Division facility (TUD) in Nasinu, Fiji. A component of the trial included testing and commissioning of the equipment suite. Twenty-three coconut logs totalling approximately 1.47 m^3 were processed during the trial producing 249 veneer sheets and 0.89 m^3 of dried veneer. Veneers were dried using conventional solid-wood techniques before being graded for a range of properties and qualities. The veneer quality potential was severely limited by the performance of the log pre-conditioning chamber which prevented target log temperatures from being reached. This limitation also prevented more optimal lathe settings from being established. Veneer roughness, brittleness, compression and splitting were identified as key quality limiting characteristics. Reducing the impact of these characteristics should be the primary focus of future trials. Significant improvements in veneer quality would be expected through modified processing protocols. Achieving target log pre-conditioning temperatures followed by optimised lathe settings would be expected to contribute to the most gains. Introductory training was provided throughout the trial to key operational and technical staff linked to the project.

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1 Introduction

A coconut stem veneer processing trial (Trial 3) was undertaken in August 2014 at the Fiji Ministry of Fisheries and Forests, Timber Utilisation and Research Division Facility (TUD) in Nasinu, Fiji. The trial was led by the Queensland Department of Agriculture and Fisheries (DAF) in collaboration with the Fiji Ministry of Fisheries and Forests, Secretariat of the Pacific Communities (SPC) and the University of Tasmania (UTAS). 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:

- Commission and test experimental veneer processing equipment that had been recently installed at TUD. The equipment included a log pre-conditioning steam chamber, 1300 mm spindleless veneer lathe, veneer out-feed conveyor and veneer clipper.
- Provide demonstration of rotary veneer produced from coconut palm stems to key participants of the *ACIAR FST/2009/062 Development of advanced veneer and other products from coconut wood to enhance livelihoods in South Pacific communities* project.
- Deliver introductory training to key project staff on veneer processing equipment setup, operation and maintenance along with veneer processing trial R&D protocols and veneer drying.
- Produce sufficient quantity of coconut veneer or ‘cocoveneer’ for recovery and quality assessments.
- Supply a quantity of cocoveneer feedstock and specifically high-density veneer (i.e. >800kg/m^3) for preliminary product development activities.

2 Material and methods

A supply of coconut palm logs were sourced for the trial from Pacific Green Industries Ltd, a company with operations close to TUD. Pacific Green commercially process coconut stems into a range of predominately sawn-based furniture and architectural items.

Logs were docked to approximately 1300 mm lengths prior to pre-conditioning. The benefits of pre-conditioning coconut palm stems prior to rotary peeling were demonstrated in Processing Trial 1 and reported by Bailleres *et al.* (2015). The pre-conditioning process involves heating the billets without moisture loss, to soften the log making the peeling operation easier and improving the resulting veneer quality. Temperatures above 80 degrees Celsius are necessary to gain the most benefit from reducing lathe cutting forces and improving veneer quality. A log temperature of 85 degrees Celsius was targeted for the trial. Pre-conditioning was undertaken in an enclosed chamber with heating provided via saturated steam (Image 1). Logs were pre-conditioned for approximately 14-18 hours prior to peeling.

Image 1 – Chamber used to pre-condition coconut palm stem logs prior to peeling

Logs were not ‘de-barked’ prior to peeling, rather the lathe was used to remove the cortex layer. Logs were ‘rounded’ at this time to remove any taper, sweep and bumps from the log, to provide a log that was close to cylindrical in preparation for peeling. A log diameter measurement was recorded at the completion of de-barking and rounding.

Rotary peeling was performed using a Malaysian-built spindleless veneer lathe (Image 2). While the lathe manufacturer had some experience with rotary peeling coconut stems, and the lathe included some design features specifically for peeling coconut stems, the knowledge and experience of the manufacturer had been restricted to low to medium density coconut only (e.g. <600 kg/m^3). Spindleless lathe performance and optimal settings for higher density coconut (i.e. >600 kg/m^3) are largely unknown. For this reason, the trial intended to include a range of lathe settings to progressively fine tune the peeling performance as the trial proceeded. Information from the lathe manufacturer, DAF experience in spindleless lathe operation combined with the laboratory peeling trials reported by Bailleres *et al.* (2015) provided the base line initial settings and guided subsequent changes. The minimum residual or peeler core size was 60 mm.

Peeled veneer was clipped targeting a sheet width of approximately 1,300 mm. Each veneer sheet was labelled with a unique identifier before being prepared for drying. While veneer is normally dried by modern industry in a specifically designed system such as a jet box drier, in the absence of such technology, veneer was stripped using conventional sawn timber practices. This included small timber strips (approximately 20 x 20 x 1,300 mm) spaced at approximately 350 mm intervals which were used to separate a double layer of veneer sheets. The void between veneer layers created by the timber strips enabled air flow and removal of moisture during drying.

Image 2 –Spindleless veneer lathe used for peeling coconut stems

Veneer stacks were loaded into a gas-assisted solar kiln (Images 3 and 4) and dried to a target moisture content (MC) of approximately 10%. Dried veneers were re-stacked, packaged and forwarded to the DAF Salisbury Research Facility in Brisbane, Australia.

Image 3 – Gas-assisted solar kiln designed for solid timber drying.

Image 4 – Cocoveneer was dried using conventional solid wood drying protocols.

Once at the DAF Salisbury Research Facility, veneers were graded for a range of natural and process induced qualities. In the absence of a veneer grading standard suitable for coconut, a grading method was developed as part of the trial to allow specific defects to be characterised. The acceptability of the size and frequency of defects will need to be determined when target end-products are more accurately defined.

The following attributes were assessed:

- Density – calculated for each veneer sheet by measuring veneer dimensions and mass.
- 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.

A subset of better quality veneers from across the density range were selected to measure veneer modulus of elasticity (MoE). From the edge of each selected veneer sheet, a sampling strip was removed which measured 150 mm (parallel to the grain) by approximately 1,200 mm long. The sampling strips were conditioned to 12% MC prior to measurement. Veneer MoE measurements followed using an acoustic natural-vibration method as described by Brancheriau and Bailleres (2002) (Image 5). Sample strip dimensions (length, width and thickness) and weight were measured allowing veneer density to be calculated for the specific sample on which MoE was measured.

Image 5 – Modulus of elasticity measurement on cocoveneer sampling strips.

3 Results

3.1 Processing

Complications with chamber preparations and gas burner commissioning of the pre-conditioning chamber limited the temperature that the logs could achieve prior to peeling. For the majority of logs, peeling was conducted with log temperatures between 40 and 55 degrees. This certainly negatively impacted the quality of the peeled veneer, especially veneer originating from the higher density periphery of the logs. The inability to have logs prepared to the target temperature also prevented more optimal lathe settings from being established.

Twenty-three coconut logs totally approximately 1.47 m^3 were processed during the trial (Image 6). A total of 249 veneer sheets were produced resulting in 0.89 m^3 of dried veneer. A gross veneer recovery of approximately 61% was achieved. While this recovery rate is very close to the gross recovery rates reported by McGavin *et al.* (2014) for veneer processing young, plantation-grown hardwood logs, there were some differences in methodologies between the two studies. For example, the method of calculating log volumes differed slightly. For the results reported by McGavin *et al.* (2014), log volumes were calculated on de-barked but unrounded logs, whereas this trial used the log diameter measured after cortex removal and log rounding. This would lead to a slightly inflated recovery rate by comparison. Also, a larger peeler core size was set for the cocoveneer trial (i.e. 60 mm versus 45 mm) meaning the log volume available for veneer production was less. The sub-optimum log peeling temperature would also have negatively affected the potential recovery rate.

Image 6 – Cocoveneer produced on a spindleless veneer lathe

3.2 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 measurements suggest the veneers from the trial contained minimal variation in colour and very little change in colour with increasing density (Fig. 1). These findings provide further support that colour is a limited indicator for density and could not be used in isolation as a grading method for separating veneer densities.

Image 7 – Colour measurement on cocoveneer

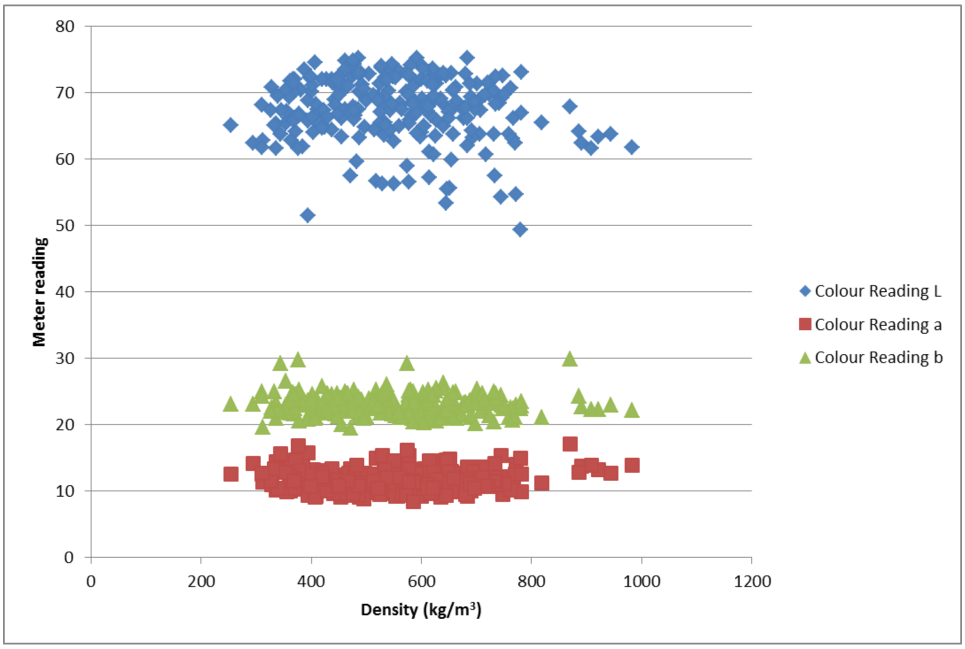

Figure 1 – Cocoveneer colour assessment.

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

3.3 Density

The distribution of veneer air-dry density is presented in Fig. 2. Veneers with densities between 400 to 700 kg/m^3 dominated and accounted for 70% of the veneer produced. Only 4% of veneers (8 sheets) contained densities above 800 kg/m^3. The lack of high density veneers indicated that the logs supplied for the trial were not completely suitable for some of the trial objectives.

As expected, the density increased from the veneer recovered from towards the centre of the log to the veneers recovered from the periphery of the log. Fig. 3 displays an example of the veneer sheet density trend produced from one log. The veneer sheet numbering in this example starts from the veneer from the inner part of the log and finishes at the sheet recovered from the log periphery. 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 will certainly have implications for pre-conditioning, processing, veneer quality segregation systems and target product manufacture.

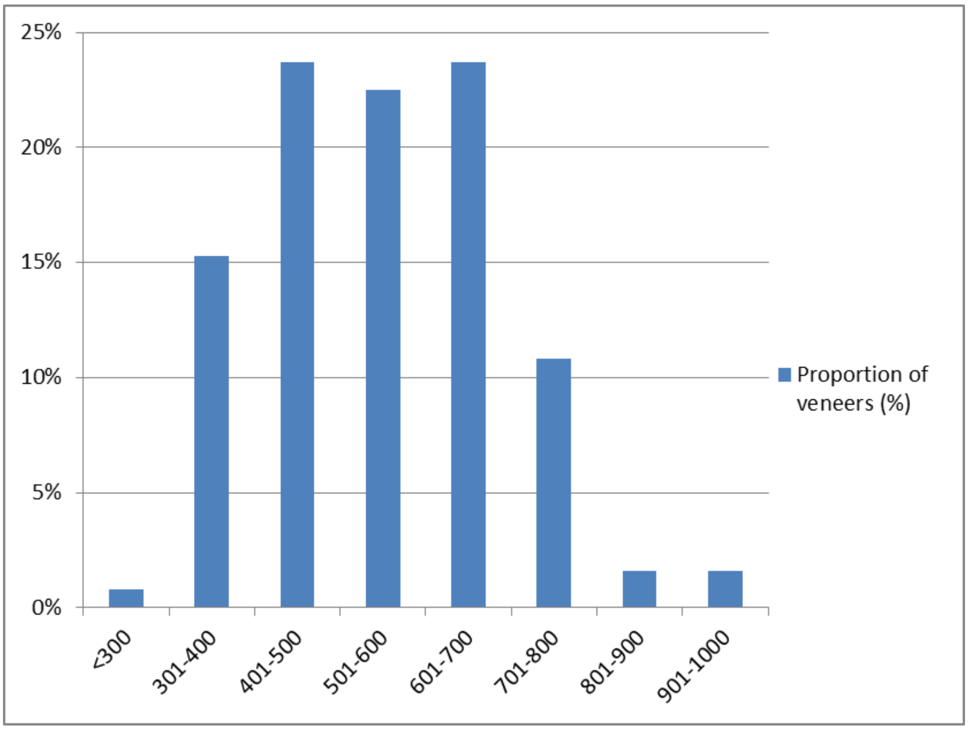

Figure 2 – Distribution of veneer air-dry density

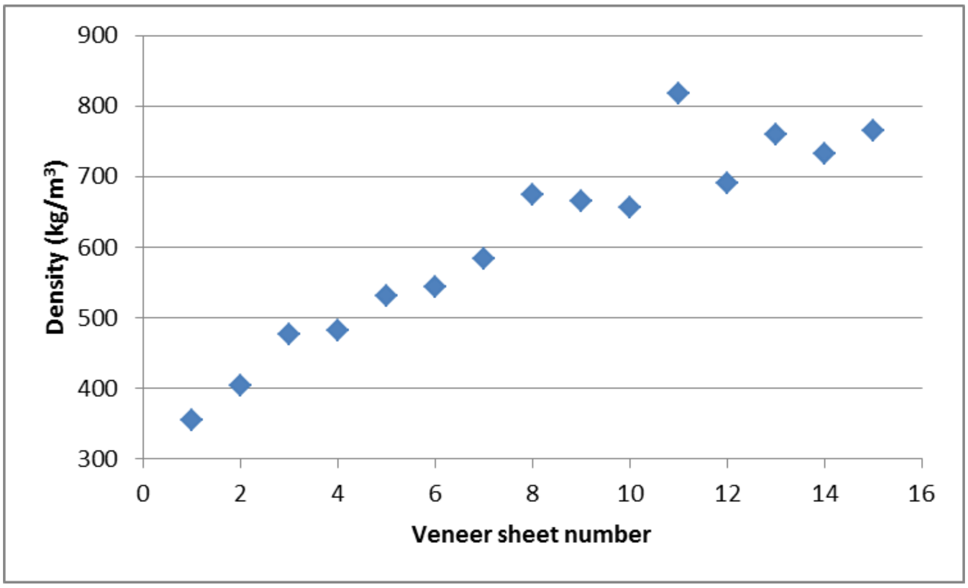

Figure 3 – Example of density radial variation from the centre to the outside of a coconut log

3.4 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 however no veneer was considered ‘smooth’ (score 1) (Fig. 4). A roughness score of 3 dominated the assessment indicating that the veneers would be expected to be made smooth after moderate sanding. 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 manufacturing process. Roughness can be particularly challenging for achieving reliable and efficient glue bonds during product manufacture.

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

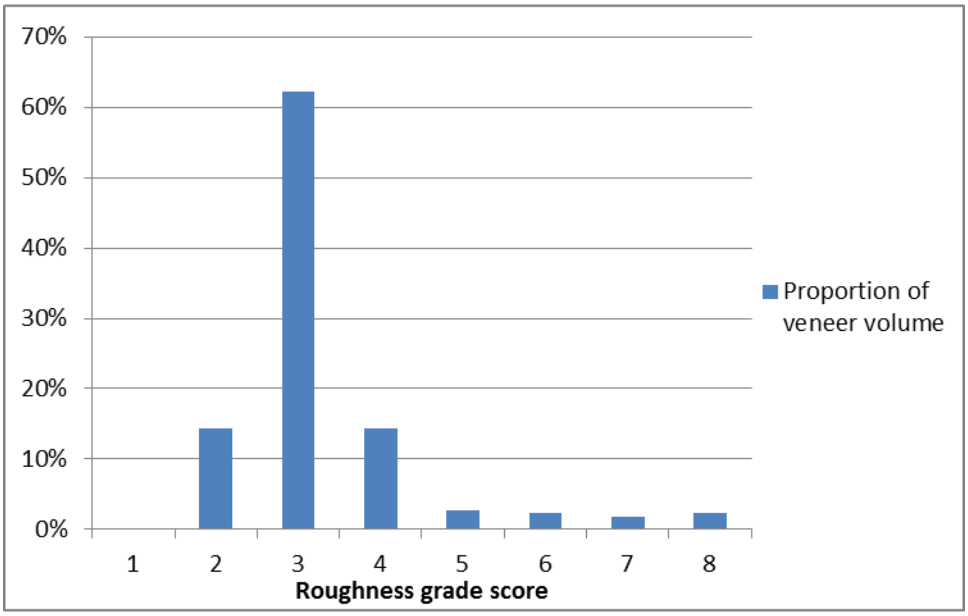

Figure 4 – Distribution of veneer roughness scores

3.5 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 3.11) although it is acknowledged that accurately identifying the source of the splits is difficult. Figure 5 displays the distribution of split grade scores. Over half of the veneer produced during the trial scored 3 or higher. Splits can have quite negative implications for the successful manufacture of end products, particularly those which demand high aesthetic qualities. Correct log pre-conditioning temperatures followed by optimised lathe settings would be expected to contribute to the most gains in reducing splits.

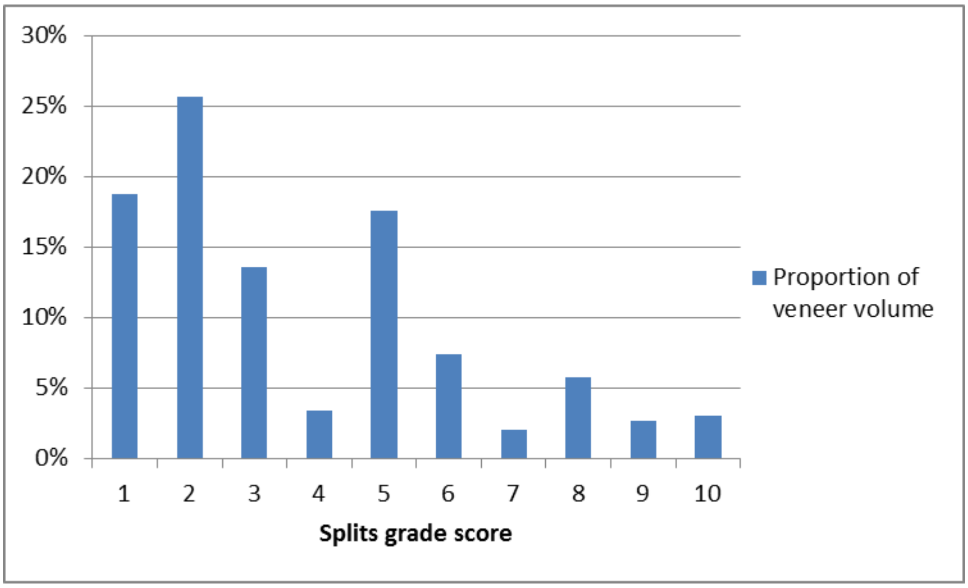

Figure 5 – Distribution of split scores

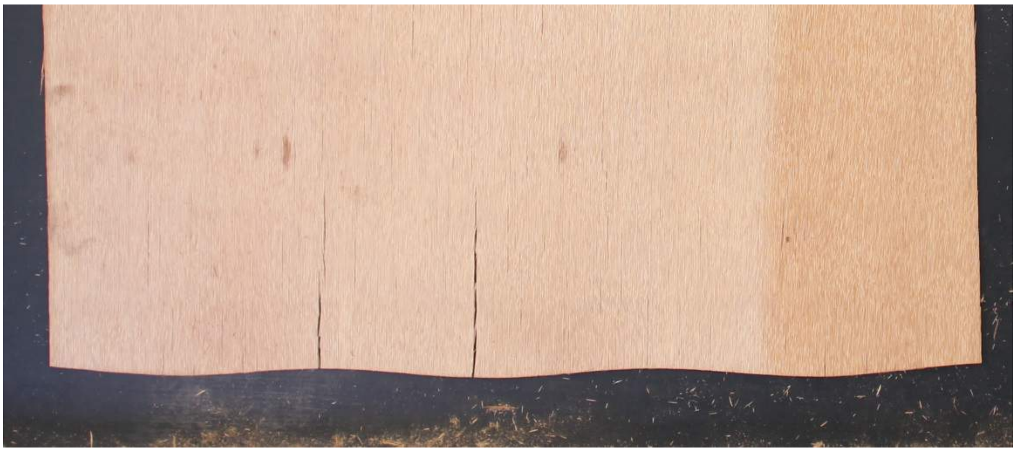

Image 8 – Example of veneer splits

3.6 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. Just under 70% of the veneer was assessed to have acceptable brittleness (Fig. 6 and Image 9). A positive but weak correlation exists between brittleness score and veneer density ($r^2 = 0.34$) confirming brittleness will be more problematic as the higher density target resource is peeled. Correct log pre-conditioning temperatures followed by optimised lathe settings would be expected to reduce veneer brittleness. The unique structure of coconut palm may also demand non-traditional target veneer thickness to assist in minimising brittleness. Efforts to reduce this particular defect should be a primary focus of future processing trials.

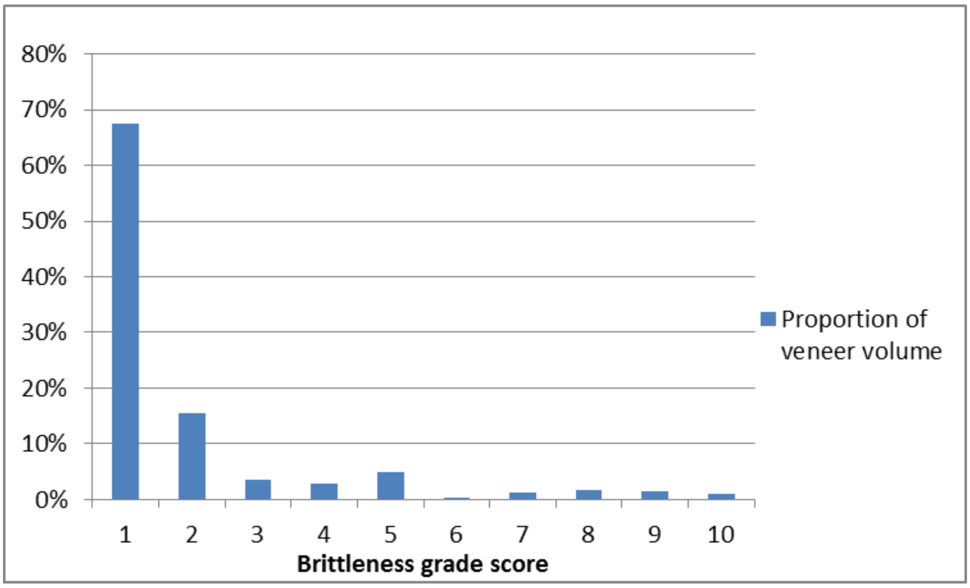

Figure 6 – Distribution of brittleness scores

Image 9 – Example of poor quality and split veneer due to brittleness

3.7 Collapse

As illustrated within Fig. 7, many of the veneers contained collapse resulting in the veneer surface being fractured and split. The final implications of this defect will be dependent on the final product application, however it would be expected that the severity and frequency of collapse would need to be improved substantially from that displayed in the trial veneer. Correct log pre-conditioning temperatures followed by optimised lathe settings would be expected to contribute to the most gains in reducing collapse in cocoveneer. Efforts to reduce this particular defect should be a primary focus of future processing trials.

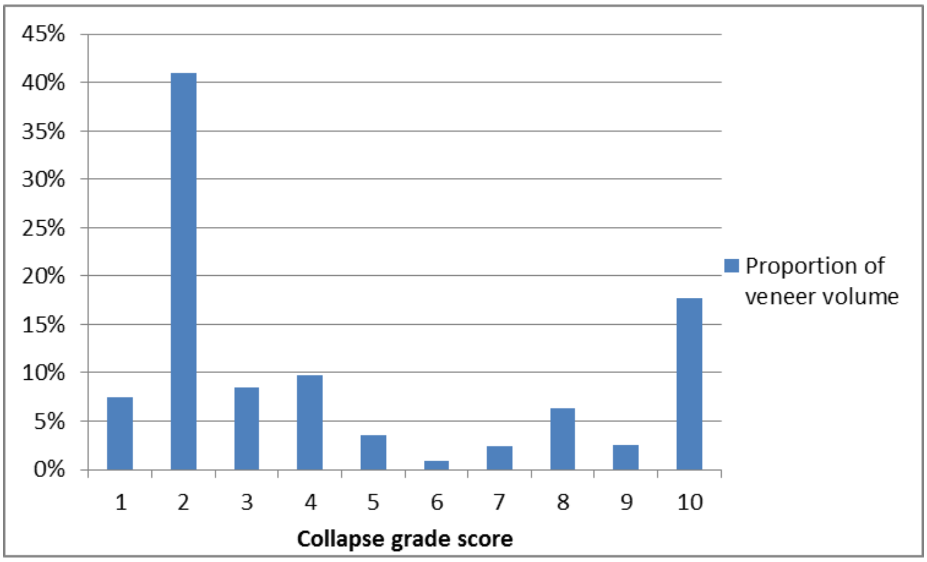

Figure 7 – Distribution of collapse scores

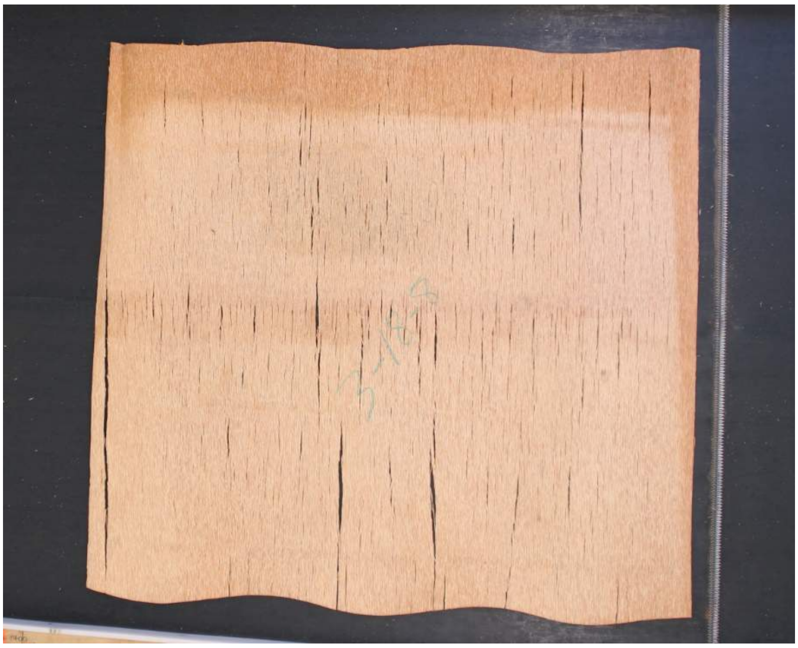

Image 10 – Example of collapse in cocoveneer

3.8 Decay

Decay was present in 14% of veneer suggesting that either decay was present in the standing palm and/or the delay between harvesting and processing was sufficient for decay to establish (Fig. 8 and Image 11). 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.

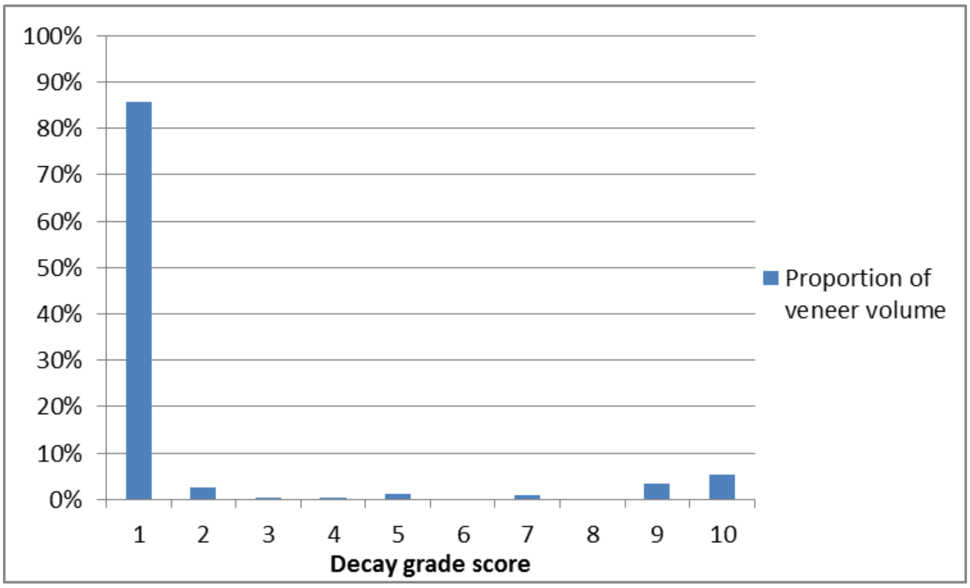

Figure 8 – Distribution of decay scores

Image 11 – Example of decay in veneer

3.9 Holes and tear-out

The presence of holes and tear-out negatively affected just over 20% of trial veneer (Fig. 9 and Image 12). The cause of this defect could be influenced by a range of factors including decay, undersized 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.

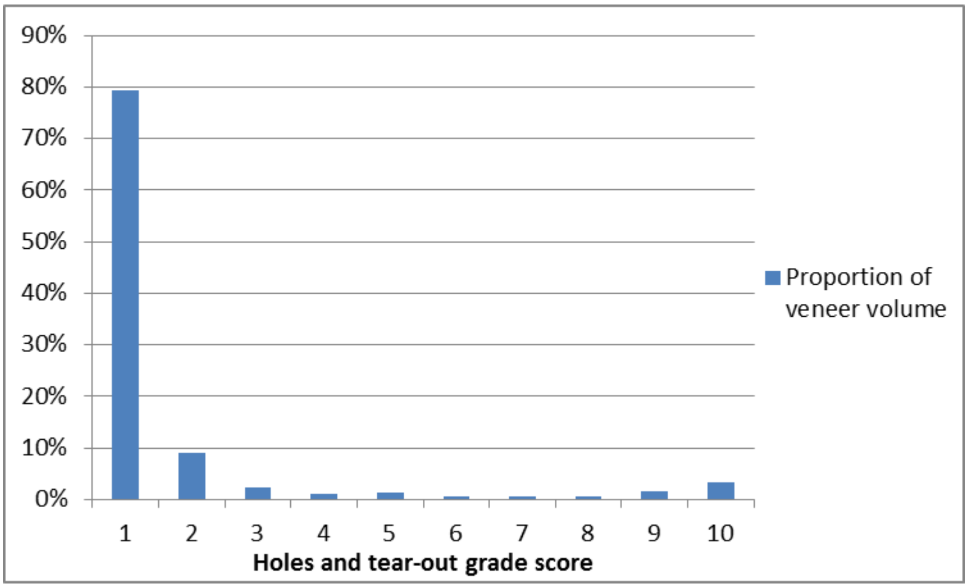

Figure 9 – Distribution of holes and tear-out scores

Image 12 – Example of tear-out in veneer

3.10 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. wavy grain) or process induced (e.g. poor log pre-conditioning and/or incorrect lathe settings). There was some degree of compression in approximately 20% of veneers (Fig. 10).

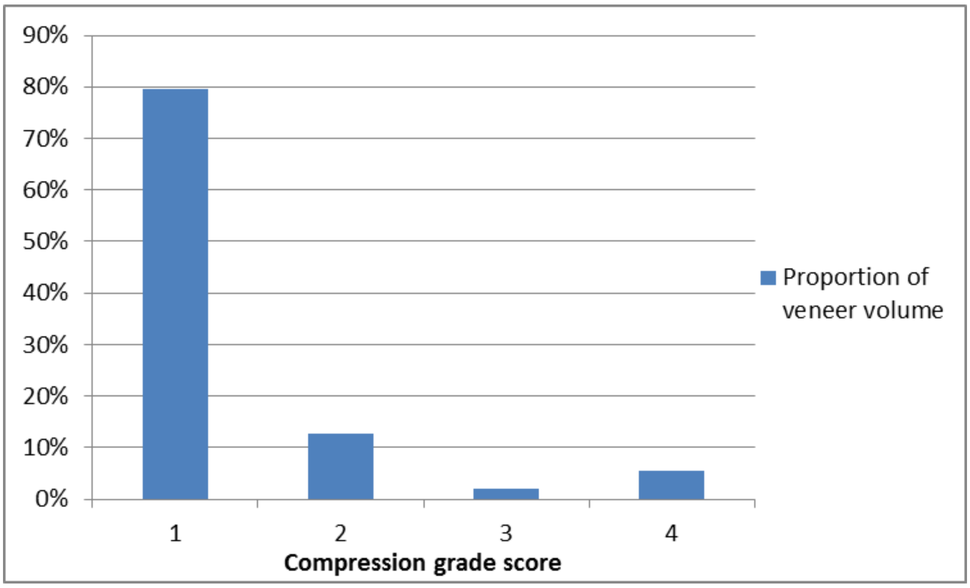

Figure 10 – Distribution of compression scores

3.11 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 3.5). 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.

Over 60% of the trial veneers were affected by handling splits (Fig. 11 and Image 13). Optimised processing and veneer handling protocols would be expected to contribute to the most gains in reducing handling splits. While not the only cause of handling splits, handling veneers from the out feed of the clipper to veneer stacks was a source of many splits. Improvements in infrastructure and handling protocols in this area should be a priority for future trials.

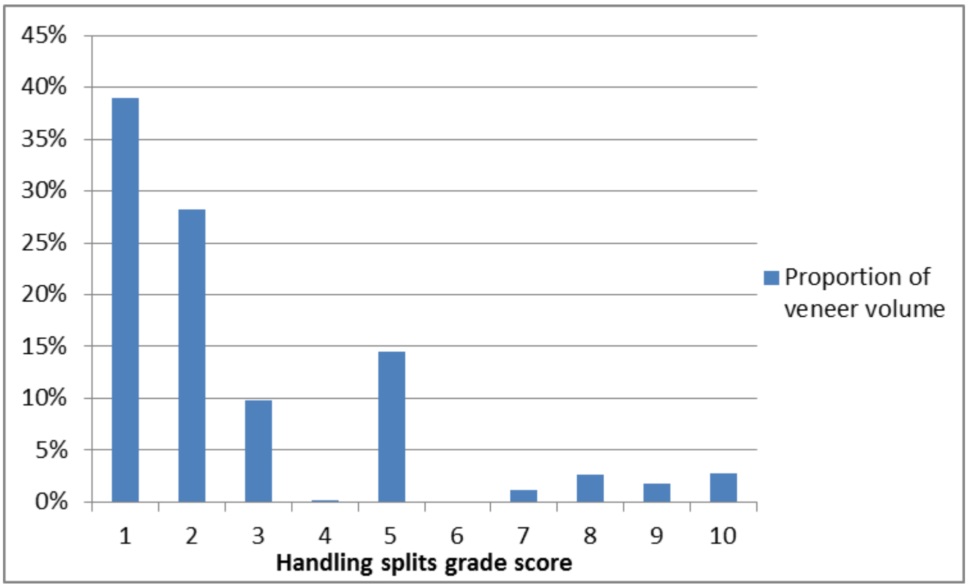

Figure 11 – Distribution of handling splits scores

Image 13 – Example of handling splits

3.12 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, 90% contained no wane, 9% contained small quantities considered manageable for product manufacture and only 1% of veneers contained wane severe enough to require rejection or major trimming before being considered usable (Fig. 12 and Image 14).

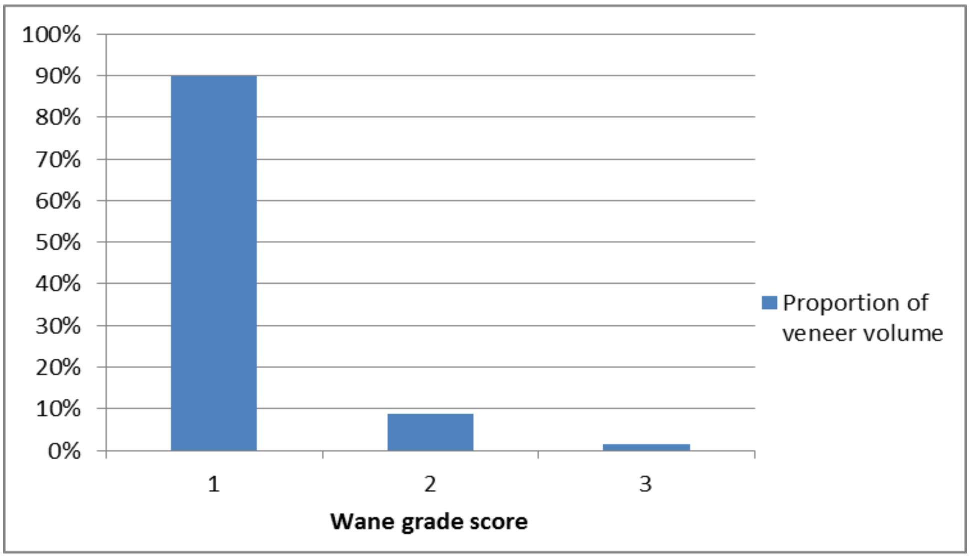

Figure 12 – Distribution of wane scores

Image 14 – Example of wane in cocoveneer

3.13 Insect tracks

Insect tracks were identified on 32% of veneers, however the size and frequency were noted as being small (Fig. 13). The impact of insect tracks on veneer usability (and value) would be very dependent on the target end product.

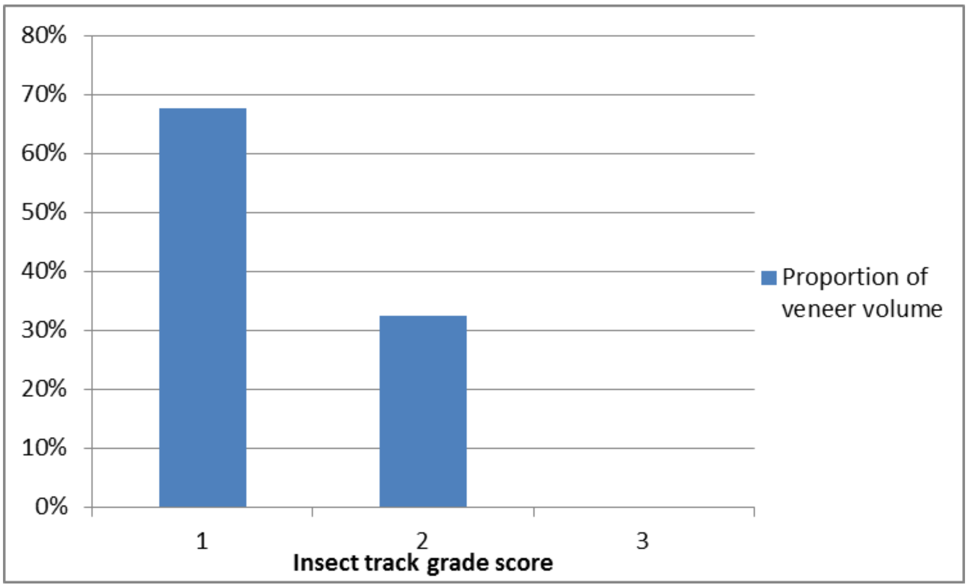

Figure 13 – Distribution of insect track scores

3.14 Modulus of elasticity

A total of 47 samples from across the range of veneer densities (345 kg/m^3 to 833 kg/m^3) were used to measure the veneer modulus of elasticity (MoE). The measurement resulted in an average MoE of 5,290 MPa (11,936 MPa maximum, 940 MPa minimum, 2,674 MPa standard deviation) (Figure 14). Figure 15 shows a moderately positive correlation between density and MoE.

The veneer MoE results are very 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. Some improvements in MoE might be possible through improved processing protocols however these gains would be expected to be marginal. These results indicate that the suitability of cocoveneer in the manufacture of structural based products would 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).

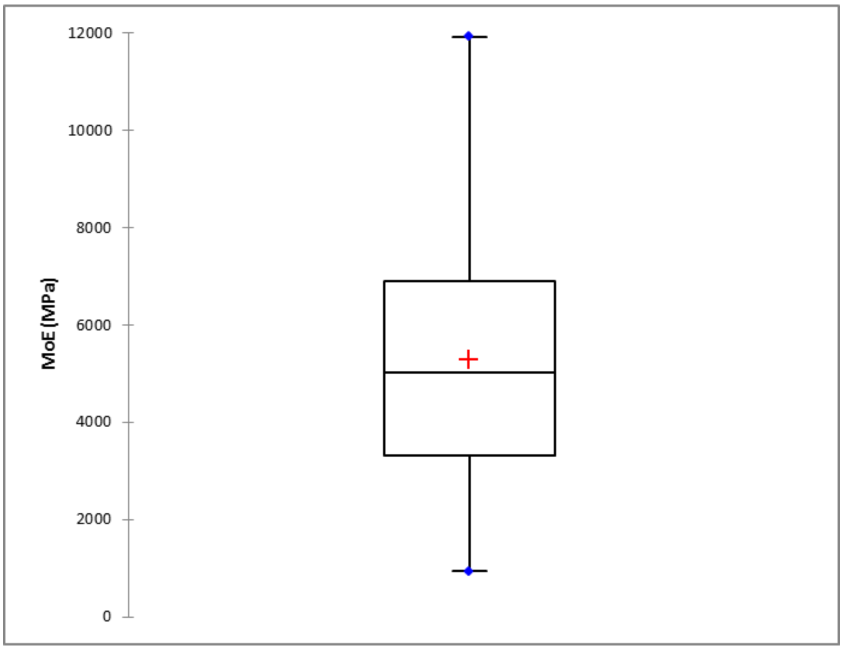

Figure 14 – Veneer MoE

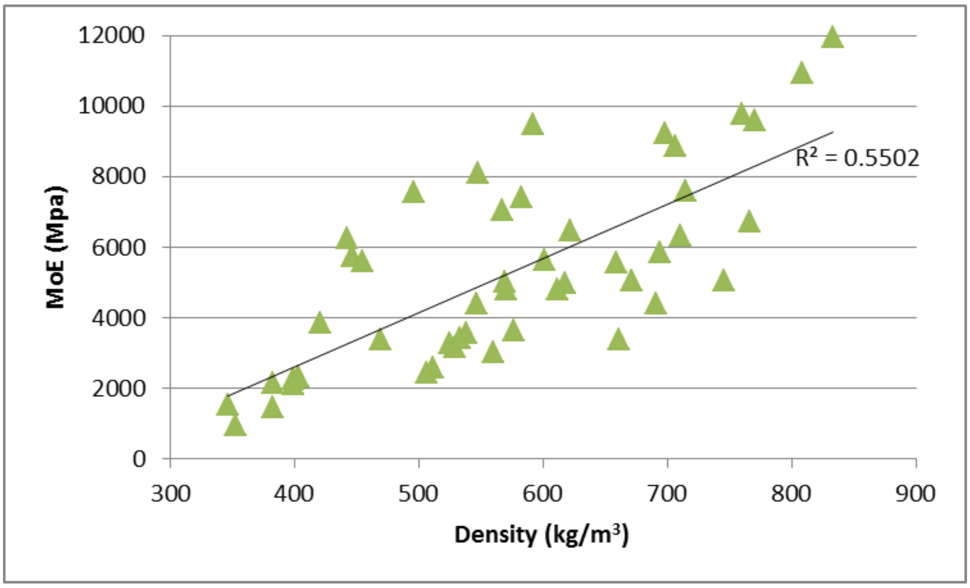

Figure 15 – Correlation between veneer MoE and density

3.15 Training

Introductory training in spindleless rotary veneer lathe setup, basic operation and lathe maintenance was provided to key operational and technical staff of TUD and SPC (Image 15). In addition, introductory training in veneer management techniques and veneer R&D data collection protocols (e.g. veneer labelling and thickness assessment), along with wood drying fundamentals and kiln operation was provided

(Images 16 and 17). Additional training and operator experience will be necessary to better enable efficient and safe operations.

Image 15 – Introductory training provided in veneer lathe setup

Image 16 – Introductory training provided in veneer quality assessment

Image 17 – Introductory training provided in veneering trial data collection protocols

4 Discussion

The trial provided an opportunity to:

- test the experimental veneer processing equipment recently installed at TUD;
- produce a quantity of veneer for quality assessments;
- supply veneer feedstock for other project activities;
- provide introductory training across a range of relevant topics; and
- demonstrate the equipment and veneer production process to key project participants.

The veneer lathe performed satisfactorily and successfully peeled coconut stems with densities up to around 800 kg/m^3. Design and commissioning problems with some supporting equipment items limited the scope and success of the trial. In particular, the pre-conditioning chamber prevented optimal log temperatures from being reached. This certainly negatively impacted the quality of the veneer produced during the trial and also prevented substantial gains in developing more optimal lathe settings and processing protocols.

Veneer quality assessments highlighted various characteristics limiting high quality veneer. These include roughness, brittleness, splitting and collapse. Potentially acceptable limits for these characteristics can not be determined until target end-products are better defined. Significant improvements in veneer quality would be expected through modified processing protocols. Achieving target log pre-conditioning temperatures followed by optimised lathe settings would be expected to contribute to the most gains.

The small volume of veneer was insufficient to facilitate any significant follow on activities in product prototyping and product manufacture. In addition, only a very small amount of high density veneer (>800 kg/m^3) was produced indicating the logs available for the trial were not optimal for this objective.

Introductory training was provided throughout the trial to key operational and technical staff of SPC and TUD. Additional training and operator experience will be necessary to better enable efficient and safe operations.

5 Acknowledgements

The *Development of advanced veneer and other products from coconut wood to enhance livelihoods in South Pacific communities* (FST/2009/062) project was supported by the Australian Centre for International Agricultural Research (ACIAR). The project was undertaken in collaboration with ACIAR, the Queensland Government Department of Agriculture and Fisheries (DAF), the University of Tasmania (UTAS), the Secretariat of the Pacific Community (SPC), the Fiji Ministry of Fisheries and Forests, Samoa Ministry of Natural Resources and Environment, and Solomon Island Ministry of Forestry.

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