Stabilization of Palm Wood using Water-based Impregnation

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by
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1 Abstract

Impregnation is a technique for stabilizing wood that involves saturating the material in a liquid and allowing it to cure before use. Stabilization methods such as this are employed for a variety of reasons; chiefly, the low dimensional stability of wood and palm means that they are subject to several failure modes that arise from changing environmental conditions, such as cracking, warping, and bending. Samples of *Borassus flabellifer*, black palm, provided by DuraPalm were impregnated with solvent-based and water-based stabilizers, and untreated wood samples used as a control group. Kop-Coat WoodYouth® Plus was used as a solvent-based stabilizer, and impregnation treatment using it was performed by Kop-Coat. BVV Wood Stabilizer and TurnTex Cactus Juice were used as water-based stabilizers, and these impregnation treatments performed by the Oregon State University Department of Forestry. Treated samples were allowed to condition for 72 hours in an environmental chamber held at 20.5 °C and 21% relative humidity using a saturated solution of lithium chloride and water as a hygroscopic agent. Sample weight gains showed that the palm samples responded well to impregnation treatment, but 72 hours was not enough time for conditioning to produce any significant change in part dimensions or surface degradation.

2 Introduction

Plyboo® has employed the resources of the Materials Engineering department at California Polytechnic State University, San Luis Obispo, and the Oregon State University Department of Forestry to test the impact of impregnation treatments using water-based stabilizers on samples of *Borassus flabellifer*, otherwise known as black palm. Black palm has a unique, attractive appearance which lends itself to use in interior decoration, but suffers from low dimensional stability; under changes to temperature and humidity in the surrounding environment, black palm, like other organic materials, shrink and swell which can lead to premature part failure including visible defects such as cracks and splits.

2.1 Problem Statement

Plyboo® is sponsoring an investigation into the behavior of black palm after impregnation treatment with water-based stabilizers. In particular, this report seeks to determine how the dimensional stability of rectangular sections of *Borassus flabellifer*, held at low humidity and heat (20% relative humidity, 20.5 °C) is influenced after impregnation treatment with water-based stabilizers (TurnTex Cactus Juice and BVV Wood Stabilizer) compared to black palm samples impregnated with solvent-based stabilizer (Kop-Coat WoodYouth® Plus) and untreated samples.

2.2 Stakeholders

Wood, palm, and other organic materials are susceptible to dimensional and shape changes resulting from changes to the surrounding environment. This experiment should serve the interests of Plyboo® by exploring the influence of different stabilization treatments on black palm samples under adverse conditions. Long part lives and durability under different environmental conditions are vital to Plyboo® products, and information on how sample treatments influence should prove valuable.

3 Background

Palm, wood, and other organic materials are typically characterized by their softness and low dimensional stability. In particular, the moisture content of wood and palm are driven towards equilibrium with the moisture content of the surrounding atmosphere, which causes uneven shrinking or swelling. This behavior can lead to splitting, cracking, and splintering, which necessitates the treatment of wood prior to use. Though palm is not in widespread use for structural applications, it has a unique appearance that is threatened by these failure modes.

3.1 Wood Drawbacks and Necessity of Pre-Processing Treatment

Wood is a natural, porous and fibrous material that is most commonly harvested from the stems of trees and other woody plants. Living or freshly cut (green) wood has a higher moisture content than wood that has been air or kiln dried, or otherwise treated. Shrinking, swelling, and other forms of dimensional instability occur as a result of wood absorbing or losing moisture in the surrounding air; given enough time, the moisture content of a given wood sample will come into equilibrium with the relative humidity of the environment. Additionally, wood suffers the liability of degradation and decomposition from natural agents such as fungi, bacteria, insects and other pests. Although these issues are not as pronounced with indoor wood furniture, fungal proliferation still poses a risk in humid environments, and pests are still a risk in instances where furniture contacts soil, such as in basements [1]. Chemical treatment processes for stabilizing wood can be separated into three categories: coatings that seal the exterior geometry of the wood without affecting the interior, which include sealers and paint; bulking agents that replace the water within the cell walls of wood prior to compression, known as compreg; cell filling, where the voids in the wood cells is replaced with a resin [2][3]. Other methods for improving the dimensional stability and mechanical properties of wood shapes and parts, such as those used for producing particle board and other types of fiberboards which produces an undesirable appearance for furniture, and produces parts with a poorer dimensional stability than the wood it is sourced from [4].

3.1.1 Wood and Palm Structure

Palm wood is distinct from the material that forms the bulk of angiosperm trees (oaks, maples) and gymnosperm trees (conifers). Palms are in the Arecaceae family of plants, and are classified as grasses. Palms are further distinguished from other trees by the absence of the vascular cambium, which results in secondary growth (thickening of the stems and roots) in dicot trees. The lack of the cambium means that palms do not form annual rings that form as a result of secondary growth in trees. The interior structure of palm consists of vascular bundles, responsible for transporting fluid throughout the plant, running through parenchymatous ground tissue [5] (**Figure 1).** This variation in the distribution of vascular bundles creates a density gradient, with the trunk being less dense nearer to the center.

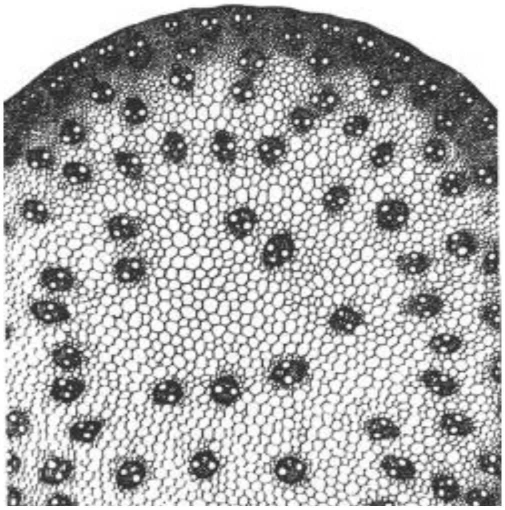

Figure 1: Cross-section of Saccharum officinarum (sugar cane) with large vascular bundles unevenly scattered in the parenchyma near the center of the cross-section, smaller vascular bundles more densely located near the edge [6]

Palm wood also lacks bark, a nontechnical term that designates plant tissues outside of the vascular cambium, as woody trees do. The outside of the central cylinder, containing the vascular bundles running through parenchyma cells is surrounded by sclerenchyma (thick-walled strengthening tissue) formed from previously shed fronds of the plant [7]. This region is known as the cortex, and the region containing the cortex and thin outer epidermis are referred to as the pseudobark.(**Figure 2**).

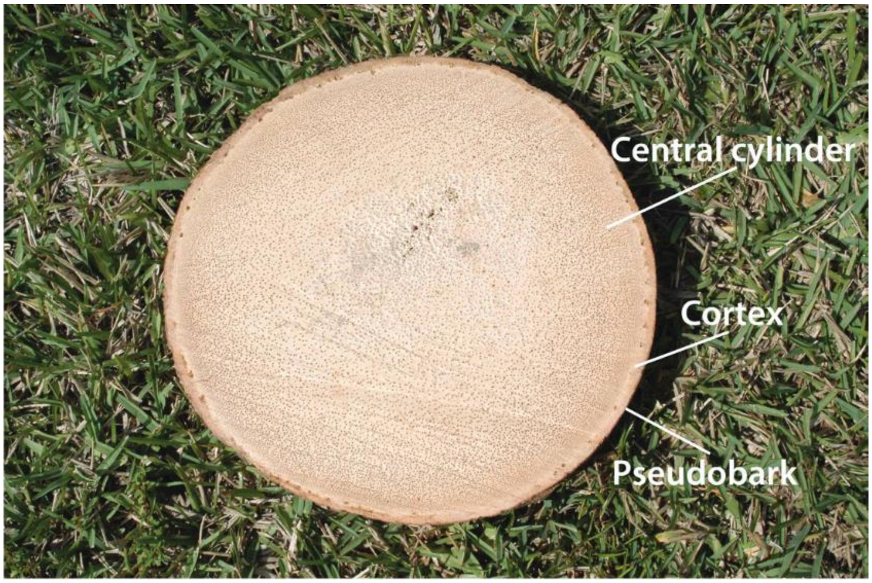

Figure 2: Labelled Sabal palmetto cross section; dark spots within the central cylinder are vascular bundles running through the parenchyma cells [7]

In other woods, the cross-sectional anatomy is more organized. Instead of vascular bundles, vessels (in hardwood species) or tracheids (softwoods) run along the length of the tree through a cellulosic fiber matrix, with the parenchyma radiating outward [8] (**Figure 3**). The arrangement of these anatomical features influences the mechanical behavior of wood and palm lumber.

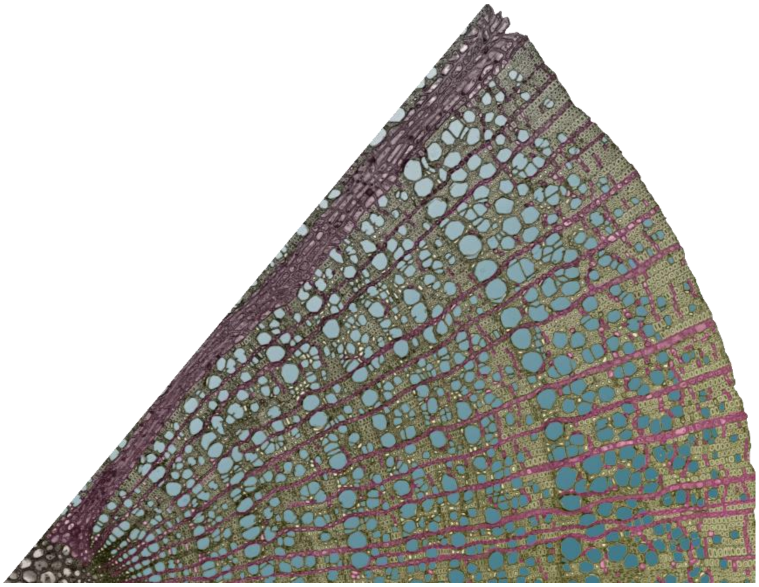

Figure 3: Stained cross section of Fagus grandifolia wood, 200x magnification; fibers are stained green, vessels stained blue, and parenchyma stained pink [8]

3.1.2 Wood and Palm Mechanical Properties

The most commonly used woods for indoor furniture include gum, poplar, and oak, and are used more often than exotic varieties such as mahogany or ebony because of their price and ability to be sustainably harvested. *Borassus flabellifer* (also known as palmyra palm) is widespread in its native habitat of the Indian subcontinent where it is also considered an important economical plant, and is found as far south as New Guinea [9]. *Borassus flabellifer* also bears nutritious fruit, and is found in limited ornamental cultivation in the United States. The already-prolific cultivation of *Borassus flabellifer* in South East Asia makes evident the possible benefits of improving its lumber, especially in terms of dimensional stability and resistance to warping and cracking, for use in indoor furniture. Some mechanical properties of this palm and other lumbers are summarized in **Table I** [10][11], all species at 12% moisture content. Untreated palmyra wood suffers from poorer mechanical properties than the most used lumbers, but the literature shows that it can be improved to a more usable state.

Table I: Mechanical properties of selected species

Species	Modulus of rupture (MPa)	Compressive strength parallel to grain (MPa)	Compressive strength perpendicular to grain (MPa)	Reference
Liquidambar styyraciflua	86	43.6	4.3	[10]
Liriodendron tulipifera	70	38.2	3.4	[10]
Quercus alba	105	51.3	7.4	[10]
Borassus flabellifer	34.05	18.86	2.79	[11]
Borassus flabellifer (densified through compression)	52.90	38.31	7.25	[11]

3.1.3 Equilibrium Moisture Content, and Mechanisms Behind Swelling

Once cut, wood will lose or gain moisture to achieve equilibrium with the surrounding environment. The moisture content of wood, *mc*, is given by the difference between W_g, the weight of the green wood, and W_o, oven-dry weight, divided by the oven-dry weight and converted into a percentage as shown in **Equation 1** [12].

$$mc = \frac{(W_g - W_o)}{W_o} \times 100\% \qquad (1)$$

The equilibrium moisture content (EMC) of wood is influenced by the relative humidity (RH) and temperature of the environment. EMC values can be estimated with the adsorption model in **Equation 2** [13], where *h* is the percent relative humidity, *T* is the temperature in Celsius, and *W* (**Equation 3**), *K* (**Equation 4**), K_1 (**Equation 5**), and K_2 (**Equation 6**) are coefficients calculated for the model.

$$EMC = \frac{1800}{W}\frac{Kh}{1-Kh} + \frac{K_1Kh + 2K_1K_2K^2h^2}{1 + K_1Kh + K_1Kh + K_1K_2K^2h^2} \qquad (2)$$

$$W = 349 + 1.29T + .0135T^2 \qquad (3)$$

$$K = .805 + .000736T - .00000273T^2 \qquad (4)$$

$$K_1 = 6.27 - .00938T - .000303T^2 \qquad (5)$$

$$K_2 = 1.91 + .0407T - .000293T^2 \qquad (6)$$

The EMC of a wood sample is directly related to the RH of the air, and inversely related to its temperature. At a RH of 50%, wood will reach an EMC of 9.5% at 10 °C, and 7.4% at 65.6 °C. These relationships are made more evident in **Figure 4.**

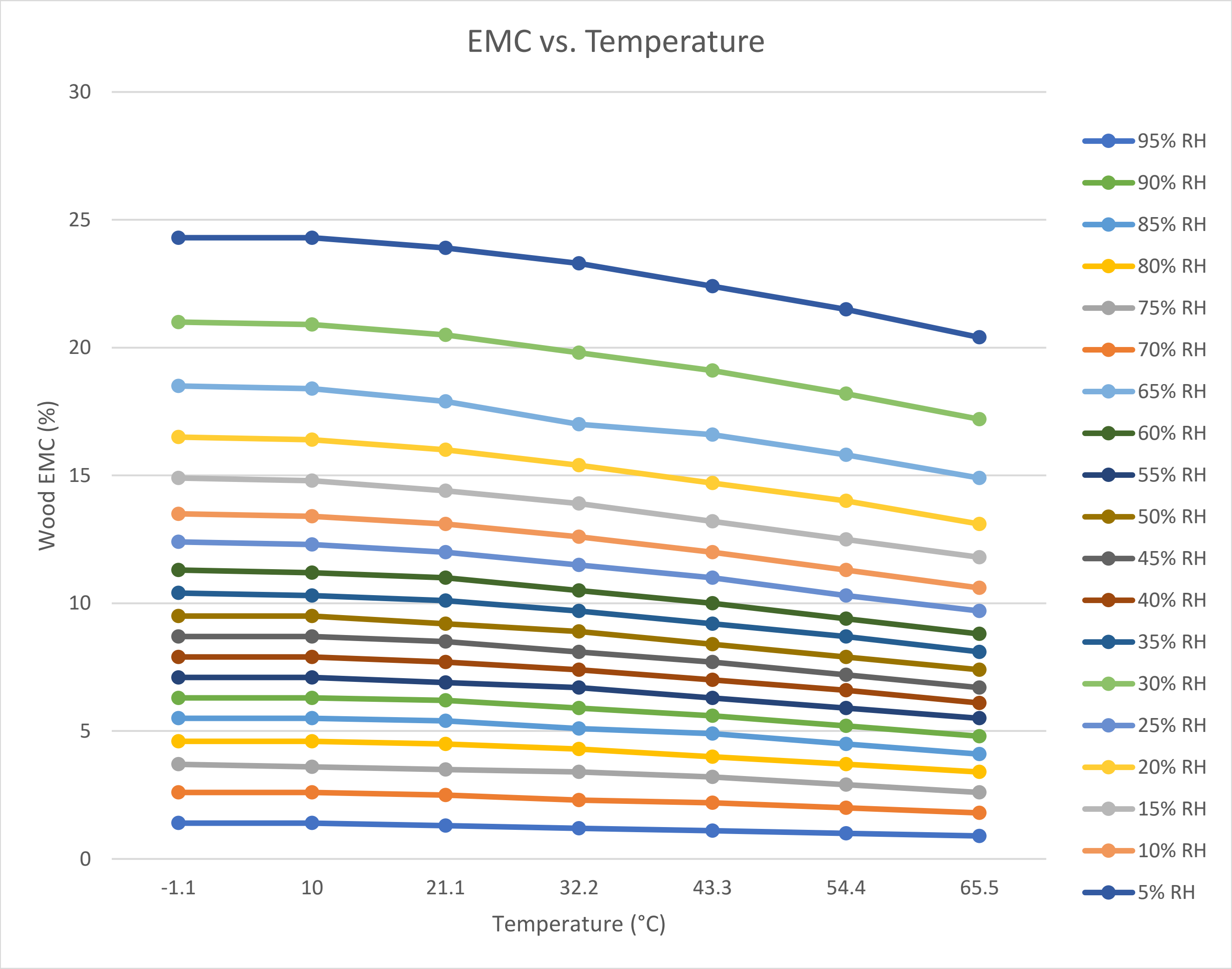

Figure 4: Equilibrium moisture content versus temperature, calculated with Eqn. 1; different trendlines represent different relative humidity values

It follows that wood shrinks as it loses mass and volume through reaching a lower EMC, and swells when reaching a higher EMC. The water found in green wood can be differentiated into two types: free water located in cell cavities and in between wood cells; water absorbed into capillaries, vascular bundles, fibers and ray cells within the cell walls [14]. When drying wood, the free water is removed first. This difference in the moisture contents of the cell cavities and cell walls is responsible for these elements moving closer or further apart from each other, which causes shrinking and swelling, respectively.

3.2 Other Failure Modes

Wood or palm furniture can fail as a result of dimensional instability in several ways. Already discussed is shrinking and swelling; aside from possible cosmetic defects that may arise from shrinking or swelling, this dimensional change places more stress on any mechanical fixtures or joints (such as nails) and adhesives. Wood shrinkage is directly responsible for the development of splits in wood and palm parts; a circular cross section of wood has a more pronounced reduction in its circumference than in its diameter, which results in the formation of a radial split [15]. This uneven shrinking and swelling is also responsible for the warping of wood in humid environments.

3.2.1 Swelling and Shrinking

Shrinkage starts as soon as wood is cut and begins to dry, but is not readily evident until the free water located in cell cavities and interstices between cells is removed. This moisture content of wood, where the only remaining water is in the saturated cell walls, is called the fiber saturation point [15]. For *Elaeis guineensis*, another widely cultivated palm, the fiber saturation point was found to be about 24% [16]. For wood lumbers, the cell walls are thicker in the tangential direction than in the radial directions. Because the cell walls in the tangential directions adsorb more water than cell walls in the radial directions do, this results in a more pronounced shrinkage in the tangential directions than in the radial [15]. The orientation of the radial and tangential directions in wood are shown in **Figure 5.**

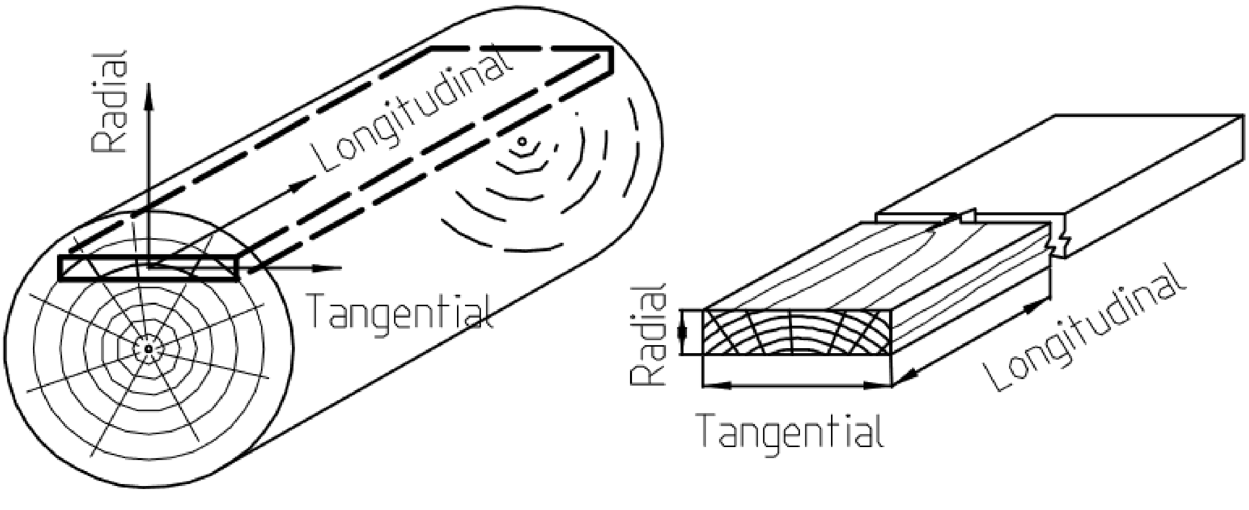

Figure 5: Diagram of a log and board with radial, tangential, and longitudinal directions [15]

Lacking growth rings, palms do not experience as pronounced of a difference between radial and tangential swelling or shrinkage as wood lumbers do. Instead, the region of trunk further from the center, harder and denser in vascular bundles, experiences less dimensional instability than the soft, parenchyma-rich center.

3.2.2 Warping and Cracking

Warping also occurs as a result of the variable swelling and shrinkage of wood along the radial and tangential axes. Warping can also occur when different regions on the same wood part is exposed to different humidities (one example being the venting of a pressure cooker inside a kitchen, which can cause the bottom of a cabinet door to swell enough to crack and distort its paint). The fact that wood pieces experience more shrinkage in the tangential directions than the radial produces distinct distortion patterns depending on the shape and location of the cut from the log or trunk (**Figure 6**).

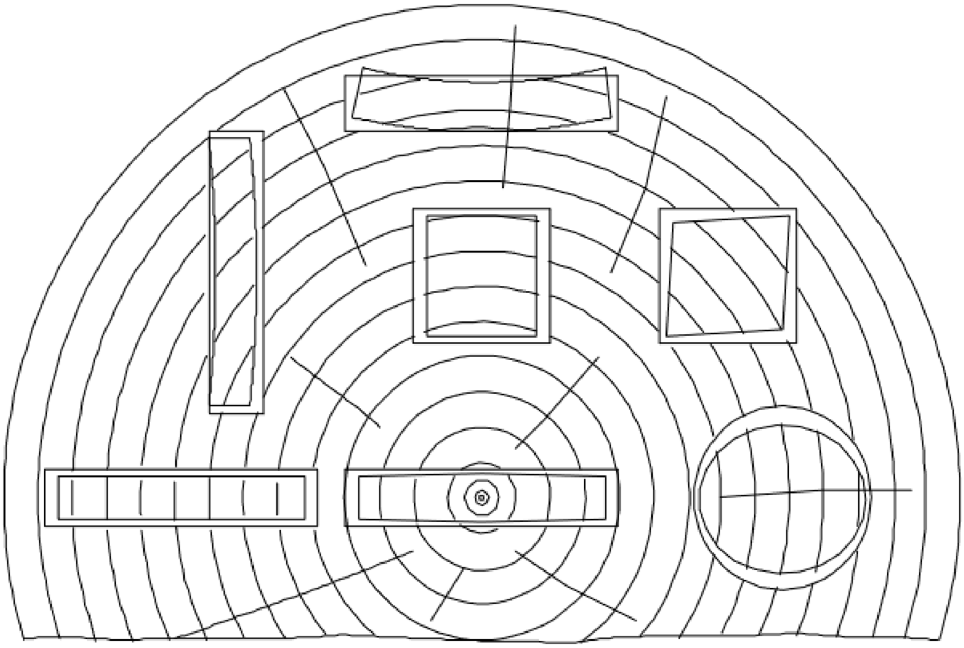

Figure 6: Diagram of log with drawn cuts on top. Smaller shapes represent distortions as a result of drying and shrinkage [15]

Because of palm's lack of growth rings, the difference between tangential and radial swelling/shrinkage is instead replaced with a higher dimensional instability in palm cut from the center, and more stability in palm cut nearer to the outside. For both wood and palm, shrinking and swelling produces internal stresses that can lead to the failure of assemblies. Miter joints are a common type of joint used in woodworking that allow to wood parts to be joined, the simplest of which involves two beams cut at 45 degrees and joined together to form a square corner. Because wood does not swell or shrink evenly, significant dimensional change will cause these joints to open on the outside of the bend in the case of swelling, and on the inside of the bend in the case of shrinkage [15]. This reduces the strength of the joint, and although the insertion of a spline through a slot cut into both parts may keep it from falling apart, still produces a gap that impacts the appearance of furniture.

3.2.3 Influence of Temperature

The fiber saturation point of a wood or palm is inversely related to the temperature of the environment, meaning that more moisture must be removed from a sample at higher temperatures in order to produce appreciable shrinkage than if the same sample were tested at lower temperatures. The relationship is roughly linear, with the fiber saturation point reducing by about .1% for every 1 °C rise in temperature [17]. With this relationship in mind, a wood part with a fiber saturation point of 30% at 20 °C would have a fiber saturation point of about 26% at 60 °C.

3.3 Wood and Palm Stabilization

Multiple physical and chemical processes exist for improving the dimensional stability of wood, most of which seek to fix the moisture content of wood through different mechanisms of blocking moisture uptake and loss. Of particular interest is impregnation treatment, which can be applied with several different types of agents to reduce dimensional change. Wood impregnation involves the penetration of the target compound, such as a resin, into the lumber under a strong vacuum. The low pressure draws the resin into voids, cell walls, and interstices between the cell walls in the wood.

3.3.1 Mechanism and Microstructure

Resin impregnation contributes to the dimensional stability of wood both by filling voids and spaces between wood cells, thereby blocking the pathways for water to enter or exit cell walls, and by migrating into cell walls which produces a physical bulking effect that is more stable than that of water [18]. The diffusion of resins through wood, and their effectiveness in affecting the dimensional stability of lumber, is in part influenced by the molecular weight of the stabilizing compound. In testing, less dense resins with number average molecular weights of 290 and 470 were found to fully penetrate through cell walls, with the lighter resin contributing more to increasing the dimensional stability of the wood [19]. In the same study, another phenolic resin with a higher molecular weight of 820 had a negligible impact on both the dimensional stability of the wood, with only a small fraction of it penetrating into the cell walls. X-ray analysis shows a much higher resin content in the wood cell walls when treated with the low weight resin (**Figure 7**) than the high molecular weight resin (**Figure 8**). Through the use of Electron Probe X-ray Microanalysis (EPMA) and Br-$L_{\alpha 1}$ X-ray maps, the resin content within the cell walls can be seen. For the low weight resin, the cell wall shape and structure are maintained, but is not as distinct after treatment with the medium weight resin.

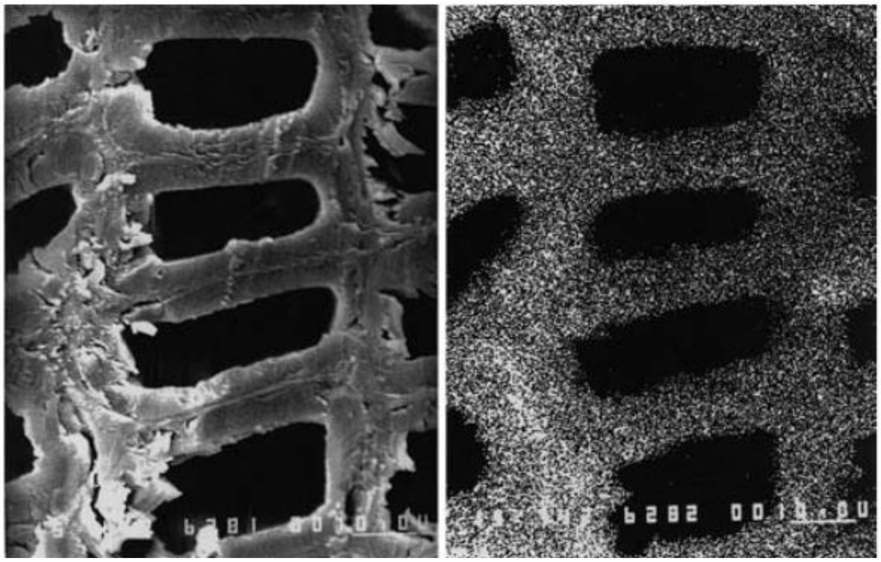

Figure 7: Transverse sections of *Cryptomeria japonica* treated with 290 number average molecular weight resin, viewed through EPMA (left) and Br-Lα1¬ X-ray mapping (right) [19]

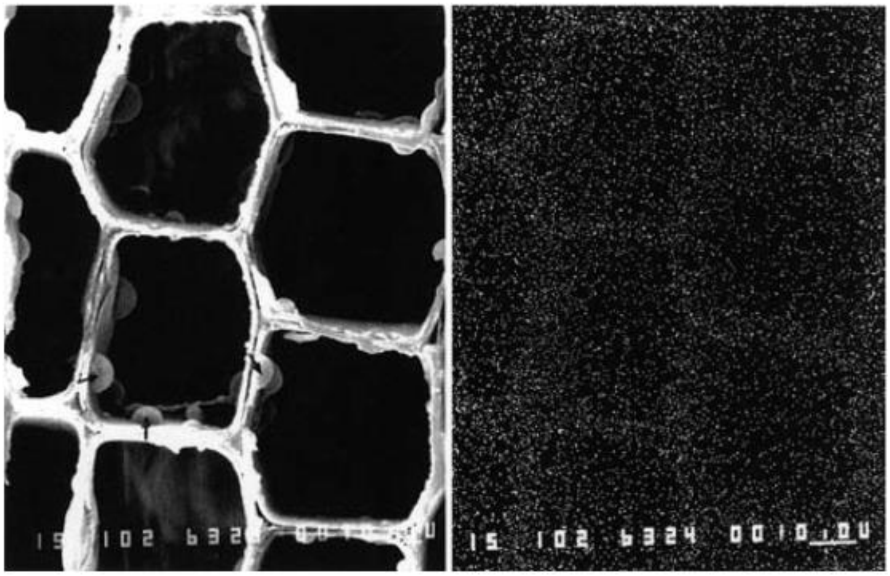

Figure 8: Transverse sections of *Cryptomeria japonica* treated with 470 number average molecular weight resin, viewed through EPMA (left) and Br-Lα1¬ X-ray mapping (right) [19]

3.3.2 Water Based Resins

Water based resins are distinguished from other types of resins by their use of water as the carrying medium, as opposed to solvent based resins which use resin , or solvent-free or solventless which use neither. Solvent based resins operate by relying on the high volatility of the solvent carrying medium; as the liquid solvent evaporates, the resin and other additives are left behind. The evaporation of volatile components causes damage to the environment and human health [20] which has led countries including the United States and Canada to enact laws limiting the acceptable emissions of volatile components, namely formaldehyde, used in wood and wood composite products. Water based resins offer an alternative by using less volatile components, but also entail their own disadvantages.

Grain raising is a phenomenon where fibers from untreated swell and lift from the surface of the wood in the presence of free water or water based treatments. This results in an increase in surface roughness that can also impact the appearance of finished wood pieces. The increase in surface roughness as a result of grain raising is more pronounced in less dense species of wood [21]. The increase in surface roughness is also influenced by the abrasive grit size of sandpaper used to treat the wood. The study also indicates that the roughness increase caused grain raising can be alleviated with sanding and planing treatments specialized for the species of lumber used, prior to chemical treatment.

4 Methodology

4.1 Materials and Sample Preparation

Samples of *Borassus flabellifer* supplied by Durapalm were tested to assess the influence of different stabilizing compounds on their dimensional stability under dry environmental conditions. Samples were 10 cm wide and 50 cm long, with thicknesses of 1.90, 3.30, and 4.45 cm.

4.2 Stabilizing Treatments

Three different stabilizing compounds were applied to the palm wood, and another set of palm samples were left untreated. TurnTex Cactus Juice and BVV wood stabilizer were selected as water-based stabilizers, and Kop-Coat WoodYouth® was used as a solvent-based stabilizer compound. Cactus Juice was mixed with the catalyst shipped with the product, while BVV Wood Stabilizer and WoodYouth® Plus were purchased premixed. Water-based stabilizing treatments were performed by the Oregon State University Department of Forestry. Palm samples were loaded into a vacuum chamber with enough stabilizer to cover all surfaces of the palm, held under a vacuum to draw in the liquid, and kiln fired to cure.

For samples treated with Cactus Juice, the samples were held under a 24 psi vacuum for four hours, and then held at 30 psi of positive pressure for 2 hours. The vacuum chamber pressure was released and samples were left to continue soaking for another 15 hours. Samples were allowed to air dry before being placed in a kiln at 90.5 °C for two hours. These samples were weighed prior to initial impregnation, before kiln firing, and once again afterwards.

Samples treated with BVV Wood Stabilizer were held under a 20 psi vacuum for 4 hours, and held at a positive pressure of 30 psi for two hours before pressure in the chamber was released. Samples were left to continue soaking for 14 hours, and left to air dry before being placed in a kiln at 107.2 °C for two hours. These samples were weighed prior to initial impregnation, before kiln firing, and once again afterwards.

Impregnation treatment using WoodYouth® Plus were performed by Kop-Coat and samples were shipped back to Oregon State University afterwards. All samples were then shipped to California Polytechnic State University, San Luis Obispo, for conditioning treatment.

4.3 Environmental Treatment

After stabilizing compounds were applied, palm pieces were placed in a SHEL LAB 3507 CO_2 Incubator (Cornelius OR, United States). The chamber’s water jacket was filled with distilled water for additional insulation. A saturated lithium chloride solution was used as a hygroscopic agent to maintain a relative humidity of 11% within the chamber, and the chamber was placed indoors where it held an average internal temperature of 21 °C. Samples were left to condition for 72 hours.

4.4 Dimensional Measurements

Palm samples were measured immediately before being placed in the environmental chamber, and once again after 72 hours, using a digital caliper. The degree of warping was also measured by holding one end of a sample on a flat surface and measuring the height the other end of the sample reached upwards. A diagram detailing this setup is shown below (**Figure 9**).

Figure 9: Representative diagram of setup used to measure the degree of sample warping

5 Results

Palm samples did not display significant dimensional change or visible surface degradation after the 72 hours of conditioning. For samples treated with water-based stabilizers, mass was measured before any treatment, after initial impregnation and after kiln firing.

5.1 Impregnation Mass Change

All water-based samples showed an increase in mass after impregnation treatment when compared with their untreated masses. While kiln firing resulted in slight mass loss, final sample masses were still higher than untreated samples. Tabulated results for mass changes recorded after different steps in the impregnation process are shown in **Table II.**

Table II: Mean mass changes for samples impregnated with water-based stabilizers

Stabilizer	Post-Impregnation Mass Change (%)	Mass Change after Kiln Firing (%)	Final Mass Change (%)
BVV Wood Stabilizer	24.13	-6.35	15.47
Cactus Juice	28.73	-4.68	19.16

Thicker samples experienced a greater change in mass after each step of the impregnation process, including mass lost after kiln firing. Results for samples treated with BVV Wood Stabilizer are shown in **Figure 10** and Cactus Juice in **Figure 11**. The greatest final mass changes recorded for samples treated with BVV and Cactus Juice were .974 kg (24.95% mass increase) and 1.172 kg (30.49% mass increase) respectively. Samples treated with Cactus Juice displayed more variability in mass changes than samples treated with BVV Wood Stabilizer, but followed the same trend of heavier samples being able to absorb more stabilizer.

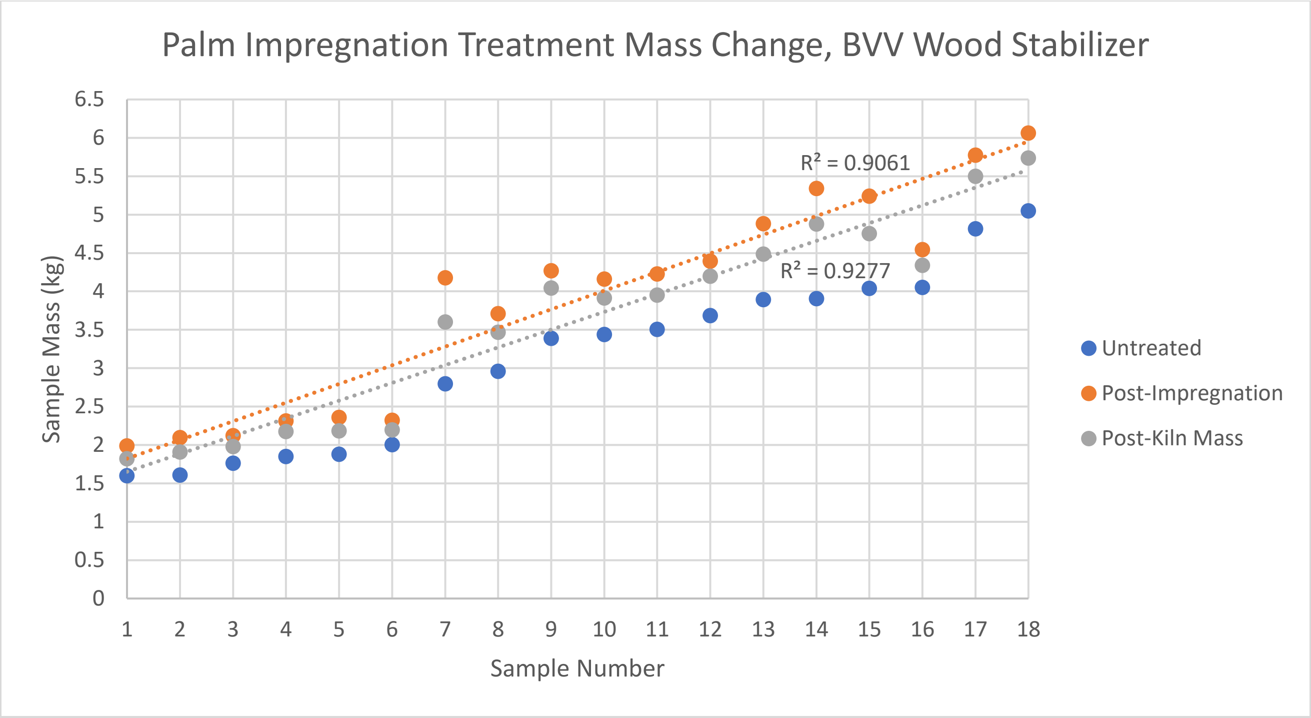

Figure 10: Sample masses before and after treatment with BVV wood stabilizer; samples are listed by pre-treatment mass in ascending order

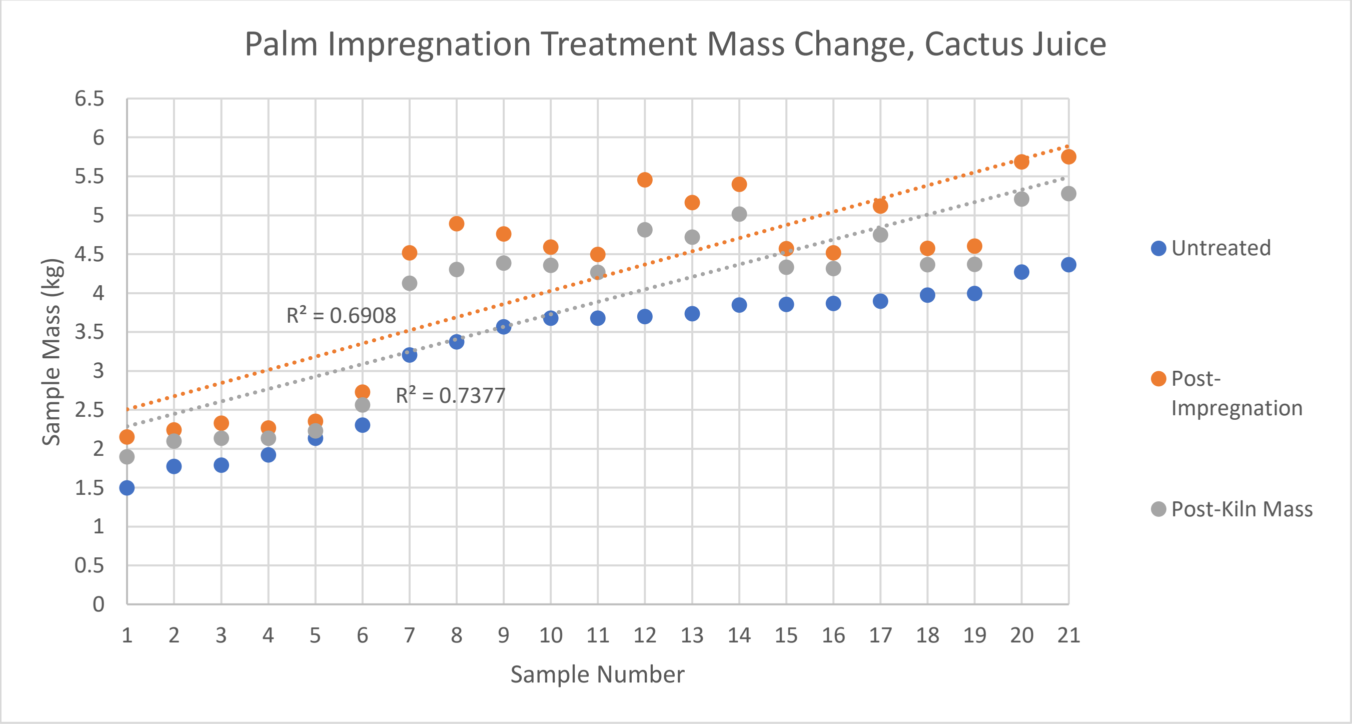

Figure 11: Sample masses before and after treatment with Cactus Juice; samples are listed by pre-treatment mass, in ascending order

5.2 Dimensional Change

Palm sample dimensions were measured after delivery to California Polytechnic State University, San Luis Obispo, and once again after 72 hours of conditioning. No statistically significant change in sample dimensions could be recorded for any treatments applied, including the control group. As such, results for the degree of warping were also statistically insignificant and could not be reported as values separate from sample height. The Shapiro-Wilk test was performed with a significance level of 5% , using the XLSTAT plugin for Excel, to determine the normality of sample dimension measurements; measurements were grouped by sample thickness and the normality test was performed on both pre-conditioning and post-conditioning measurements (**Table III**). The p-value for the Shapiro-Wilk test performed on pre-conditioning widths of 3.3 cm thick samples and preconditioning thicknesses of 4.5 cm thick samples fall below the α of .05, meaning the null hypothesis of these groups following a Normal distribution is rejected. This may be attributed to experimental error, including the caliper jaws sinking into the soft wood, and the fact that palm samples are not uniform.

Table III: Shapiro-Wilk normality results on sample measurements, α = .05

1.9 cm thick samples

Variable	Shapiro-Wilk (p)
W (cm)	0.533
H (cm)	0.070
W' (cm)	0.923
H' (cm)	0.447

3.3 cm thick samples

Variable	Shapiro-Wilk (p)
W (cm)	**0.019**
H (cm)	0.992
W' (cm)	0.568
H' (cm)	0.512

4.5 cm thick samples

Variable	Shapiro-Wilk (p)
W (cm)	0.814
H (cm)	**0.003**
W' (cm)	0.696
H' (cm)	0.487

Using Excel, paired sample t-tests were performed on sample widths (**Table IV**) and thicknesses (**Table V)**, grouped by part thickness, before and after conditioning. Even with a higher significance level of 10% (α = .1), the null hypothesis that there was no difference between sample means before and after conditioning could not be rejected in any group of samples. Subsequent t-tests grouped by stabilizer used were not performed because of the overall lack of dimensional change.

Table IV: Paired two sample t-tests for means, sample widths

Sample Thickness (cm)	Mean W (cm)	Mean W' (cm)	P(T<=t) two-tail	N
1.9	10.01	9.91	.359	22
3.3	9.89	10.07	.201	10
4.5	9.99	10.19	.267	15

Table V: Paired two sample t-tests for means, sample thicknesses

Sample Thickness (cm)	Mean H (cm)	Mean H’ (cm)	P(T<=t) two-tail	N
1.9	1.84	1.84	.962	22
3.3	3.30	3.27	.364	10
4.5	4.20	4.18	.869	15

6 Discussion

72 hours of conditioning was not sufficient for any statistically significant change in part dimensions, between any groups of sample thicknesses or stabilizers used, at the temperature and relative humidity at which they were tested. Testing is still ongoing; considering that the long term behavior of black palm in response to cool, dry conditions is unknown, as long of a testing time as possible is desired.

The mass changes recorded for samples treated with BVV Wood Stabilizer and Cactus Juice were comparable with results from other studies performed on other species of palm, using various solvent-based stabilizers. This suggests both that the palm anatomy responds well to impregnation treatment, and that black palm can be successfully treated with water-based stabilizers. Their effect on dimensional stability on black palm has yet to be fully measured.

Other methods to measure the effect of each stabilizer treatment on the behavior of *Borassus flabellifer* samples were either attempted, or suggested and found to be impractical. Photographic analysis was attempted to determine the formation of crack growth and propagation, but was unfeasible because of the natural dark color of the wood, and the short conditioning time. Periodic weighing of samples throughout conditioning would provide information on how much moisture is lost or gained but would require taking samples out of the conditioning chamber. Because the surrounding environment can not be as closely controlled, this may influence the behavior of the palm samples. Samples needed to be removed from the conditioning chamber to perform post-conditioning, but were placed back into the chamber quickly enough that the humidity and temperature within the chamber did not experience significant change.

7 Conclusions

1. *Borassus flabellifer* samples treated with water-based stabilizers all showed an increase in mass even after kiln-firing, with thicker, heavier samples able to retain more stabilizer. Mean mass change is comparable with other studies performed on other species of wood, tested with solvent-based impregnation compounds.

2. A conditioning time of 72 hours was not enough for any significant dimensional change or surface degradation to be observed. Either a significantly longer conditioning time or accelerated weathering are necessary to understand the influence of different stabilization treatments on the palm samples.

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