PhD Theses

Characterisation of Eucalyptus Hybrid Plywood Produced in Ghana, A Potential Substitute for the European Birch Plywood.

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Introduction

Plywood remains the most demanded wood-based panel despite the existence of other wood-based panels such as medium-density fibreboard (MDF), particle board, and oriented strand board (OSB), (Chapman 2006, Gonçalves et al. 2018, Mantanis et al. 2018, Rathke et al. 2012, Yu & Fan 2017). According to the Forest Product Statistics (2021), plywood production makes up 118 million m^3, representing about 32.2% of the worldwide supply of wood-based panels. Plywood is used widely for several construction products, including ceilings, cabinets, doors, furniture, and many others. According to research, the density and mechanical properties of plywood depend on the wood species and quality of the veneer, the glue layer, the compression or pressure during production, etc. (Kajaks et al. 2012, Okuma 1976, Bekhta et al., 2012, 2020) . Ghana has been one of the countries in the plywood industry that supplies plywood to the world market. In a report published by FLEGT IMM (2022), ITTO estimated Ghana's export of plywood volumes as 16,904 m^3 in the year 2020, a sharp decline from the 2018 export of 24,000 m^3, which can be attributed to the dwindling of the natural forest at an alarming rate, in the last few decades, and this is due to the indiscriminate logging of trees (Ewudzie et al. 2018). Also, the global demand for premium wood species has contributed significantly to this phenomenon.

The raw material needs of the local plywood production cannot be overlooked, as there is demand for bigger-diameter logs for production. The traditional species dominating plywood production in Ghana are the *Ciber pentandra, Lovoa klaineana*, etc. (Ghana Forestry Commission 2011). This situation is affecting the carbon sink potential of the Ghanaian natural forest. Innovative and sustainable measures are being explored to supply the market while protecting the forest cover to curb this problem. In supporting this agenda, a forest organization is exploring the use of fast-growing Eucalyptus (*Eucalyptus globulus*) as a raw material to produce plywood to augment the increasing demand from the European and American markets. This will sustainably boost the contribution to the forest product of 3% of the Gross

Domestic Product of Ghana, which contributes about $240.9 million in total exports (Tuffour-Mills et al. 2020).

The intervention of using juvenile eucalyptus to produce plywood has coincided with supply issues faced by the European plywood industry, which relies heavily on birch plywood importations from Russia. Alternative means to bridge the supply and demand gaps need to be explored as early as possible to safeguard the plywood market within the European Union. The birch plywood produced in Russia is proven to be top-notch plywood. Eucalyptus hybrid plywood is an engineered wood product made from thin layers of eucalyptus wood veneer bonded together. The strength characteristics of Eucalyptus hybrid plywood can vary depending on several factors, including the quality of the veneers, the type of adhesive used to bond the veneers, and the manufacturing process, particularly the pressing time.

Problem Statement

The EU markets for decades have depended heavily on Russian birch plywood with an annual demand of 1.5 million m^3 in the estimated 2.2 million m^3 industry (Blasten, 2022). There is a high shortage of products in the EU market due to the trade sanctions imposed on Russia by the European Union. To meet the demand gap, an alternative supply source is needed. Meanwhile, Ghana is faced with the challenge of forest depletion affecting the raw material for plywood production. To address these pressing issues, exploring sustainable forestry practices in Ghana could provide a dual solution by replenishing forest resources while supplying the EU market with much-needed plywood alternatives. Characterizing the properties of plywood produced from *Eucalyptus pellita* will be essential in determining its viability as a substitute for the birch plywood.

Research Objectives

The main objective of this study is to characterize the properties of the plywood produced from the hybrid eucalyptus (*Eucalyptus pellita*) plywood bonded by MUF and PF adhesives. The specific objective of the research is as follows.

i) Determine the modulus of elasticity (MOE) and modulus of rupture of the five different thicknesses.
ii) Determine the physical properties, including thickness swelling, Density, and moisture content of the various thicknesses.
iii) Determine the bonding quality of the selected thicknesses of eucalyptus plywood according to EN 314- 1& 2.
iv) Determine the biological durability of birch and eucalyptus plywood against Fungi and Termite attacks.

Literature Review

The literature review provides a comprehensive synthesis of existing research on plywood materials, emphasizing their composition, production processes, mechanical and physical performance, and sustainability considerations. It highlights how plywood's properties are influenced by factors such as wood species, adhesive type, manufacturing parameters, and veneer configuration, while also noting the growing shift toward bio-based and environmentally friendly adhesives in response to regulatory and ecological pressures. Additionally, the review outlines the various classifications and types of plywood, their broad applications in construction, furniture, transportation, and specialized industries, as well as recent technological advancements aimed at improving durability, efficiency, and environmental performance. It also discusses the potential of fast-growing species, such as Eucalyptus pellita, for plywood production, detailing their anatomical, physical, and mechanical suitability. Finally, it explores sustainability issues, including life cycle assessment, waste management, and regulatory compliance. It examines broader plywood market trends, competitive dynamics, and global demand drivers that continue to shape industry development.

Research Methodology

Three plywood panels were randomly selected over three months (one per month) to ensure consistent production conditions. Five thicknesses were evaluated (9, 12, 15, 18, and 21 mm), giving three panels per thickness. Two adhesive types were studied across all thicknesses: Melamine Urea Formaldehyde (MUF) and Phenol Formaldehyde (PF), each with specified viscosity, pH, specific gravity, and gel time.

1. Mechanical Properties

i) Mechanical testing focused on modulus of elasticity (MOE), modulus of rupture (MOR), and tensile strength parallel to the grain. Bending properties were determined according to EN 326-1:1994 and EN 310:1993. For each panel, 20 test specimens were cut 10 in the longitudinal direction and 10 in the transverse direction. Sample dimensions were based on formulas relating span length to panel thickness, and all thicknesses met EN 315:2000 tolerance requirements.

ii) Before testing, specimens were conditioned in a controlled climate chamber (65 ± 5% RH, 20 ± 2 °C) until constant mass was achieved, ensuring uniform moisture content (12%).

iii) Bending tests were conducted using a 3-point bending setup with rounded supports and loading heads as specified in EN 310. The crosshead speed was set so that failure occurred within 60 ± 30 seconds. The Hegewald and Peschke universal testing machine (50 kN load cell) applied the load. MOE and MOR were calculated using the standard EN 310 formulae.

iv) Post-testing, all data were processed, analysed, and graphed using Microsoft Excel and OriginPro.

2. Physical Properties

i) The density and thickness swelling of plywood samples were evaluated following relevant EN standards. Density samples (50 × 50 × *t*) were prepared according to EN 326-1 and measured in accordance with EN 323. Actual sample dimensions (length, width, thickness) were taken with a

Vernier calliper to reduce measurement uncertainty. All samples were conditioned in a climate chamber at 65 ± 5% relative humidity and 20 ± 2 °C until constant mass was reached after three days.

ii) Density was determined by measuring mass and dimensions (EN 325) and calculating values using the standard density formula.

iii) Thickness swelling tests used the same sample dimensions and conditioning procedure. Samples were immersed in neutral-pH water (20 ± 1 °C) for 24 hours in a water bath. After removal and surface drying, swelling was calculated as the percentage increase in thickness, following EN 317.

3. Bonding Quality

i) Bonding quality was assessed following EN 314-1, EN 314-2, and EN 326-1 standards. Samples were cut in both longitudinal and transverse directions using a sliding table saw, with dimensions of 25 × t × 150 mm (where t = 9, 12, 15, 18, or 21 mm). Nicking spaced 25 mm apart were made to ensure each glue line was tested.

ii) Pre-treatment procedures depended on the adhesive type.

MUF-bonded plywood underwent:
(1) 24-hour water immersion at 20 ± 3 °C, and
(2) 6-hour boiling, followed by cooling.

PF-bonded plywood received a more severe conditioning:
(1) 24-hour immersion at 20 ± 3 °C,
(2) 4-hour boiling, 16-hour oven drying at 60 ± 3 °C,
(3) another 4-hour boil, and cooling.

iii) After pre-treatment, samples were surface-dried and measured. Shear tests were conducted by clamping each specimen with 50 mm held on each side, leaving 50 mm as the shear area. The load was applied at a constant rate until failure within 20–40 seconds. Shear strength was calculated from the maximum load and shear area. Wood-fiber failure was assessed visually using EN 314-1 guidelines and magnification tools.

4. Biological Durability

4.1 Termite Exposure Experiment

i) Three plywood types (birch, MUF-bonded MIRO, PF-bonded MIRO) and a low-density control wood (Wawa) were tested for termite resistance. Samples were prepared following EN 350, EN 117, and EN 252-2, with plywood dimensions of 300 × 50 × *t* mm and control wood at 20 × 20 × 300 mm.

ii) A 20 × 12 ft field site was prepared by clearing vegetation and digging 15-cm-deep holes. Stakes were arranged at 30 cm spacing within rows and 60 cm between rows. All samples were oven-dried before and after exposure (104 °C, 72 h) to ensure accurate mass-loss measurements. Soil particles were carefully removed using brushing and air-blowing to avoid losing wood material.

iii) Durability ratings followed EN 117 and EN 252-2, using a 0–4 scale reflecting the severity of termite attack. The experiment was considered valid when at least 75% of control samples reached rating 4 (failure).

4.2 Fungal Exposure Experiment

i) Birch plywood, MUF-bonded MIRO plywood, PF-bonded MIRO plywood, and beech wood (control) were tested for fungal resistance. Samples were prepared to 50 × 50 mm (matching plywood thicknesses of 12 and 15 mm), with additional control samples sized 15 × 25 × 50 mm. All were conditioned to 12% moisture content before testing, and selected specimens were oven-dried to determine initial dry mass.

ii) A malt-extract agar medium (20 g malt extract, 20 g agar, 1 L water) was prepared, sterilized in an autoclave, allowed to solidify, and inoculated with *Coriolus versicolor*. Inoculated flasks were incubated at 22 °C and 75% humidity. Plywood and control samples were placed onto the fungal culture and incubated for 16 weeks.

iii) Durability was determined according to CEN/TS 15083-1 based on percentage mass loss, classified from DC1 (very durable, ≤5% loss) to DC5 (not durable, >30% loss).

Results and Dissertation Theses

Thesis 1: Mechanical Properties

A significant new finding of this study is the affirmation of an inverse correlation between panel thickness and mechanical strength (MOE and MOR) in juvenile *Eucalyptus pellita* plywood. Thinner panels consistently outperformed thicker ones, particularly in PF-bonded plywood, which exhibited enhanced stiffness and strength. This demonstrates the importance of veneer layering and adhesive penetration for performance, a relationship that hasn't been well-documented before for tropical plywood. The research additionally indicated that anisotropy effects were more pronounced in thinner panels and diminished as thickness increased, owing to a more uniform distribution of stress across multiple layers. These insights highlight the potential of thinner eucalyptus panels as viable substitutes for birch plywood, which has gained popularity due to its strength in structural applications that require high strength-to-weight ratios

Related Publications

Seidu, Haruna; Nemeth, Robert; Owusu, Francis Wilson; Korang,

James; Emmanuel, Appiah Kubi; Govina, James Kudjo; A.A Younis, Fath Alrhman; Ibrahim, Safia. *Mechanical properties of PF and MUF bonded juvenile hybrid eucalyptus plywoods produced in Ghana Wood Research*68 : 3 pp. 521-531. , 11 p. (2023).
https://doi.org/10.37763/wr.1336-4561/68.3.521531

Seidu, Haruna ; Bejó, László ; Németh, Róbert
Comparative Analysis of MOE and MOR of PF and MUF-Bonded Eucalyptus Plywood of Varying Thickness.
WOOD RESEARCH 70 : 3 pp. 478-486. , 9 p. (2025)
https://doi.org/10.37763/wr.1336-4561/70.3.478486

Thesis 2: Physical Properties (Density and thickness swelling)

The study first revealed the important role of adhesive type in affecting the physical properties of juvenile *Eucalyptus pellita* plywood. PF-bonded panels consistently showed higher densities and less thickness swelling than MUF-bonded panels, demonstrating better resistance to moisture-induced deformation. This adhesive effect became especially important as thickness increased, with PF maintaining dimensional stability while MUF-bonded plywood showed greater variability. The research also confirmed that swelling depends not only on veneer quality or panel thickness but also on adhesive penetration and bonding properties. These findings provide a practical basis for selecting adhesives to improve durability in humid or outdoor environments.

Related Publications

Haruna, Seidu; Robert, Nemeth
Influence of Adhesive Type and Panel Thickness on the Density and Dimensional Stability of Juvenile Eucalyptus Pellita Plywood. WOOD RESEARCH (2025)
https://m2.mtmt.hu/api/publication/36459169

Thesis 3: Bonding Quality

The bonding quality results demonstrated that PF-bonded eucalyptus plywood achieved substantially higher wood failure percentages (78–83%) compared to MUF-bonded panels (53–72%), indicating stronger adhesive–wood interactions. A notable outcome of this study is the observed decline in bond quality with increasing panel thickness. This reduction is likely due to non-uniform pressure distribution during pressing; while the outer layers receive adequate pressure, the inner layers often experience insufficient compression, leading to weaker bonds. Although thin PF-bonded panels promoted desirable wood failure, this relationship diminished as thickness increased, suggesting a trade-off between panel size and bonding performance. Such adhesive–thickness interactions have rarely been examined in tropical plywood. Overall, the findings underscore PF as the preferred adhesive for structural and industrial-grade panels, whereas MUF appears more suitable for non-structural or decorative applications.

Related Publications

Thesis 4: Biological Durability

This research provided the first comparative assessment of termite and fungal resistance between juvenile *Eucalyptus pellita* plywood and birch plywood. Novel insights emerged, showing that untreated birch plywood, despite its mechanical reputation, was highly vulnerable to termites (40.59% mass loss, “Not Durable”). In contrast, PF-bonded eucalyptus plywood proved resistant (9.44% mass loss, “Durable”), and MUF-bonded eucalyptus achieved only moderate resistance (14.03% mass loss, “Moderately Durable”). Interestingly, adhesive type strongly influenced termite resistance (PF > MUF) but had little effect on fungal durability, where both eucalyptus and birch plywoods showed very low mass losses (<3.5%) and were classified as “Very Durable.” This dual evaluation demonstrates the potential of eucalyptus plywood, particularly PF-bonded, as a sustainable alternative to birch in regions prone to termite and fungal infestations, while also highlighting the crucial role of adhesive technology in determining biological durability.

Related Publications

Haruna, Seidu ; Bak, Miklos ; Németh, Róbert

Evaluating Termite Resistance: Comparative Study of Birch and Eucalyptus Plywood. In: *Book of Abstracts of 8th International Conference on Process Technologies for the Forest and Biobased Products Industries 2025*. Salzburg University of Applied Sciences Design and Green Engineering Department Campus Kuchl (2025) 62 p. pp. 21-21. , 1 p.

https://m2.mtmt.hu/api/publication/36407984

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