Review: Development of Particle Boards with Fillers from Various Kinds ofWood Scraps and Agricultural Residues Using Binders

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ABSTRACT

Wood is still an important forest commodity in Indonesia because wood is a resource that is widely used for various uses, although it is classified as a resource that can be simplified, its potential continues to decrease due to increasing needs. Agricultural residues and wood waste canpotentially be used in several ways. Based on its designation, wood waste can be sorted, processed, and provided as a raw material for making particle boards. Particleboard is made from particles of wood or other fibrous material, which are shaped and pressed together using an organic binder together with one or more materials, such as heat, pressure, catalyst, and so on. A good selection of agricultural residues including wheat straw, sugarcane, sunflower seed husks, bamboo,and palm have been used successfully in the manufacture of particleboard. On particle board, the commonly used binders are urea formaldehyde and phenol formaldehyde.
Keywords: Particle Board, Filler, Binder

INTRODUCTION

Particleboards are widely used because they enable wood particles from relatively useless small-size and/or low-grade timber to be transformed into useful large wooden panels. Particleboards are manufactured from particles of wood or other fibrous materials,which are formed and pressed together using an organic binder together with one or moreagents, such as heat, pressure, catalyst, and so on. Wood is the primary raw material usedin the particleboard industry; nevertheless, the use of wood residues was the initial purpose. Though particleboard is not as strong as fiberboard or plywood, it is more cost-effective, lightweight, and easy to handle. (Solace *et al.* 2015)

Thus, it has continuously been produced and used in vast amounts for construction, furniture, and interior decoration. According to the Food and Agricultural Organization (FAO, 2018), particleboard production grew from 186 million m^3 in 2000 to 420 million m^3 in 2017. The worldwide expanding demand for particleboard in the last decades caused enormous pressure on forestlands. Considering the shortage of forest resources and rising wood prices, significant research interests have been attracted to using agroforestry waste as a wood alternative for benefiting the environment and socioeconomic. (Mahieu *et al.* 2019)

METHODS

This is a rapid review of studies conducted in May 2023. The authors extracted relevanttexts from published articles indexed in the Science Direct Elsevier and were used to retrieve related articles. During this review, the search was done by using keywords such as; "Particle Board," and "Agro Waste." The study used the Boolean operators, "and" to incorporate these keywords. Only studies published in the English language between 2000and 2021, and meeting the eligibility criteria were included in this rapid review.

RESULTS AND DISCUSSION

Hamidreza *et al.* 2014 had produced particleboards manufactured from mixture of sycamore leaves and wood particles. The aim of this study was to evaluate the physical andmechanical properties of particleboards manufactured from mixture of sycamore leaves and wood particles. Five panel types were made from mixtures of wood particles/sycamoreleave (100/0, 90/10, 80/20, 70/30 and 60/40%, respectively). Some mechanical (modulusof rupture, modulus of elasticity and internal bonding strength) and physical properties (thickness swelling and water absorption) of the particleboards were determined.

Figure 1. Sycamore leaves (Hamidreza et al. 2014)

The results show that with the incorporation of sycamore leaves up to 20%, the mechanicaland physical properties of resulting particleboards improve. Nevertheless, the mechanicalproperties of all the panels exceed the minimum requirements of EN Standards for furniture manufacturing. Using renewable biomaterials like sycamore leaves for manufacturing particleboards could contribute solution of raw material shortage for the particleboard industry, decreasing the pressure on forest resources and diminishing environmental problems regarding their burning. (Hamidreza *et al.* 2014)

Petr *et al.* 2016 produced particleboards manufactured from agricultural crop. Germany-grown cup-plant (Silphium perfoliatum L.), sunflower (Helianthus annuus L.) and topinambour (Helianthus tuberosus L.) were used as raw materials for particleboards produced at a conventional density of 600 kg/m^3. Particleboards were gluedwith two different adhesives, with methylene diphenyl diisocyanate (MDI) as well and urea formaldehyde (UF) resins. The physical and mechanical properties of prepared panels weremeasured according to standards. The raw materials were analyzed for their chemical composition; particle geometry was carefully monitored.

Figure 2. Cross sectional images of the produced particleboards, using spruce wood (SP), sunflower stalks (SF), topinambour stalks (TP), and cup-plant stalks (CP). (Petr et al. 2016)

It is shown that the obtained particleboards have acceptable performances, though properties were below those obtained from conventional spruce particleboards. Modulus of rupture of the alternative material particleboards were found to be lower than the spruceparticleboards. Likewise, thickness swelling and water absorption of the agricultural residues made particleboards were higher than the compared spruce-made particleboards.The finding relevant for industrial applications was that the agricultural residue-produced particleboards bonded with MDI resins fully comply with the European standard EN 312 class P1 (use in dry conditions). This means that non-wood particleboards are suitable to be used in furniture production. (Petr *et al.* 2016)

Kristaps *et al.* 2021 had performed into the use of hemp shive as a fast-growing and carbon-storing agricultural waste material in the production of particleboard for the construction industry. Hemp shives were acquired and prepared for board production withthe use of milling and sieving to reach two target groups with 0.5 mm to 2 mm and 2 mm to 5.6 mm particle size ranges. The cold pressing method was used to produce hemp boards with Kleiberit urea formaldehyde resin as a binder. The boards were made as 19 mm thicksingle-layer parts with a density range of 300 ± 30 kg/m^3, which qualifies them as low- density boards. Exploratory samples were made using milled hemp fibers with higher density. Additional components such as color pigments and wood finishes were added to test improved features over raw board samples.

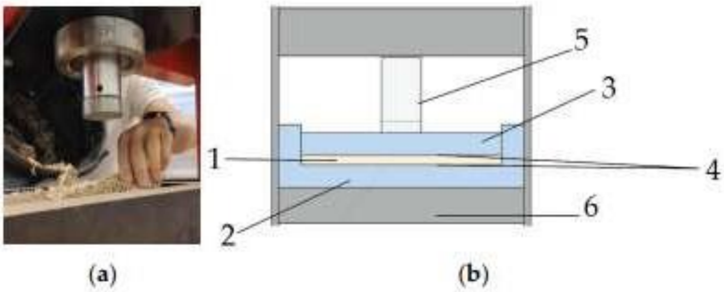

Figure 3. a) Formation of mixture into the mold; b) forming setup of hydraulic press and mol. (Kristaps et al. 2021)

Tests were performed to determine moisture contents, density range, structural properties, and water absorption amounts. Produced board bending strength reached 2.4 MPa for the coarser particle group and thermal conductivity of 0.057 ± 0.002 W/(mK). The results were compared with existing materials used in the industry or the development stage to indicate options of developed board applications as indoor insulation material inthe construction industry. (Kristaps *et al.* 2021)

Figure 4. Surface view of board samples. (Kristaps et al. 2021)

Petr *et al.* 2018 were studied Miscanthus x giganteus stalks as a possible replacement for wood in particleboards. Produced particles from Miscanthus contained 38% of cellulose,and 17% of lignin, while spruce had 45% cellulose, and 28% lignin. The number of hemicelluloses was the same for both, spruce and Miscanthus (21%). Miscanthus-made particleboards were produced at two levels of methylene diphenyl diioscyanate resination, i.e. 4% and 6%. Modulus of rupture (MOR), modulus of elasticity (MOE), internal bonding strength (IB), thickness swelling and water absorption were measured. Mechanical properties of the Miscanthus-made particleboards were overall reduced: compared to spruce, MOR and MOE were down by 30%, while IB was lowered by 60%.

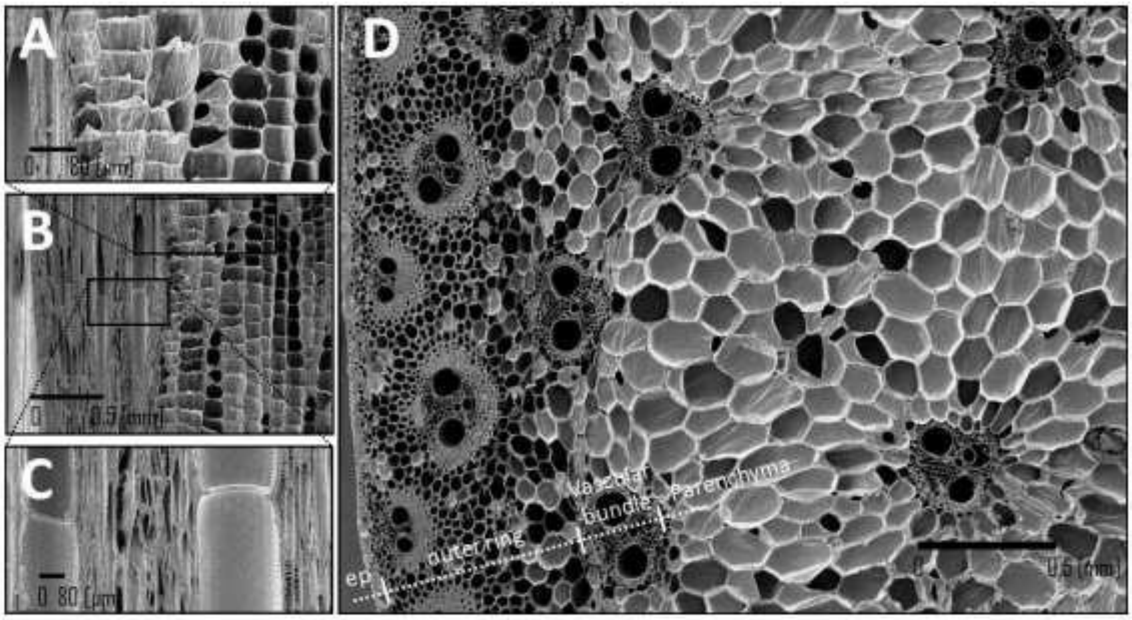

Figure 5. Microscopic structure of Miscanthus stalks. The longitudinal (A–C) and transverse cross-section (D). ep – epidermis. (Petr et al. 2018)

Microscopic analysis of fracture surfaces of the Miscanthus-made particleboards afterIB testing showed collapsed cells regions in the soft parenchyma, with no obvious adhesive failures. In contrast, spruce-made particleboards revealed much smoother fracture surfaces with structural failures running through cell walls and possibly also through gluelines. The collapsed parenchyma cell regions suggest a direct link to the reduced mechanical properties. Further, compared to spruce the Miscanthus-made particleboards have shown higher thickness swelling, but lower water absorption. For Miscanthus, no effects of higher MDI adhesive dosages on MOE, MOR and IB were observed. To further improve properties of Miscanthus-made particleboards, at sorting-out of parenchyma tissue components to the highest degree possible is recommended, prior to hot-pressing. (Petr *et al.* 2018)

Banjo *et al.* 2016 had examined the possibility of developing a composite corncob (CC)and sawdust (SD) particle board using urea formaldehyde as binder. The panels were produced using 0%, 25%, 50%, 75% and 100% variations for both agricultural wastes with a constant volume of adhesive to evaluate their effect on the physical and mechanical properties. The results showed that 25% and 50% replacement of SD with CC had favourable physical properties recommendable for indoor uses in buildings.

Figure 6. Mortar crushed CC (Banjo et al. 2016)

In contrast, the particleboards cannot be recommended for load bearing purposes based on poor mechanical properties which improved as the composition of CC increased from 25% to 75% and also because it failed to satisfy European Standard requirements. 75% CC replacement had the highest value for both MOR and MOE but possessed poor physical properties. Within the experimental investigation and possible limitations the panels with 50% CC replacement were the most preferred since they had preferableperformances for both physical and mechanical properties. (Banjo *et al.* 2016)

Figure 7. Composite SD and CC particle boards

Borysiuk *et al*. 2019 had investigated Increasing demand for production of particleboard and environmental concerns drive to seek new sources of lignocellulosic materials other than wood. Sugar beet pulp (SBP) is one of the most common agro-residues, which remains after sugar production. Conducted investigation was to determine thesuitability of SBP as a raw material for particleboard manufacturing. Three-layer particleboards with the core layer made of mixture SBP and industrial wood particles wereprepared. Tested particleboards varied in proportions of SBP and wood particles used for the core layer. Investigation included following physical and mechanical parameters of boards: density and density profile, thickness swelling (TS), water absorption (WA), modulus of rupture (MOR), modulus of elasticity (MOE), internal bond (IB) and screw holding (SH).

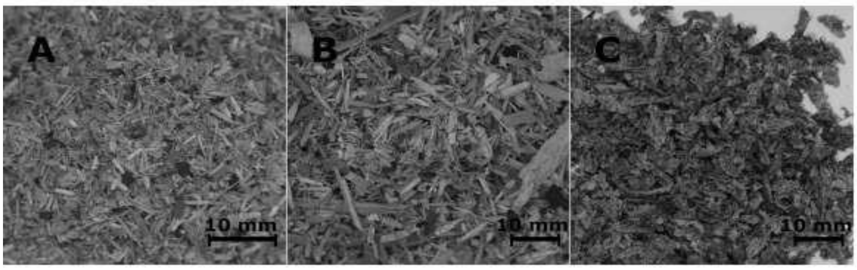

Figure 8. Particles used to particleboard preparing: A. industrial wood particles for face layers, B. industrial wood particles for core layer, C. SBP after drying. (Borysiuk et al. 2019)

The results indicated a negative impact of high-content SBP on the board properties. Particleboards containing up to 30% SBP exceed the minimal requirements for MOR and MOE set in the European standards, for boards for interior fitments (including furniture) for use in dry conditions. The WA and TS values for that variant were similar to the control particleboard. All of the particleboards produced with the shear of SBP particles in the core had higher IB than required. (Borysiuk *et al*. 2019)

Dagne 2021 has presented an experimental work that investigates the potentiality maize cob in the production of particle board using modified starch adhesives and wood glue (top bond) as an alternative source of adhesive and also studied effects of control variables in the product. A general factorial design was used for to prepare 27 experimentsby varying control parameters. The maize cob particle, modified starch, wood glue (top bond) and the mixed ratio adopted were 69.2%, 15.4, 17.9%, 20.3% and 15.4% respectively, thoroughly mixed manually by using the mixer. The mixture was then pouredinto a mould with a dimension 100 mm × 100 mm × 15 mm. The particleboard was compacted using a hydraulic press in two compacts.

Figure 9. Experimental products of maize cob particle board. (Dagne 2021)

The panels of densities were varied between 6840 kg/m3 and 9083.33 kg/m3. Percentage of water absorption was increased with increasing time of immersion. An average moisture content of all boards was found to be 11.43%. The average internal bonding was 0.132 N/mm2 relatively low internal bonding compared with urea and phenolformaldehyde resin made PB. The results showed that the maize cob, starch and wood glue(top bond) combination have high potential to be used indoor application for ceiling roofs or by laminating Formica or veneers; it can be used for building and furniture applications. (Dagne 2021)

Figure 10. Test setup of IB test MC particle board. (Dagne 2021)

Nongman *et al.* 2016 had produced Laminated composites were made by laminating the binderless banana stem particle boards with banana leaf tapes using adhesive in the form of a double-sided tape. The effect of the lamination on the tensile and flexural properties of the particle board panel was investigated. Results obtained showed that increasing the number of layers of banana leaf tapes altered the mechanical properties of the particle board.

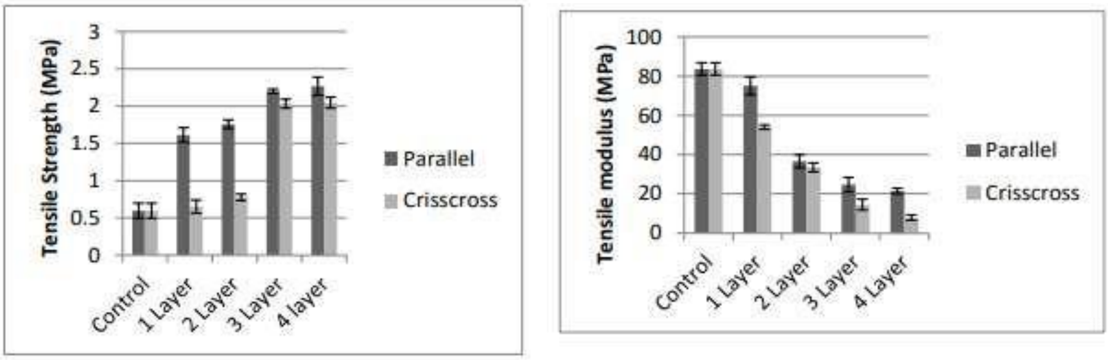

Figure 11. Tensile strength and modulus of laminated board panels

Particle board with four layers gave the highest flexural strength. Flexural modulus also increased with the increase in the number of layer of banana leaf tapes. There is also an improvement in tensile strength with the number of layers of banana leaf tapes. Particleboard panel laminated with four layers of banana leaf tapes showed the highest tensile strength. The tensile modulus, on the other hand, decreased with increasing layer of bananaleaf tapes. The fibre orientation in the banana leaf tapes also influenced the mechanical properties of the particle board. Particle board with the banana leaf fibre orientation parallel to the test direction showed higher tensile strength. The effect of banana leaf tape fibre orientation on the flexural strength was not significant. (Nongman *et al.* 2016)

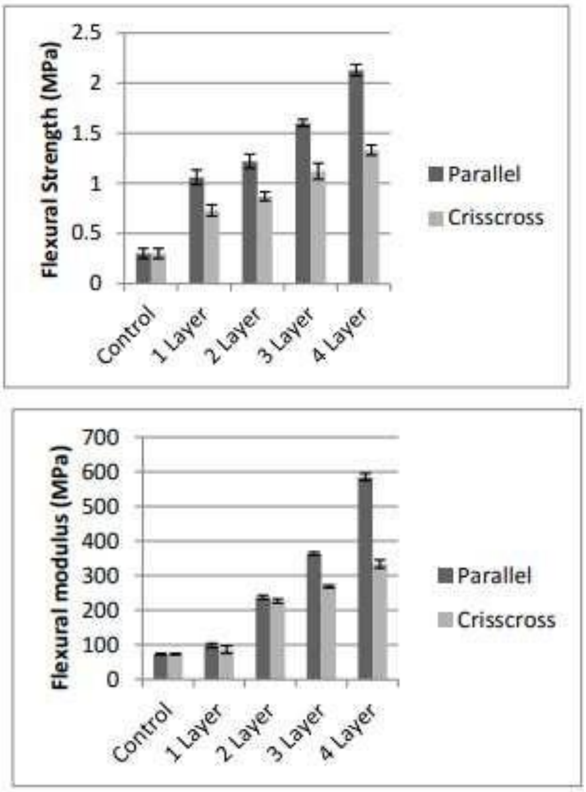

Figure 12. Flexural strength and modulus of laminated board panels

Kamran *et al.* 2023 had examined Tea oil camellia (Camellia oleifera Abel.) is a uniqueoil crop belongs to the genus Camellia of the Theaceae family with more than 4.4 million hectares in China to produce more than 2.4 million-ton fruit in 2019. There are about 1.8 million-ton by-products of tea oil camellia shell (TCOS). In view of the huge amount of TCOSproduced, it is a severe concern to utilize the TCOS on a large scale instead of discarding it to cause various forms of environmental pollution and problems. Herein, we investigated the feasibility of using TCOS as a new lignocellulose resource instead of wood for particleboard production. The effective variables, including adhesive content, hot-pressing parameters (temperature, time, and pressure), and the ratio of shell particles to wood particles, were systematically investigated.

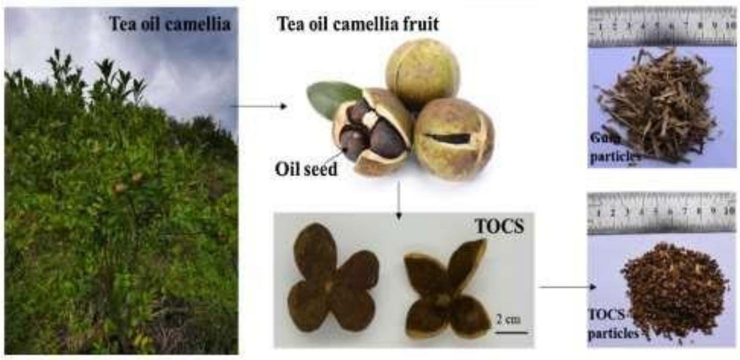

Figure 13. Tea oil camellia to TOCS particles. (Kamran et al. 2023)

Results showed the suitability of TOCS as a raw material for the particleboard industry.Accordingly, using 50 % of TOCS particles and 50 % commercial wood particles in the matwith 8% pMDI adhesive exhibited modulus of rupture (MOR) value of 13.4 N/mm^2, modulus of elasticity (MOE) of 1840 N/ mm2, and internal bonding strength (IB) of 1.22 N/mm^2, qualified EN standard for particleboard type P2 (dry conditions), and its thickness swelling (TS) of 17 % met the minimum requirement of EN 312 for particleboard type P3. (Kamran *et al*. 2023)

Odeyemi *et al.* 2020 had examined reducing the amount of wastes deposited into the environment has become important. A fresh approach in doing this is by recycling them. This paper investigated the physical and mechanical properties of cement bonded particleboards from agricultural wastes. The particle boards were tested for their physical (density, water absorption and thickness swelling) and mechanical (modulus of elasticity and modulus of rupture) properties. Scanning Electron Microscopy (SEM) analysis was carriedout to determine the internal microstructure of

the boards.

Figure 14. (a) Sawdust and (b) Ground Periwinkle Shells. (Odeyemi et al. 2020)

The results revealed that periwinkle shell and cement have a great influence on the density of the board, cement and sawdust have a great influence on water absorption and thickness swelling, cement has a great influence on Modulus of Rupture & Modulus of Elasticity for all the combinations tested. The SEM photograph of the cut surface of the boards showed good fibre matrix adhesion at mix ratio of 1:1.5 (cement/waste). At lower fraction of cement matrix to waste ratio, the cement bonded particle board lost its adhesiveforce. It was concluded that sawdust and periwinkle shells are suitable materials in the production of particle boards. (Odeyemi *et al.* 2020)

CONCLUSIONS

Accumulation of unmanaged agro-waste especially from the developing counties has an increased environmental concern. Recycling of such wastes into sustainable, energy efficient construction materials is a viable solution for the problem of pollution and natural resource conservation for future generation. The various methodologies to design particle boards have been reviewed. Various physical, mechanical properties of particleboards are studied in accordance with reviewed literature and relevant standards. Agro-wastes have shown the potential to develop energy efficient and cost-effective sustainable particleboards along with enhanced thermomechanical behavior. From the various literatures it is observed that particleboards produced from various agro-waste materials are comparatively cheaper, have lower thermal conductivity and are durable, lightweight, and environmentally friendly than the conventional one. The application of agro-wastes and its by-product as a raw material is of practical significance for developing material components as substitutes for traditional particleboards and are environmentally friendly.

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