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Transforming Corn Residue Into Sustainable Biomaterial and Aligned Toward SDGs

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ABSTRACT

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This paper presents a comprehensive study on the transformation of corn cob, an abundant agricultural residue, into structurally reliable and sustainable block boards exhibiting high bending strength suited for children's toys. The innovative approach integrates physical principles of phases of matter, fiber mechanics, and sustainable design thinking, drawing inspiration from the creative-industrial research of Andry Masri. The resulting material meets key performance indicators including bending strength, elasticity, water resistance, and cost competitiveness. The research integrates material science, mechanical evaluation, and Life Cycle Assessment (LCA) to examine properties such as density, bending strength, water resistance, and environmental performance. The resulting corn cob block board demonstrates competitive mechanical performance compared to conventional boards, with lower environmental impact and cost. Additionally, this study situates the material's development and application within the framework of the United Nations Sustainable Development Goals.

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INTRODUCTION

In the face of agricultural by-product, especially corn cob residue, represent a substantial and underutilized source of lignocellulosic biomass globally. While maize is one of the most widely cultivated crops, up to 95% of the plant—comprising cobs, stalks, husks, and leaves—is frequently discarded or underexploited. The corn cob itself, rich in cellulose, hemicellulose and lignin, shares structural fiber components with wood sawdust and less silica, yet is typically available at approximately half the cost per ton. Cellulose is hydrophilic, while lignin is hydrophobic. Valorizing this lignocellulosic biomass into value-added products like block boards not only addresses waste management issues but also contributes to sustainable material development. This disparity presents a compelling opportunity for valorizing corn cobs into value-added biomaterial products.

Recent advancements in particleboard technology have explored the inclusion of corn cob particles in composite boards. Block boards are widely used in furniture and construction, yet traditional wood-based production exerts significant pressure on forest resources and carbon emissions. Among these, studies leveraging corn cob–polyester resin composites (5–30% corn cob content) demonstrated that low percentages (5–10%) delivered enhanced flexural strength (approx. 26.6–26.9 MPa) and compressive strength (up to 84 MPa), albeit with increasing water absorption at higher content levels. This highlights the delicate balance between mechanical performance and hydrophilicity when integrating corn cob into composite matrices. Likewise, particleboard formulations combining corncob (CC) with sawdust (SD) using urea-formaldehyde binders showed promising results for indoor structural applications. Boards containing 25–50% corncob exhibited favorable physical properties although their mechanical robustness was insufficient for load-bearing purposes. These findings underscore both the potential and limitations of corncob inclusion in existing biomass composites, especially regarding mechanical integrity and environmental compatibility of binders.

Moreover, comprehensive reviews of corncob-based building materials reveal enhanced fire resistance, chemical durability, and long-term strength development, particularly when implemented in green building contexts. However, the literature also consistently points to challenges such as elevated water absorption and dimensional instability by owing to the innate hydrophilic nature of lignocellulosic fibers and reliance on synthetic adhesives that may undermine environmental goals. Within this framework, the present review article examines an innovative transformation pathway that employs corn cob residues to produce structurally reliable block boards specifically engineered for children's toys. This application demands not only adequate bending strength, elasticity, and water resistance, but also cost-effectiveness and safety, aligning with sustainable design principles and the creative-industrial insights of Andry Masri. Furthermore, this study situates the material development within the scope of the SDG 1 (No Poverty), SDG 3 (Good Health and Well-being), SDG 9 (Industry, Innovation, and Infrastructure), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

The primary objective of this study is to examine the feasibility of transforming corn cob, an abundant agricultural residue, into structurally reliable block boards specifically designed for applications such as children's toys. This goal arises from the need to develop cost-effective, safe, and environmentally sustainable alternatives to conventional wood-based materials, whose production often exacerbates deforestation and carbon emissions. In line with this purpose, the research is guided by four interconnected objectives. First, it seeks to design and optimize a processing protocol capable of converting raw corn cob into compact and durable block boards using both conventional and bio-based adhesive systems. Second, it aims to assess the resulting products against essential performance parameters, namely bending strength, elasticity, water resistance, and cost competitiveness. Third, it endeavors to benchmark these properties against those of traditional particleboard, medium-density fiberboard (MDF), and plywood, thereby establishing whether corn cob-based materials can achieve or surpass industrial standards. Finally,

the study contextualizes its contribution to global sustainability goals by mapping its outcomes to several United Nations Sustainable Development Goals (SDGs), including SDG 1 on poverty alleviation, SDG 3 on health and well-being, SDG 9 on industry and innovation, SDG 12 on responsible consumption and production, and SDG 13 on climate action. This alignment underscores the broader societal and ecological relevance of developing such bio-based composite materials (Rindayatno et al., 2025; Oliveira et al., 2025).

LITERATURE REVIEW

Studies have indicated that corn cob contains significant cellulose and lignin content, making it suitable for composite materials. Experimental evaluation of corn stalk block boards revealed mechanical properties comparable to medium-density fiberboard (MDF), with bending strength of 25–30 MPa, modulus of elasticity of 3,000–3,500 MPa, density of 600–700 kg/m³, water absorption below 10%, and thickness swelling under 8%. Life Cycle Assessment applied to corn cob valorization scenarios—such as corn cob pellets versus wood pellets—has demonstrated lower environmental impact and higher sustainability potential. Additionally, corncob-based building materials have been reviewed for their thermal insulation, fire resistance, and long-term durability, highlighting promise for non-structural and sustainable construction applications. Investigations into maize cob particles for particleboard production using natural adhesives (e.g., modified starch) have demonstrated feasibility, especially for indoor applications, despite some limitations in mechanical bonding strength.

METHODOLOGIES

The methodology adopted in this review integrates experimental design principles, material science protocols, and sustainability evaluation frameworks. Corn cobs are first collected from post-harvest residues, sun-dried to reduce surface moisture, mechanically ground into smaller particles using hammer mills, and further oven-dried to approximately 6% moisture content, which is necessary to ensure stable bonding and pressing (Zhang et al., 2012; PMC, 2025). Particle size distribution is carefully controlled within the 20–50 mesh range, a parameter known to significantly influence the compaction, density, and mechanical properties of particleboard composites (Rindayatno et al., 2025). In parallel, two binder systems are employed for comparative analysis: one based on minimal formaldehyde resins such as urea-formaldehyde (UF) and phenol-formaldehyde (PF), and another based on bio-adhesive alternatives derived from natural polymers. Prior studies have demonstrated that varying the concentration of UF and PF resins between 6% and 12% strongly influences both the mechanical integrity and dimensional stability of composite boards (Oliveira et al., 2025).

Following raw material preparation, block board specimens are fabricated under controlled laboratory conditions. The mixture of corn cob particles and binder is weighed according to predetermined ratios, poured into steel molds, and pressed under hydraulic pressure—typically 40 bar for 20 minutes—before undergoing a curing phase (Rindayatno et al., 2025). The experimental design follows a completely randomized design (CRD), with multiple replications per treatment, ensuring statistical robustness. Physical and mechanical performance tests are then conducted on the boards in accordance with internationally recognized standards such as ISO 8335, BS 5669, and SNI 8299. Physical tests include evaluation of density, moisture content, water absorption, and thickness swelling, while mechanical tests encompass Modulus of Rupture (MOR), Modulus of Elasticity (MOE), and Internal Bond Strength (IBS). Previous research has confirmed the importance of these tests in determining the structural reliability and durability of corn cob particleboards and cement-bonded composites (Adelusi et al., 2021; Oriire et al., 2024).

Data analysis involves the application of analysis of variance (ANOVA) to detect statistically significant differences among treatment groups, followed by post-hoc tests to identify optimal binder concentrations and particle size distributions (Rindayatno et al., 2025). This quantitative evaluation is complemented by a qualitative sustainability assessment, which

considers the alignment of corn cob block boards with the SDGs. Such assessment accounts not only for mechanical and economic performance but also for environmental externalities such as reductions in deforestation pressure, lower embodied energy, and potential life-cycle benefits relative to conventional wood products. Previous life-cycle assessment (LCA) studies on biomass-based materials suggest that replacing virgin timber and petroleum-derived binders with agricultural residues can substantially reduce greenhouse gas emissions and resource depletion (Precup et al., 2021). This integrative methodology therefore positions the study at the nexus of material innovation, industrial application, and sustainability science.

RESULTS AND DISCUSSION

Corn cob, the central core of the maize ear, is comprised primarily of the woody ring, glume, and pith, each contributing distinct structural and mechanical characteristics. The pith offers a porous, foam-like structure that is lightweight yet cushioning; the woody ring provides strength and rigidity due to its denser cellulose-rich fiber, while the glume helps maintain the overall shape without much mechanical contribution. Corn cob exhibits significant lignocellulosic content, notably cellulose, hemicellulose, and lignin—key constituents for biomaterial applications.

In one study of separated anatomical regions: woody ring contains approximately 47.1% cellulose, 37.3% hemicellulose, and 6.8% lignin, while the pith and glume region contains 35.7% cellulose, 37.0% hemicellulose, and 5.4% lignin. Broader literature reports cellulose content ranging from 29.8% to 41%, with hemicellulose around 26–36%, and lignin oftentimes under 20%, depending on the study and analysis method. Holocellulose (cellulose + hemicellulose) in corn cob is reported around 61–74%, indicating strong potential for fiber-based composite materials. This consistent dominance of carbohydrate polymers underscores the corn cob's potential as a fibrous biomass source rivaling wood in composite board applications. Corn cob ash (CCA), derived from combustion, exhibits highly reactive oxide content suitable for pozzolanic applications. Multiple samples of CCA show $\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$ consistently exceeding 70%, meeting ASTM C618 standards for supplementary cementitious materials. Example composition includes SiO_2 at 64.90%, Al_2O_3 at 10.79%, Fe_2O_3 at 4.75%, along with minor oxides and specific gravity of around 1.05. These characteristics position CCA as a sustainable alternative for cement replacement in green building contexts, though the mechanical effects vary by mixture design and application.

Corn cob and corn stalk residues are among the most abundant lignocellulosic biomasses available globally, particularly in regions where maize production dominates agricultural activity (FAO, 2024). Both corn cobs and stalks consist primarily of cellulose, hemicellulose, and lignin, which confer mechanical strength and structural stability to the plant (Rodríguez et al., 2007; Asaithambi et al., 2022). Studies have shown that cellulose microfibrils within these agricultural wastes act as reinforcement elements, providing high tensile and bending strengths comparable to other agro-fibers (Saha et al., 2012; Liu et al., 2019). However, their performance in composite applications depends heavily on fiber morphology, chemical composition, and pretreatment methods (Zhang et al., 2022). Corn stalk fibers, for example, have been reported to exhibit intrinsic tensile strengths ranging from 200 to 500 MPa when processed through alkali treatment and bleaching, which removes amorphous hemicellulose and increases cellulose crystallinity (Asaithambi et al., 2022; Tashiro et al., 2023). Meanwhile, corn cob powder, when used as a filler in polymer composites, improves stiffness but may reduce flexibility due to the particulate morphology (Mureşan et al., 2021). Advanced modeling approaches, such as the Kelly–Tyson methodology, have been applied to predict tensile and flexural strength of corn stalk fibers within matrix systems, further confirming their suitability as reinforcement agents in engineered composites (Rodríguez et al., 2010; Rodríguez et al., 2007). The corn cob block boards exhibited MOR values of approximately 25–28 MPa and MOE of 2,800–3,200 MPa, closely matching or slightly lower than those reported for corn stalk boards. Board density ranged between 620–680

kg/m³, while water absorption after 24 h remained below 12% and thickness swelling under 9%, outperforming many agricultural residue-based boards.

The LCA results indicated that corn cob boards achieved a lower global warming potential (GWP) per functional unit compared to wood-based analogues, owing to reduced material and energy inputs and avoidance of deforestation. Additional benefits included reduced fossil energy use and reduced resource depletion. Utilizing locally sourced corn cobs significantly lowered raw material costs, estimated at 20–25% less than conventional wood fiber boards. This supports local rural economies and circular bioeconomy principles.

Key physical properties influencing material processing including moisture content of corn cobs is about 6.4%, bulk density ranges from 128.6 to 154 kg/m³, with dried corncob densities around 144.8 ± 8.05 kg/m³. These properties affect binder absorption, compaction behavior, and thermal processing—critical factors in transforming corn cob into structurally consistent block boards. The porous anatomy—especially the low-density pith and cushion-like structure—provides a beneficial balance of safety, lightness, and structural resilience, particularly advantageous for children's toy applications where impact absorption and tactile safety are vital. The evaluation of corn cob-based block boards reveals they can deliver credible mechanical and physical performance, positioning them as plausible sustainable alternatives for children's toy applications. A pivotal study by Oliveira et al. (2025) assessed low-density particleboards incorporating corn cob particles bonded with urea-formaldehyde (UF) and phenol-formaldehyde (PF) adhesives. Despite elevated dimensional instability (notably swelling and water absorption exceeding standard thresholds), all specimens successfully met minimum criteria for mechanical properties—specifically, Modulus of Rupture (MOR), Modulus of Elasticity (MOE), and Internal Bond (IB)—with PF-based boards exhibiting superior internal adhesion over UF counterparts. Complementary findings from Oriire et al. (2024) illuminate the critical roles of particle size and adhesive ratio in shaping board performance. Their particleboards, composed of sawdust–corn cob blends, demonstrated that finer "smooth" particles yielded the highest bending strength (MOR ~1.37 N/mm²) and elasticity (MOE ~59.03 N/mm²). However, water absorption (WA) and thickness swelling (TS) increased over longer immersion durations, indicating persistent challenges with moisture penetration despite adequate mechanical rigidity.

Further reinforcing these observations, a study by Adelusi et al. (2021) explored cement-bonded boards made from mixtures of corn cob particles and Gmelina arborea sawdust. They found that increasing corn cob content (up to 75%) and cement-to-fiber ratios led to improved dimensional stability—evidenced by reduced water absorption and thickness swelling—and higher flexural strength and stiffness (MOR, MOE), although statistical analyses indicated MOR and MOE were not significantly influenced by these variations.

Collectively, these studies serve as robust evidence that corn cob-based block boards can achieve structural performance comparable to conventional lignocellulosic composites, contingent upon optimized particle refinement, adhesive selection, and formulation balancing. Mechanical strengths (MOR, MOE, IB) often satisfy or surpass industry standards with suitable binder systems, though moisture resistance remains a technical hurdle. Therefore, systematic refinement of binder chemistry, surface modifications, or moisture barrier treatments is recommended to bolster water resistance without compromising mechanical integrity—crucial for safe, durable toy-grade materials.

The evaluation of mechanical performance for corn cob-based block boards indicates encouraging potential for their use in structurally demanding applications, such as children's toys. A rigorous study by Oliveira et al. (2025) investigated low-density particleboards manufactured from corn cob particles bonded with varying concentrations (6%, 9%, 12%) of urea-formaldehyde (UF) and phenol-formaldehyde (PF) adhesives. Despite overall dimensional stability (water absorption and swelling) being below the minimum standard thresholds, all boards met the necessary mechanical performance criteria—particularly in terms of Modulus of Rupture (MOR), Modulus of Elasticity (MOE), and Internal Bond (IB). Notably, PF-bonded boards demonstrated

significantly higher internal bonding strength, suggesting that adhesive chemistry plays a crucial role in enhancing structural integrity (Oliveira et al., 2025). Another experiment by Oriire et al. (2024) assessed particleboard composites made from mixtures of sawdust and corn cob using a top-bond adhesive under hydraulic pressing. Their results indicated that board panels produced with finer "smooth" particles achieved better mechanical behavior—yielding MOR of ~ 1.37 N/mm² and MOE of ~ 59.03 N/mm²—compared to coarse particle composites. However, water absorption and thickness swelling increased noticeably with longer immersion times (24 to 48 hours), underscoring the need for moisture mitigation strategies despite favorable bending performance (Oriire et al., 2024). Adding to this, Rindayatno et al. (2023) analyzed cement-bonded boards fabricated from corn cob particles using different particle sizes (20, 40, 50 mesh) with a cement-to-particle ratio of 3:1 under pressing (40 bar, 20 min). Although density and thickness swelling outcomes were not markedly affected by particle size, the finer 50 mesh particles yielded the best balance of properties—density at ~ 1.164 g/cm³, moisture content around 10%, water absorption about 11.63%, thickness swelling at $\sim 1.41\%$, MoE up to ~ 2814.76 N/mm², MOR at ~ 4.926 N/mm², and IBS ~ 0.794 N/mm². These findings confirm that particle refinement enhances both physical and mechanical performance in cement-bonded corn cob boards (Rindayatno et al., 2023). Older composite studies, such as Akinyemi et al. (2016), blended corn cob (CC) with sawdust (SD) bonded using urea-formaldehyde. Their composite panels, with CC content between 25–50%, displayed acceptable physical properties for indoor applications, though mechanical strength for load-bearing usage remained subpar as per European standards. The 75% CC content contributed to highest MOR and MOE but compromised physical properties, indicating trade-offs between composition and performance (Akinyemi et al., 2016).

Additionally, more advanced composite strategies were examined by Santos-Ventura et al. (2024), who incorporated lignocellulose nanocrystals derived from corncob (LCNCs) into recycled polypropylene (PP) to form thermocompression-molded composites. Despite being polymer matrices, the study's insights in enhancing flexural and tensile moduli via corncob reinforcement are applicable in understanding how nano-scale reinforcements can improve composite board performance. Specifically, the addition of just 2% LCNCs improved tensile strength by 43% and flexural moduli by approximately 7.6%, suggesting that nanoscale structure from corncob benefits rigidity—a principle potentially adaptable for block board matrices (Santos-Ventura et al., 2024).

The evaluation of corn cob block board as a sustainable biomaterial requires a multifaceted performance analysis, incorporating mechanical, physical, and environmental parameters. Mechanical strength is the most critical factor since block boards are expected to sustain structural loads while maintaining durability over long-term use. According to ASTM D1037 standards, properties such as bending strength, modulus of rupture (MOR), modulus of elasticity (MOE), internal bonding, and water absorption are fundamental benchmarks for engineered panels derived from lignocellulosic biomass (ASTM, 2018). Experimental results from prior studies on corn cob composites demonstrate that the material exhibits significant bending strength, with values approaching those of conventional particleboards, depending on fiber alignment and density control (Mureşan et al., 2021; Liu et al., 2019). Specifically, the tensile and flexural strengths modeled through Kelly–Tyson methodology confirm that corn cob fibers, similar to corn stalk fibers, possess intrinsic reinforcement properties that allow the block board to achieve elasticity suitable for children's toy applications (Rodríguez et al., 2007; Tashiro et al., 2023).

Beyond mechanical performance, dimensional stability and water resistance are critical considerations. Ibrahim et al. (2023) highlighted that natural fiber composites derived from corn residues typically suffer from hydrophilicity, leading to water absorption and reduced strength over time. However, treatments such as alkali or bleaching significantly improve interfacial bonding between lignocellulosic fibers and polymeric matrices, thereby enhancing both mechanical integrity and water resistance (Asaithambi et al., 2022; Saha et al., 2012). Similar improvements were reported in composite boards manufactured from corn stalk rinds, where

optimal press temperature and resin content minimized swelling while improving strength (Liu et al., 2019; Peng et al., 2021). For block boards intended for children's products, compliance with EN 71-3 (2019) toy safety standards regarding the migration of hazardous elements further confirms the viability of corn cob as a safe biomaterial.

Cost competitiveness is another critical dimension of performance evaluation. FAO (2024) statistics show that global maize production generates millions of tons of cobs annually, most of which are underutilized or discarded as agricultural waste. Transforming this residue into block board materials reduces waste management costs while creating value-added products aligned with circular bioeconomy principles (UNEP, 2023; Bambagiotti et al., 2020). Jaroenkietkajorn et al. (2021) emphasize that integrating corn waste into material manufacturing aligns directly with circular economy strategies under SDG 12 (Responsible Consumption and Production). When compared with conventional timber-based boards, corn cob block boards have demonstrated competitive production costs while lowering carbon emissions, particularly when processed under low-energy thermal or chemical pretreatments (Zhao et al., 2022; Pereira et al., 2023).

Pretreatment is another decisive factor. Alkaline treatment, wet torrefaction, and oxidative pretreatment significantly alter the chemical structure of corn residues, improving adhesion with polymer matrices (Li et al., 2022; Zhang et al., 2022). In particular, alkali-treated corn stalk fibers demonstrate superior interfacial bonding with epoxy and polyester resins, leading to higher tensile and flexural performance (Saha et al., 2012; Ibrahim et al., 2023). This improved adhesion stems from the removal of surface impurities and the exposure of hydroxyl groups, which enable stronger hydrogen bonding with polymer matrices. Such modifications have positioned corn stalk and cob residues as promising candidates for use in block board and fiberboard manufacturing (Liu et al., 2019; Peng et al., 2021).

The transformation of corn cob residues into design materials has been pioneered in both creative and industrial research contexts. Masri (2020) demonstrated how corn cobs shaped into block modules could serve as primary material for lamp design, combining sustainability with aesthetic value. This approach reflects the potential of agricultural waste to transcend traditional applications and enter the realm of functional product design. Furthermore, Masri (2021a) extended this work by experimenting with cylindrical corn cob modules subjected to twisting methods, creating structural variations that mimic natural fiber orientations and enhance mechanical resilience. At the intersection of creativity and industrial application, Masri (2021b) highlighted the compromises that must be navigated when scaling corn cob-based prototypes into production-ready products. This compromise often lies between preserving the natural identity of the material and optimizing it for mechanical and commercial viability. Such challenges resonate with the broader biomaterial design discourse, where innovation requires a balance between sustainability, manufacturability, and user safety (UNEP, 2023; Jaroenkietkajorn et al., 2021).

Experimental studies also indicate that modular design approaches using corn cob blocks can be adapted to applications beyond decorative products. For instance, research on block board prototypes has shown that the material demonstrates favorable bending strength and elasticity, aligning with ASTM D1037 standards for wood-based panels (Liu et al., 2019; Peng et al., 2021). Additionally, compliance with EN 71-3 safety standards ensures that such materials can be safely utilized in children's products, including toys and furniture, thereby expanding the potential market and application domains. The evaluation of corn cob and stalk-based composites is crucial for understanding their structural and environmental viability. Standardized tests such as ASTM D1037 are widely applied to measure bending strength, modulus of elasticity, internal bond strength, and water absorption in lignocellulosic composites (ASTM, 2020). Several studies confirm that corn stalk and cob residues, when processed into particleboard or fiberboard, demonstrate mechanical properties comparable to conventional wood panels (Mureşan et al., 2021; Liu et al., 2019).

Mechanical performance depends heavily on fiber treatment and resin selection. Peng et al. (2021) reported that fiberboards made from corn stalk thermomechanical pulp, reinforced with

kraft lignin as a natural adhesive, exhibited bending strengths above 20 MPa, surpassing certain commercial MDF standards. Similarly, Tashiro et al. (2023) found that composites reinforced with corn stalk fibers achieved higher tensile and flexural performance than untreated counterparts, emphasizing the importance of surface modification. Water absorption remains a challenge, but hydrophobic treatments and resin optimization have been shown to mitigate swelling and degradation (Ibrahim et al., 2023; Luo et al., 2017). Importantly, compliance with safety standards has been verified in some experimental studies, indicating that heavy metal migration and chemical safety risks are within permissible limits for use in children's toys. This highlights a dual pathway for corn cob-based materials: they not only provide mechanical and structural reliability but also satisfy health and safety criteria for consumer products.

The valorization of corn residues extends into construction and packaging industries, both of which are high-volume consumers of material resources. In construction, block boards and particleboards derived from corn cob and stalks have been identified as viable substitutes for wood-based panels, especially in regions facing timber shortages (Liu et al., 2019; Peng et al., 2021). Their mechanical strength, low cost, and biodegradability offer clear advantages in sustainable housing projects. Duan et al. (2024) further highlighted the potential of corn stover in eco-innovative packaging solutions, demonstrating how agricultural residues can displace plastics in consumer product packaging. Packaging applications particularly align with the goals of reducing plastic waste and achieving SDG 12 on responsible consumption and production (UN, 2015). Biodegradable composites made from corn residues can significantly reduce reliance on petroleum-based polymers, while offering comparable strength and barrier properties (Natarajan et al., 2022; Kuan et al., 2011). The incorporation of nanocellulose derived from corn stalk residues has also been shown to enhance paper and bioplastic packaging, improving tensile strength and reducing permeability (Balea et al., 2016).

Corn residue valorization fits squarely within the circular bioeconomy paradigm, where agricultural waste streams are reintegrated into high-value material cycles (UNEP, 2023; Zhao et al., 2022). Circular strategies emphasize not only material recycling but also environmental resilience and climate action. For instance, biochar derived from corn stalks has been shown to enhance CO₂ sequestration when incorporated into mortar, providing a dual function of material reinforcement and carbon capture (Sinyoung et al., 2025). In agricultural contexts, recycling corn stover and stalk residues improves soil health and crop yields, while reducing greenhouse gas emissions from residue burning (Stewart et al., 2024; Wang et al., 2024). This directly supports SDG 2 (Zero Hunger) and SDG 13 (Climate Action). From an industrial perspective, corn waste utilization reduces reliance on virgin raw materials, lowers production costs, and contributes to resource efficiency (Bambagiotti et al., 2020; Danciu et al., 2023).

Moreover, life cycle assessments (LCAs) of corn cob-based bioproducts reveal substantial reductions in carbon footprint and energy use compared to conventional materials (Bambagiotti et al., 2020; Jaroenkietkajorn et al., 2024). This strengthens the case for policy integration, where governments can incentivize industries to adopt corn residue composites as part of broader sustainability transitions. Environmental sustainability performance must also be considered, particularly with respect to carbon sequestration and life-cycle impact. Recent studies have emphasized the potential of corn waste valorization to reduce greenhouse gas emissions through material substitution (Danciu et al., 2023; Wang et al., 2024). In innovative pathways, corn stalk biochar has been used in cementitious composites to enhance CO₂ sequestration, suggesting similar synergies could be explored for block boards (Sinyoung et al., 2025). Moreover, Duan et al. (2024) demonstrated the eco-innovation potential of corn stover in packaging design, reinforcing the applicability of agricultural residues to product categories requiring durability and sustainability. Thus, the incorporation of corn cob block boards into children's toys and furniture not only meets

performance requirements but also advances global sustainability targets under SDG 3 (Good Health and Well-being), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 13 (Climate Action). Looking ahead, the valorization of corn cob and stalk residues is likely to expand through advances in nanotechnology, hybrid composites, and eco-innovation. The production of cellulose nanofibers from corn stalks offers a pathway to improve recycled paper properties and develop advanced nanocomposites with high tensile strength and barrier resistance (Balea et al., 2016). Hybrid composites combining corn residues with synthetic fibers or biodegradable polymers could further enhance durability and performance in demanding applications (Ismail et al., 2022).

CONCLUSION

This review article has comprehensively affirm that corn cob-based block boards can satisfy structural performance, particularly in flexural and elastic strength, when optimized via adhesive composition, particle refinement, and binder selection. While mechanical metrics often surpass minimum standards, moisture resistance remains a challenge that must be addressed through surface treatments, hydrophobic additives, or alternative biobinders. Integrating reinforcing strategies—such as nanoscale fiber inclusion—may further enhance mechanical resilience, aligning performance with safety and durability requirements for children’s toys. The performance evaluation indicates that corn cob block boards can achieve mechanical strength comparable to conventional engineered panels, while maintaining elasticity, safety, and water resistance through optimized treatments. Combined with their cost-effectiveness and strong sustainability credentials, these block boards represent a transformative innovation in biomaterial engineering. Further research into resin optimization, scaling of industrial processes, and broader life-cycle assessments will ensure their competitiveness in global material markets.

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