OPEN ACCESS

Orapuh Journal

ORIGINAL ARTICLE

Journal of Oral & Public Health

Valorization of Cellulosic Waste in Kinshasa: Production of Quail Egg Trays Using Local Additives

Mungangila, A. G., Nyembo, N. B., Mesongolo, L. C., Ndaywel, N. O., Nsiala, O. G., & Biey, M. E.

Laboratory of Ecotoxicology, Chemical Safety and Environmental Biotechnology, Program in Environmental Science and Management, Faculty of Science and Technology, University of Kinshasa, Kin XI, Kinshasa, Democratic Republic of the Congo

ARTICLE INFO

Received: *11 April 2026*
Accepted: *20 July 2026*
Published: *09 September 2026*

Keywords:
Recycling, paper waste, Kinshasa, quail egg trays, circular economy, biodegradable composites

Peer-Review: *Externally peer-reviewed*

Correspondence to:
Mungangila Ayila Gracia
gracia.mungangila@unikin.ac.cd

To cite:
Mungangila, A. G., Nyembo, N. B., Mesongolo, L. C., Ndaywel, N. O., Nsiala, O. G., & Biey, M. E. (2026). Valorization of cellulosic waste in Kinshasa: Production of quail egg trays using local additives. *Orapuh Journal, 7*(8), e1472. https://doi.org/10.4314/orapj.v7i8.72

ISSN: *2644-3740*

Published by ***Orapuh, Inc.***, F. Gaye Res., Sukuta-Jamisa, Greater Banjul, The Gambia.

Editor-in-Chief: *Prof. V. E. Adamu (editor@orapuh.org)*

ABSTRACT

Introduction
Kinshasa generates approximately 9,000 metric tons of solid waste daily, while the local poultry sector faces a shortage of suitable biodegradable packaging. This dual challenge highlights the urgent need for sustainable waste valorization strategies.

Purpose
This work is an experimental comparative study evaluating the production of quail egg trays from recycled cellulosic waste under low-technology conditions.

Methods
Paper waste was processed through pulp preparation, sequential bleaching with sodium hypochlorite (NaClO) and hydrogen peroxide (H_2O_2), and manual compression molding. Three formulations were tested: untreated pulp (control, F_0), pulp reinforced with dissolved expanded polystyrene binder (Isomo, F_1), and pulp reinforced with wood sawdust (F_2). For each formulation, ten trays (n=10) were produced and tested in triplicate following ISO 5263, ISO 18134-1, and EN 12390 standards. Statistical analysis was performed using R software via one-way Analysis of Variance (ANOVA) and Tukey post-hoc tests at a 95% confidence interval.

Results
The purification stage induced a mass loss of 75±1.2%. Mechanical testing revealed that sawdust-reinforced trays (F_2) achieved the highest impact resistance (188.18±8.16 kJ/m^2; p<.001), followed by Isomo-based trays (F_1: 157.47±8.54 kJ/m^2) and binder-free trays (F_0: 140.11±8.31 kJ/m^2). Hygroscopic analysis revealed that Isomo trays maintained the lowest moisture content (6% after 72 h at 60ºC) and exhibited superior thermal stability.

Conclusion
The study demonstrates the technical feasibility of producing biodegradable quail egg trays from recycled paper waste in Kinshasa. Sawdust reinforcement significantly improves mechanical strength, while the Isomo binder enhances thermal and moisture stability. These findings provide a scalable pathway for waste valorization, reduce reliance on plastic packaging in the local poultry supply chain, and contribute to circular economy practices in African megacities.

INTRODUCTION

Human activities inevitably generate waste, defined as materials discarded after losing utility during production or consumption. In the era of rapid urbanization, local environmental degradation produces broader ecological and socioeconomic repercussions. Beyond financial imbalances, ecological deficits compromise sustainable development prospects, particularly in developing regions (Djemaci, 2012). Unmanaged solid waste contributes directly to local climate stress, biodiversity loss, and public health risks (Nguyen et al., 2023).

Waste Management Challenges in Kinshasa

In Kinshasa, waste management constitutes a major environmental and public health challenge. According to the Régie d'Assainissement de Kinshasa (RASKIN, 2020), approximately 9,000 metric tons of waste are generated daily, nearly 65% of which consists of organic matter. Existing waste management systems remain structural and operational bottlenecks, insufficient to ensure efficient collection, sorting, recycling, recovery, or safe disposal.

The proliferation of uncontrolled dumping sites, odor nuisances, and direct waste discharge into waterways illustrates these structural deficiencies. These practices violate local regulatory frameworks, such as Article 57 of Law No. 11/009 of 9 July 2011, which explicitly prohibits waste disposal in locations likely to harm public health and environmental safety.

Environmental Impacts and Technological Solutions

Pollution of local water, air, and soil ecosystems due to unmanaged municipal, industrial, and household waste continues to intensify in Kinshasa. Recent estimates indicate that the city generates nearly 7,800 tons of municipal solid waste daily, with current management practices emitting over 640,000 tons of CO_2 equivalent annually (Kang et al., 2023). Household-level analyses further reveal that over 60% of municipal waste is organic and biodegradable, with substantial recyclable fractions remaining underexploited due to inadequate sorting infrastructure (Yawili et al., 2025). Persistent practices such as open burning and uncontrolled self-evacuation create acute ecological and epidemiological threats in densely populated communes (Masamuna et al., 2026). These environmental pressures underscore the need for low-cost, context-appropriate technology options to transform cellulosic waste fractions into value-added products.

Evolution of Waste Production

Since the 1950s, global solid waste production has accelerated due to population growth and expanded consumption patterns in urban environments (Macqueron, 2009; Rogaume, 2006). In developing megacities such as Kinshasa, municipal infrastructure development has failed to keep pace with demographic expansion. However, cellulosic fractions within the municipal waste stream remain a major unexploited secondary resource for bio-based materials and secondary recycling schemes (Masamuna et al., 2026; Yawili et al., 2025).

Research Gap, Rationale, and Objectives

Despite extensive global literature on pulp recycling and molded fiber packaging, few studies have explored the physical and mechanical performance of mixed urban cellulosic waste transformed under low-technology conditions in Sub-Saharan Africa. Furthermore, the performance effects of locally available structural additives—such as wood sawdust and expanded polystyrene residues—on recycled pulp matrices remain insufficiently quantified.

This study addresses this empirical gap by evaluating a low-technology pulp molding process adapted to the urban context of Kinshasa.

Research Question: Can mixed urban cellulosic waste combined with locally sourced wood sawdust or expanded polystyrene residues yield molded quail egg packaging with structural and physical properties suitable for transport and storage?

Hypothesis: Incorporating wood sawdust as a lignocellulosic filler enhances impact resistance and mechanical toughness relative to expanded polystyrene binders, whereas expanded polystyrene enhances moisture resistance and dimensional stability.

Objective: This study aims to experimentally evaluate the production and physical-mechanical performance of molded quail egg trays fabricated from recycled paper pulp using locally available additives (Isomo and wood sawdust).

METHODS

Study Area and Sampling Framework

Raw post-consumer paper waste was collected from academic and administrative units across the University of Kinshasa campus.

Inclusion criteria

Standard office paper, notebooks, printed documents, and uncoated paper with high cellulosic content.

Exclusion criteria

Multi-layer coated paper, plastic-laminated sheets, metals, carbon papers, and heavily contaminated materials.

Manual sorting was performed to isolate the fibrous feedstock prior to mechanical disintegration, following standard protocols for laboratory pulp preparation (ISO, 2023).

Raw Materials and Reagents

The primary raw materials, reagents, and their respective operational roles in composite tray fabrication are summarized in **Table 1**.

Table 1:
Raw Materials, Reagents, and Operational Roles in Composite Processing

Material / Reagent	Quantity	Primary Function / Operational Role
Cellulosic paper waste	Variable	Primary fibrous matrix providing structural cohesion via hydrogen bonding
Expanded polystyrene (Isomo)	Variable	Binder phase (post-dissolution) to decrease porosity and improve cohesion
Gasoline	400 mL	Organic solvent for polystyrene dissolution
Wood sawdust	6.0 kg	Lignocellulosic filler reinforcement to improve energy absorption
Water	15.0 L	Medium for fiber swelling, defibrillation, and slurry dispersion
Vegetable oil	50 mL	Mold release agent
Sodium hypochlorite (NaClO)	Variable	Oxidizing bleaching agent for partial delignification
Hydrogen peroxide (H_2O_2)	Variable	Chlorine-free bleaching agent for fiber brightening

Safety Note: Dissolution of expanded polystyrene in gasoline was conducted in a dedicated laboratory fume hood using personal protective equipment (nitrile gloves, safety goggles, and organic vapor respirators) to avoid exposure to volatile organic compounds (Nguyen et al., 2023).

Experimental Design

A single-factor complete randomized design was utilized to evaluate three distinct formulations:

i. F_0 **(Control):** 100% purified recycled paper pulp.

ii. F_1 **(Polymer-Modified):** 85% purified paper pulp +15% dissolved expanded polystyrene (Isomo) binder by wet mass.

iii. F_2 **(Lignocellulosic-Reinforced):** 80% purified paper pulp +20% wood sawdust by wet mass.

Ten trays (n=10) were molded per formulation group. All analytical characterizations were conducted in triplicate (n=3).

Pulp Preparation, Defibrillation, and Bleaching

Paper waste was mechanically shredded into 2–5 cm fragments and soaked in water at ambient temperature (25±2ºC) for 24 h to facilitate fiber swelling. Mechanical defibrillation was conducted using a high-shear laboratory blender for 10 min to produce a uniform fiber suspension (ISO, 2023). The pulp was subsequently washed over a 150μm mesh sieve with distilled water to remove soluble inks and particulate debris.

Sequential chemical bleaching treatments were applied to evaluate matrix purification:

a) **NaClO Bleaching:** Alkaline bleaching conducted at controlled pH ranges (pH 9–11) to decompose residual lignin and chromophoric functional groups.

b) **H_2O_2 Bleaching:** Stabilized oxidation designed to increase brightness without inducing excessive chain scission of cellulose macromolecules.

Following chemical treatment, pulps were washed thoroughly with deionized water until reaching neutral pH (≈ 7.0).

Mold Fabrication and Forming

To maintain uniform tray dimensions, a custom molding apparatus was fabricated through a two-stage process:

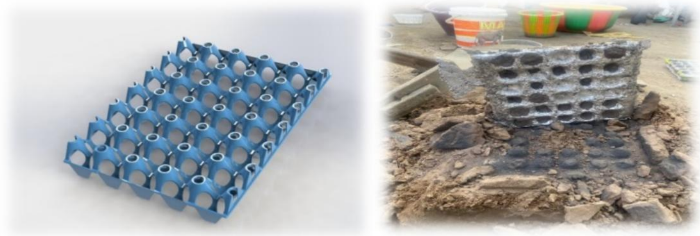
1. **Prototype Design:** A plastic prototype tray (20×15 cm, 30 cavities) was generated using 3D printing to define geometry, wall draft angles, and cavity spacing **(Figure 1a)**.

2. **Aluminum Casting:** The prototype was replicated in sand molds and cast using molten aluminum (≈ 30 kg). Machining yielded a rigid two-piece aluminum mold (20 × 14 × 2 cm) equipped with

https://doi.org/10.4314/orapj.v7i8.72

internal heating elements (2×500 W) for controlled thermal dewatering (Figure 1b).

Figure 1:
Molding Equipment Prototypes
(a) 3D-printed plastic prototype used for dimensional validation;
(b) Solid aluminum cast mold with integrated heating elements.



a) *b)*
(**Source:** Author's experimental setup, 2026).

Standardized Processing Sequence

The conversion of raw cellulosic waste into molded trays followed the standardized linear sequence illustrated in **Figure 2**.

Figure 2:
Process Flow for Cellulosic Waste Transformation and Tray Fabrication

*(**Source:** Adapted from ISO 5263 [2023], EN 12390 [2020], Nguyen et al. [2023], and Yawili et al. [2025]).*

Homogenized slurries were transferred to pre-oiled molds and manually compressed to expel bulk liquid and induce fiber mat consolidation **(Figure 3)**. All molded samples were dried in a forced-air drying oven at 45 ± 2°C for 48 h until constant mass was reached.

Figure 3:
Defibrillation and Molding Stages
(a) Intermediate pulp suspension showing partially disintegrated fibrous bundles;
(b) Formed molded fiber egg tray specimen after mechanical dewatering.

Characterization and Testing Standards

Physical and mechanical testing protocols applied across all formulations are outlined in **Table 2**.

Table 2:
Physical and Mechanical Test Specifications

Tested Parameter	Applied Standard	Test Equipment / Method	Analytical Objective
Purification Mass Loss	ISO 5269	Gravimetric balance (±0.01 g)	Measure solid mass loss during pulping and bleaching
Moisture Content	ISO 18134-1:2016	Convection oven (105°C)	Quantify residual moisture and hygroscopic capacity
Impact Resistance	EN 12390-5	Drop-weight Charpy impact tester	Measure mechanical energy absorption capacity
Compressive Strength	EN 12390-3	Universal Testing Machine (UTM)	Measure vertical load-bearing capacity
Flexural Resistance	EN 12390-5	Three-point bending fixture	Evaluate bending stress limits
Thermal Stability	ISO 18134-1	Exposure oven (60–100°C)	Assess dimensional stability and weight loss over time

Compressive stress (Rc, in MPa) was calculated according to Equation 1:

$$Rc = SP \quad (1)$$

where P is the peak breaking load (N) and S is the loaded surface cross-sectional area (mm^2).

Statistical Analysis

Data were evaluated using R statistical software (version 4.3.1). Descriptive metrics are reported as Mean±Standard Deviation (SD). Group variance was evaluated using one-way ANOVA. Where primary effects achieved significance ($p<.05$), pairwise mean comparisons were executed using Tukey's Honest Significant Difference (HSD) post-hoc test.

RESULTS

Pulp Defibrillation and Bleaching Optimization

Initial soaking for 24 h resulted in partial swelling but proved insufficient for complete defibrillation. Subsequent high-shear mechanical agitation disintegrated paper sheets into discrete fiber bundles.

Comparative bleaching trials demonstrated distinct behavior between oxidizing agents:

a) **H_2O_2 Bleaching:** Yielded progressive color removal without inducing severe fiber degradation, maintaining stable yield metrics **(Figure 4)**.

b) **NaClO Bleaching:** Highly dependent on pH control. Optimal bleaching efficiency occurred between pH 9.0 and 11.0. Deviations below pH 9.0 accelerated cellulose degradation via unbuffered hypochlorous acid hydrolysis (Figure 5).

Figure 4
Pulp Discoloration Stages During H2 O2 Chemical Bleaching
(Stages: Initial raw pulp, 20 min, 1 h, and 2 h reaction times).

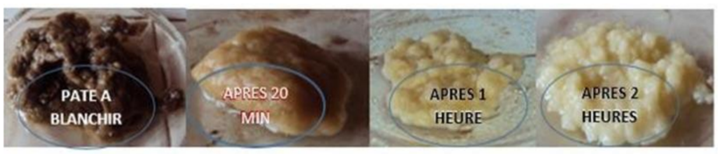
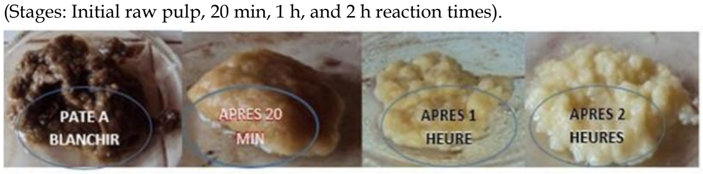


Figure 5
Pulp Discoloration Stages During NaClO Chemical Bleaching
(Stages: Initial raw pulp, 20 min, 1 h, and 2 h reaction times).



Purification Yield and Physical Properties

Mass balance evaluation across both chemical bleaching methods demonstrated an average purification mass loss of 75±1.2% **(Table 3)**.

Table 3:
Mass Balance and Purification Yields for Bleaching Treatments

Processing Parameter	Unit	H2 O2 Treatment	NaClO Treatment
Initial Raw Paper Mass	kg	2.00	2.00
Final Recovered Dry Pulp Mass	kg	0.50	0.50
Cumulative Mass Loss Rate	%	75.0±1.2	75.0±1.2

Note: One-way ANOVA revealed no significant difference in solid yield between the two bleaching reagents ($F(1,4)=0.03$, $p=.87$).

Mechanical Performance

Mechanical characterization revealed significant performance differences across formulations **(Table 4)**.

Table 4:
Impact Energy and Resilience of Molded Composite Trays (Charpy Test)

Formulation Code	Primary Additive	Mean Absorbed Energy (J)	Resilience (Kcu , kJ/m²)	Standard Deviation (kJ/m²)
F0	Control (No additive)	6.30	140.11	8.31
F1	Expanded Polystyrene Binder	6.74	157.47	8.54
F2	Wood Sawdust Filler	8.22	188.18	8.16

Wood sawdust reinforcement (F_2) provided the highest impact resilience (188.18 ± 8.16 kJ/m^2), significantly outperforming both the polymer binder formulation F_1 (157.47 ± 8.54 kJ/m^2) and the control F_0 (140.11 ± 8.31 kJ/m^2).

Statistical evaluation confirmed primary formulation effects ($F(2,27) = 45.6$, $p<.001$). Tukey HSD post-hoc tests established significant differences between all treatment pairs ($F_2 > F_1 > F_0$; $p<.05$). Pearson correlation analysis demonstrated a strong positive linear relationship between fiber volume fraction and impact resilience ($r=.91$). Linear regression modeling yielded Equation 2:

$$\text{Resilience (kJ/m}^2) = 0.95 \times \text{Fiber Content (\%)} + 120 \quad (R^2 = .83) \quad (2)$$

Thermal and Hygroscopic Behavior

Equilibrium moisture content dynamics under controlled oven exposure (60◦ C–100◦ C) over 72 h are detailed in **Table 5**.

Table 5:
Moisture Content Retention (%) Under Thermal Conditioning

Temperature (°C)	Exposure Duration (h)	Control F_0 (%)	Polystyrene Binder F_1 (%)	Wood Sawdust F_2 (%)
60	24	8	9	9
60	72	6	6	11
80	24	7	7	8
80	72	5	5	5
100	24	8	9	9
100	72	6	6	11

Note: Statistical comparison confirmed that the polystyrene binder (F_1) significantly reduced equilibrium moisture retention under extended thermal conditioning relative to sawdust reinforcement (F_2) ($p<.01$).

Production Yield Projections

Based on the empirical solid pulp yield of 25% post-purification, mass balance scaling yields the operational material requirements in **Table 6**.

Table 6:
Material Balance and Industrial Output Projection

Operational Input / Output Variable	Measured / Calculated Value	Unit
Raw Waste Paper Feedstock Input	10,000	kg
Processed Purified Dry Pulp Yield (25%)	2,500	kg
Finished Molded Unit Tray Target Mass	100	g
Projected Finished Tray Output Volume	25,000	Units

DISCUSSION

Technological Optimization and Yield Characteristics

This study establishes the technical feasibility of transforming post-consumer paper waste into functional packaging adapted to Kinshasa's poultry supply chain. Given Kinshasa's municipal waste generation rates (≈ 9,000 metric tons/day; RASKIN, 2020), localized recycling solutions offer a practical pathway toward urban circular economy models (Djemaci, 2012).

The observed mass loss during pulp purification (75 ± 1.2%) exceeds standard industrial deinking losses (40%–60%). This higher loss rate is attributable to the un-segregated nature of municipal paper waste in Kinshasa, which contains elevated fractions of non-cellulosic fillers, inorganic coatings, and short degraded fibers. These metrics underscore the importance of implementing basic source-separation programs at the municipal level to enhance process yields.

Mechanical Performance and Microstructural Behavior

The measured impact resilience values (140.11–188.18 kJ/m^2) align with reported ranges for molded lignocellulosic fiber composites (Zhang et al., 2022). Sawdust incorporation (F_2) provided superior toughness due to interlocking particulate fillers that promote mechanical energy dissipation through micro-crack deflection and localized delamination (Kumar et al., 2022). Conversely, while expanded polystyrene dissolution (F_1) improved fiber coating cohesion, it yielded lower impact strength than wood sawdust. However, F_1 provided superior moisture resistance and thermal stability. Hydrophobic polystyrene matrices seal interfacial void networks, preventing water vapor uptake under high ambient humidity.

Socioeconomic and Environmental Implications

Transitioning local poultry egg packaging from single-use synthetic plastics to bio-based molded fiber trays directly supports environmental compliance with national environmental regulations (Law No. 11/009, Article 57). Expanding local pulp molding capacity converts solid waste streams into commercial value, creating secondary economic activity for waste collectors, processors, and agricultural enterprises (Kang et al., 2023; Masamuna et al., 2026; Yawili et al., 2025).

CONCLUSION

This study established the technical feasibility of transforming un-sorted urban paper waste into functional, biodegradable quail egg trays under low-technology processing conditions, directly addressing the dual challenges of municipal waste accumulation and sustainable packaging shortages in Kinshasa. By evaluating locally available additives, the findings demonstrate that incorporating wood sawdust (F_2) significantly enhances mechanical toughness, achieving the highest impact resistance (188.18 ± 8.16 kJ/m^2) through a dense lignocellulosic network capable of withstanding physical handling. Conversely, reinforcing the pulp matrix with dissolved expanded polystyrene binder (F_1) provides superior moisture resistance and dimensional stability under thermal conditioning, rendering it effective for humid storage environments. Although the chemical bleaching and purification stages resulted in a notable dry pulp recovery rate of 25% due to high initial contamination levels in the raw waste stream, the overall process validates a low-cost, scalable pathway for waste valorization. Ultimately, this work demonstrates that recycled cellulosic composites can successfully replace plastic packaging in the local poultry supply chain, advancing circular economy practices and sustainable urban waste management in African megacities.

Study Limitations

a. **Purification Losses:** High process mass losses (75%) require substantial feedstock volumes for continuous production.

b. **Testing Scope:** Performance evaluations were restricted to static laboratory configurations; dynamic field distribution testing was not conducted.

c. **Additive Scope:** Only two additives (Isomo and wood sawdust) were evaluated; alternative bio-fillers warrant further research.

Recommendations

1. **Source Separation:** Municipal authorities should establish targeted paper collection networks to reduce pulp contamination and improve purification yields.

2. **Process Dewatering:** Thermal drying configurations should incorporate passive solar thermal collectors to lower electricity requirements.

3. **Natural Binder Research:** Future research should evaluate natural bio-resins and plant extracts to replace gasoline-dissolved polystyrene with non-toxic, fully biodegradable waterproofing agents.

Acknowledgments: The authors express their gratitude to the technical staff of the Polytechnic Faculty at the University of Kinshasa for manufacturing support, to Professor Mbuyi Katshiatshia Mukole for analytical consultation, and to academic colleagues within the Faculty of Science and Technology for research assistance.

Use of Artificial Intelligence (AI) Declaration: ChatGPT was used solely to assist with language editing, grammatical correction, and improvement of the manuscript's clarity and presentation. The study design, data collection, data analysis, interpretation of results, and scientific conclusions were conducted by the authors, who take full responsibility for the content of the article.

Authors' Contributions:
Mungangila Ayila Gracia, Nyembo Nkoso Bénédicte, Mesongolo Lialia Credo, Ndaywel Nsenge Olivier, Nsiala Oyangala Gurvitch, and Biey Makaly Emmanuel contributed to the conception, methodology, experimental work, data analysis, interpretation of results, and preparation and revision of the manuscript. All authors reviewed and approved the final version of the manuscript.

Data Availability Statement: The data generated and analyzed during this study are available from the corresponding author upon reasonable request.

Ethical Approval: Ethical approval was not required for this study, as it involved only the experimental processing and laboratory testing of non-biological, post-consumer waste materials and did not involve human participants, animal subjects, or sensitive personal data.

Funding: The authors declare that no financial support was received for the research, authorship, or publication of this article.

Conflicts of Interest: The authors declare that they have no conflicts of interest.

ORCID iDs:

Mungangila, A. G.:	Nil identified.
Nyembo, N. B.:	Nil identified.
Mesongolo, L. C.:	Nil identified.
Ndaywel, N. O.:	Nil identified.
Nsiala, O. G.:	Nil identified.
Biey, M. E.:	Nil identified.

REFERENCES

Djemaci, A. (2012). *Gestion des déchets et développement durable en milieu urbain*. L'Harmattan.

European Committee for Standardization. (2020). *Testing hardened concrete — Part 3: Compressive strength of test specimens* (EN Standard No. 12390-3:2020).

International Organization for Standardization. (2016). *Solid biofuels — Determination of moisture content — Oven dry method — Part 1: Total moisture — Reference method* (ISO Standard No. 18134-1:2016).

International Organization for Standardization. (2023). *Pulps — Laboratory wet disintegration* (ISO Standard No. 5263:2023).

Kang, Y. O., Yabar, H., Mizunoya, T., & Higano, Y. (2023). Environmental and economic performances of municipal solid waste management strategies based on LCA method: A case study of Kinshasa. *Heliyon*, *9*(3), Article e14372. https://doi.org/10.1016/j.heliyon.2023.e14372

Kumar, R., Singh, A., & Patel, S. (2022). Biodegradable composites reinforced with natural fibers: Mechanical performance and environmental implications. *Materials Today Sustainability*, *18*, Article 100123. https://doi.org/10.1016/j.mtsust.2022.100123

Macqueron, J. (2009). *Recyclage des fibres cellulosiques et valorisation industrielle*. Presses Universitaires de Lyon.

Masamuna, P. K., Vuni, A. S., Mwen, A. M. N., Iyolo, F. H., Bifubiambote, G. S., & Nzo, G. A. N. M. (2026). Déchets solides ménagers à Kinshasa: Opportunités et menaces pour l'environnement et la population. *Journal Africain des Sciences*, *1*(2), 137–146.

Nguyen, T. H., Pham, L. T., & Vo, D. T. (2023). Waste composition and recycling potential in urban megacities: Lessons for sustainable management. *Resources, Conservation and Recycling*, *189*, Article 106694. https://doi.org/10.1016/j.resconrec.2023.106694

Régie d'Assainissement de Kinshasa. (2020). *Rapport annuel sur la gestion des déchets solides à Kinshasa*. RASKIN.

Rogaume, T. (2006). *Évolution de la production mondiale de déchets et ses impacts*. Éditions Techniques.

Yawili, J. K., Bandi, M. M., Boliale, P.-C. B., & Nyami, B. L. (2025). Caractérisation des déchets ménagers solides à Kinshasa: Analyse et perspectives. *Revue Africaine d'Environnement et d'Agriculture*, *8*(2), 124–133. https://doi.org/10.4314/rafea.v8i2.11

Zhang, X., Li, Y., & Chen, W. (2022). Advances in molded fiber packaging and biodegradable composites: A review. *Journal of Cleaner Production*, *356*, Article 131927. https://doi.org/10.1016/j.jclepro.2022.131927