Usability-Focused and Eco-Design for the Development of an Interior Partition Panel Made from Recycled Polylaminate.

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ABSTRACT

The development of remote work and home office arrangements has increased the need to adapt interior spaces for work activities. At the same time, post-consumer multilayer packaging presents recycling challenges due to its material composition. This study aimed to develop a preliminary interior partition panel using recycled Tetra Pak packaging, applying ecodesign principles and a circular economy approach. The proposal consisted of a composite structure with two outer layers of recycled cardboard and a core made of stucco mixed with shredded post-consumer Tetra Pak. Five experimental formulations were prepared, each containing 90 g of stucco and different amounts of shredded Tetra Pak: 0, 5, 10, 15, and 20 g. The mixtures were observed during preparation and evaluated preliminarily according to their workability, cohesion, integrity, and behavior during demolding. The observations showed that increasing the amount of recycled packaging made the mixtures more fibrous and voluminous and increased their water requirements. The formulation containing 90 g of stucco and 5 g of Tetra Pak showed the most favorable relative performance during demolding, retaining greater integrity than the other formulations. However, this sample still exhibited flexibility and fragility. The formulation without Tetra Pak fractured during demolding, while the mixtures with higher packaging contents showed reduced apparent cohesion. In addition, some of the samples retained moisture during evaluation, limiting direct comparisons between formulations. These findings indicate that shredded Tetra Pak can be incorporated into a stucco matrix, but the proportions of the materials and the amount of water require further optimization. The formulation containing 5 g of Tetra Pak is therefore considered a starting point for subsequent experimentation rather than a definitive material solution.

Further controlled tests are necessary to evaluate the panel's properties before determining its suitability for interior partition applications.

Keywords: Ecodesign, circular economy, Tetra Pak waste, interior partition panel, recycled materials.

INTRODUCTION

The development of remote work and home office arrangements has increased the need to adapt interior spaces to accommodate work activities. The organization of these spaces has become an important consideration in interior design, as physical conditions and ergonomics can influence users' well-being and experience. Vizioli Libório et al. (2023) address the relationship between neuroarchitecture and design in home office environments, providing a background for considering the adaptation of spaces to work-related needs. In this context, interior partition panels represent a possible design solution for organizing areas within a room without requiring major structural changes.

At the same time, the use and disposal of materials have become relevant considerations in product development. Multilayer packaging, such as Tetra Pak containers, combines different materials in a single structure, which can make its recovery and recycling more challenging. Segundo-Galeana (2022) examines the disposal and treatment alternatives for multilayer packaging, highlighting the relevance of exploring different approaches to managing

this type of waste. In Mexico, 43,676 tonnes of post-consumer Tetra Pak packaging were recycled in 2020, slightly more than 30% of the annual total (Tetra Pak, 2020). Therefore, incorporating post-consumer packaging into new material proposals offers an opportunity to investigate alternative uses for resources that would otherwise be discarded.

Ecodesign and the circular economy provide a framework for exploring these possibilities. Hermida Balboa and Domínguez Somonte (2014) describe the relationship between circular economy principles and ecodesign, emphasizing their relevance to product development. From this perspective, the design process can consider the use of recovered materials and their incorporation into new applications. However, the feasibility of a material proposal must also be examined through experimentation, since its behavior depends on the materials used, their proportions, and the conditions under which the prototype is prepared.

Previous studies show that waste Tetra Pak can be used in building materials, either hot-pressed into boards for non-structural uses (Bekhta et al., 2016; Macías Gallego et al., 2020) or as fibrous filler in gypsum-based composites (Balti et al., 2024; Foti et al., 2019). However, sandwich panels with recycled cardboard faces and a stucco core, prepared with accessible techniques and without specialized machinery, have received little attention, and the water demand and moisture behavior of these mixtures remain unresolved.

The aim of this study was to develop a preliminary interior partition panel using post-consumer Tetra Pak packaging under ecodesign principles. The specific objectives were: (1) to propose a sandwich-type panel with two outer layers of recycled cardboard and a core of stucco mixed with shredded Tetra Pak; (2) to prepare five formulations with 90 g of stucco and 0, 5, 10, 15, and 20 g of shredded Tetra Pak; and (3) to compare their workability, cohesion, and integrity during preparation and demolding in order to identify a starting formulation for further optimization.

This paper contributes a preliminary exploration of ecodesign and material recovery applied to an interior partition panel, together with initial observations on how the proportion of shredded Tetra Pak influences a stucco matrix. These observations are a basis for subsequent controlled testing, not a mechanical characterization of the material.

LITERATURE REVIEW

#	Autores (Año)	Objetivo	Materiales / Método	Resultados clave	Limitaciones / Brecha
1	Hermida Balboa & Domínguez Somonte (2014)	Analyse the relationship between circular economy and eco-design	ECO-3 Conceptual Model	It proposes the circular economy as a framework for eco-design	Conceptual approach, without experimentation
2	Segundo-Galeana (2022)	Describe the layout and treatment options for multilayer packaging	Literature Review	Identifies challenges in recycling Tetra Pak and opportunities for resource recovery	It does not propose specific technical solutions
3	Ayrilmis et al. (2016)	Evaluate Tetra Pak composite panels and PE waste without adhesives	Hot-pressing, MOR testing, and dimensional stability	MOR up to 15.5 MPa (40% Tetra Pak); complies with EN standards	Higher Tetra Pak content reduces resistance and stability
4	Hidalgo-Salazar et al. (varias)	Manufacturing rigid composites from aluminum and Tetra Pak LDPE	Separation and Forming	Good mechanical properties and low water absorption	Complex separation process
5	Koh-Dzul et al. (2023)	Study sandwich panels with cores	PAC and PAL cores +	Good impact performance; potential for construction	Impact-Only Assessment

		made from recycled Tetra Pak	aluminum faces; low-velocity impact		
6	Balti et al. (2024)	Reinforcing plaster with long fibers from Tetra Pak	Tetra Pak fibers in gypsum-paper mortar	+34% flexural strength, −20% density, −17% thermal conductivity	First study of its kind; further research needed
7	Ferrández et al. (2023)	Incorporating LDPE waste into gypsum composites	Partial replacement of gypsum with LDPE granules/crumbs	Reduced density and thermal conductivity; acceptable mechanical properties	Low-residue foods
8	Zaragoza-Benzal et al. (2025)	Developing gypsum composites using recycled PET from preforms	Volumetric substitution 7.5–22.5%	Resistance exceeding standards; −10% conductivity; reduced environmental impact	Focus on Prefabricated Blocks
9	Mourid et al. (2025)	Evaluate gypsum reinforced with plastic waste (GPPS)	Addition of 0–15% plastic aggregates of various sizes	Significant thermal improvements; acceptable compressive strength (EN 13279)	Slight loss of workability
10	Antwi-Afari et al. (2023)	Select the optimal partitioning system from a circular economy perspective	MCDA + LCA + circularity indicator	Partition with 95.83% recyclable material and a lower environmental impact	Specific Case Study
11	Capasso & Radogna (2025)	Design a system of circular and flexible interior partitions	Hemp panels + wooden frame; Design for Disassembly	High recyclability, modularity, and interior comfort	Conceptual Prototype
12	CEVE / Tetrabrik boards (2026)	Characterize structural panels made from uncrushed Tetrabrik	Thermal Compaction at Different Temperatures	Flexural strength up to 27 MPa; lower water absorption than particleboard/OSB	Laboratory-scale evaluation
13	Production of fiberboard with Tetra Pak (BioResources)	Manufacturing fiberboard using Tetra Pak and wood fiber	Blends of 0–100% Tetra Pak + PF adhesive	Improves physical properties; reduces mechanical properties; suitable for non-structural applications	Conventional adhesive
14	Recycled Tetra Pak insulating panels (Sustainability, 2022)	Develop insulating panels made from recycled polylaminate	Thermal Reuse Method	Low thermal conductivity (better than chipboard and PE)	Thermal characterization, primarily
15	Mechanical properties of composites from recycled Tetra Pak (Redalyc)	Evaluate the mechanical properties of Tetra Pak composites	Hot-pressing of fragments of various sizes	Tensile strength up to 37.4 MPa; suitable for nonstructural applications	Finite Element Analysis
16	Gypsum composites with paper waste (RSM)	Optimizing Plaster with Paper Waste and Surfactant	Experimental Design (RSM)	Low density and low brittleness; acceptable mechanical properties for interior insulation	Optimization on a laboratory scale
17	Eco-design gypsum with end-of-life tyres	Developing plaster with recycled rubber aggregates	Substitution of up to 30% by volume	Reduction in thermal conductivity >35%; resistance exceeds regulatory minimums	Focus on Prefabricated Panels

18	Circular gypsum composites with EPS waste	Create circular composites made from recycled gypsum and EPS	Upcycling of Construction Waste	−44% density, −27% conductivity; −56% emissions	EPS Dissolution Process
19	Partition wall blocks from secondary materials (LCA)	Design partition blocks made entirely from recycled materials	Complete replacement of cement with recycled aggregates	Up to −82% in CO_2eq emissions	The Context of Hong Kong
20	Lightweight plaster with expanded polyethylene waste	Evaluate lightweight gypsum board with EPE residue for LSF partitions	Substitution of up to 30% by volume	−43.9% thermal conductivity; improved thermal resistance of walls	Cradle-to-gate assessment

Table 1.- Summary of the reviewed studies"

Table 1 presents a systematized review of 20 relevant studies following PRISMA-oriented criteria (identification, selection, and synthesis of evidence). The articles were selected based on their direct or indirect relationship with the development of interior partition panels made from recycled multilayer packaging (Tetra Pak/polylaminate), the use of stucco or gypsum matrices, and ecodesign and circular economy approaches.

The table organizes the information into five columns: (1) authors and year, (2) the main objective of the study, (3) materials and methods used, (4) key reported results, and (5) identified limitations or research gaps. This structure makes it possible to quickly identify what has been investigated, which materials have been used, which properties have been measured, and where knowledge gaps exist that justify the proposal presented in the manuscript.

The studies range from conceptual reviews of circular economy and ecodesign (Hermida Balboa & Domínguez Somonte, 2014; Segundo-Galeana, 2022) to experiments involving Tetra Pak panels, gypsum composites reinforced with fibers or recycled plastics, and evaluations of partition systems from a life cycle perspective. The synthesis shows that incorporating multilayer packaging waste into construction materials is technically feasible, particularly in gypsum matrices or through thermocompression. However, challenges remain regarding cohesion, workability, process standardization, and long-term performance evaluation.

Tabla de Análisis de la Literatura

The following table summarizes the trends, methodological approaches, key findings, and gaps identified based on the 20 studies reviewed.

Dimension of Analysis	Tendencias observadas	Trends Observed	Gaps / Opportunities
Materials and Matrices	Predominant use of plaster/stucco and Tetra Pak thermo-compaction. Use of recycled fibers, LDPE, PET, and EPS.	Feasible incorporation of waste. Improvements in density and thermal insulation. Acceptable mechanical properties at low percentages.	There has been little experimentation with sandwich-type structures (cardboard + stucco core + Tetra Pak) such as the one proposed in the manuscript.
Manufacturing Methods	Hot-pressing, thermal compaction, manual mixing, and molding. Some processes do not require additional adhesives.	Low-tech processes are feasible. Tetra Pak's own polyethylene can act as a binder.	Failure to optimize the water-to-residue-to-matrix ratio and to control residual moisture during setting.

Properties Evaluated	Flexural/compressive strength, density, thermal conductivity, water absorption, and dimensional stability.	Reductions in density (15–44%) and thermal conductivity (10–35%). Resistance values exceeding regulatory minimums in several cases.	Few studies evaluate performance under real-world indoor conditions (ambient humidity, load cycles, surface finish).
Sustainability Approach	Eco-design, the circular economy, LCA, and Design for Disassembly are becoming increasingly common.	CO_2eq emissions reductions of up to 56–82% when replacing virgin materials. High potential for recyclability.	Limited integration of user-centered design principles with eco-design in interior partition panels.
Target Applications	Partition panels, interior insulation, non-structural panels, and precast blocks.	Confirmed suitability for non-structural interior uses and spatial organization (home office).	Limited attention to adaptability, modularity, and ease of installation/disassembly in remote work settings.
Recurring Limitations	Laboratory scaling, residue variability, loss of workability, and residual moisture.	The results are promising at the prototype scale, but they require more controlled experimental validation.	The need for standardized protocols for characterization and end-of-life studies (disassembly and material recovery).

Table 2.- Synthesis of trends, findings, and gaps

This table groups the evidence from the 20 studies into six key dimensions. It shows that the literature supports the technical feasibility of using multilayer packaging and plastic waste in gypsum/stucco matrices, particularly to improve thermal insulation and reduce environmental impact. However, it identifies a clear gap in the exploration of sandwich-type structures using recycled cardboard and in the integration of user-centered design criteria (adaptability of workspaces) with eco-design principles, which justifies the contribution of this study.

METHODOLOGY

The ecodesign methodology was used for the development of this project. Hermida Balboa and Domínguez Somonte (2014) propose that the circular economy constitutes a framework for ecodesign because both approaches seek to reduce the waste of resources and promote the reintegration of materials into new production cycles. From this perspective, design can contribute to waste reuse, material optimization, waste reduction, and the development of products with greater potential for recovery at the end of their useful life. This methodology was selected because it allows environmental criteria to be integrated into the industrial design process, considering not only the functionality and aesthetics of the product but also the impacts that may arise during material acquisition, manufacturing, use, maintenance, and final disposal.

The methodological process was divided into five main stages: diagnosis, qualitative life cycle analysis, definition of ecodesign strategies, design and prototyping, and evaluation and improvement.

Problem Diagnosis and Project Definition

In Mexico, the use of drywall as an interior construction solution has become established due to its light weight, ease of installation, and low market cost. However, this material presents significant limitations in terms of sustainability, recyclability, and adaptability to rural or low-income contexts. Conventional drywall depends on centralized processes, specialized transportation, and a supply chain that excludes communities with limited access to standardized raw materials. At the same time, the country is overwhelmed by post-consumer waste, one of the main types being Tetra Pak, which is composed of layers, primarily polyethylene, aluminum, and cardboard.

In Mexico, 43,676 tons of post-consumer Tetra Pak packaging were recycled in 2020, representing an annual recycling rate of slightly over 30% nationwide (Tetra Pak, 2020). Although this material is technically recyclable, it is difficult to treat and process under conventional conditions, making it a persistent waste in recycling facilities, landfills, and urban environments. Despite collection and recycling efforts, a large proportion of Tetra Pak packaging in the country ends up unused, representing an untapped opportunity for the development and manufacture of new functional materials based on a national environmental problem. Given this situation, there is a need to develop an agglomerated Tetra Pak panel capable of replicating the technical properties of drywall: structural rigidity, ease of cutting, low flame propagation, and light weight. This panel must be viable in both urban and rural contexts, using manufacturing methods accessible to students in a professional degree program and, above all, allowing local production without relying on specialized or expensive machinery. The aim is not to replace a standardized material such as drywall, but to dignify the use of national waste through a constructive, replicable, economical, and environmentally responsible solution. The technical challenge lies in developing an agglomeration process that allows the cellulose and layers of the Tetra Pak packaging to bond solidly without compromising mechanical strength or indoor safety. In later stages, it will be necessary to investigate thermal processes, accessible adhesives, fire-retardant additives, and pressing techniques that can be applied in community workshops or microenterprises. It will also be essential to measure the panel's performance in relation to moisture, structural load, and prolonged exposure to ensure its functionality in partition walls, ceilings, and basic furniture.

The project seeks to address a multidimensional problem: the lack of sustainable construction materials in marginalized areas, the accumulation of waste that is difficult to recycle, and the need for technical solutions that can be adopted by local communities. The creation of agglomerated Tetra Pak panels represents not only an innovation in ecodesign but also a strategy for social transformation, in which waste becomes a resource and technology becomes a tool for dignification.

Product Life Cycle Analysis

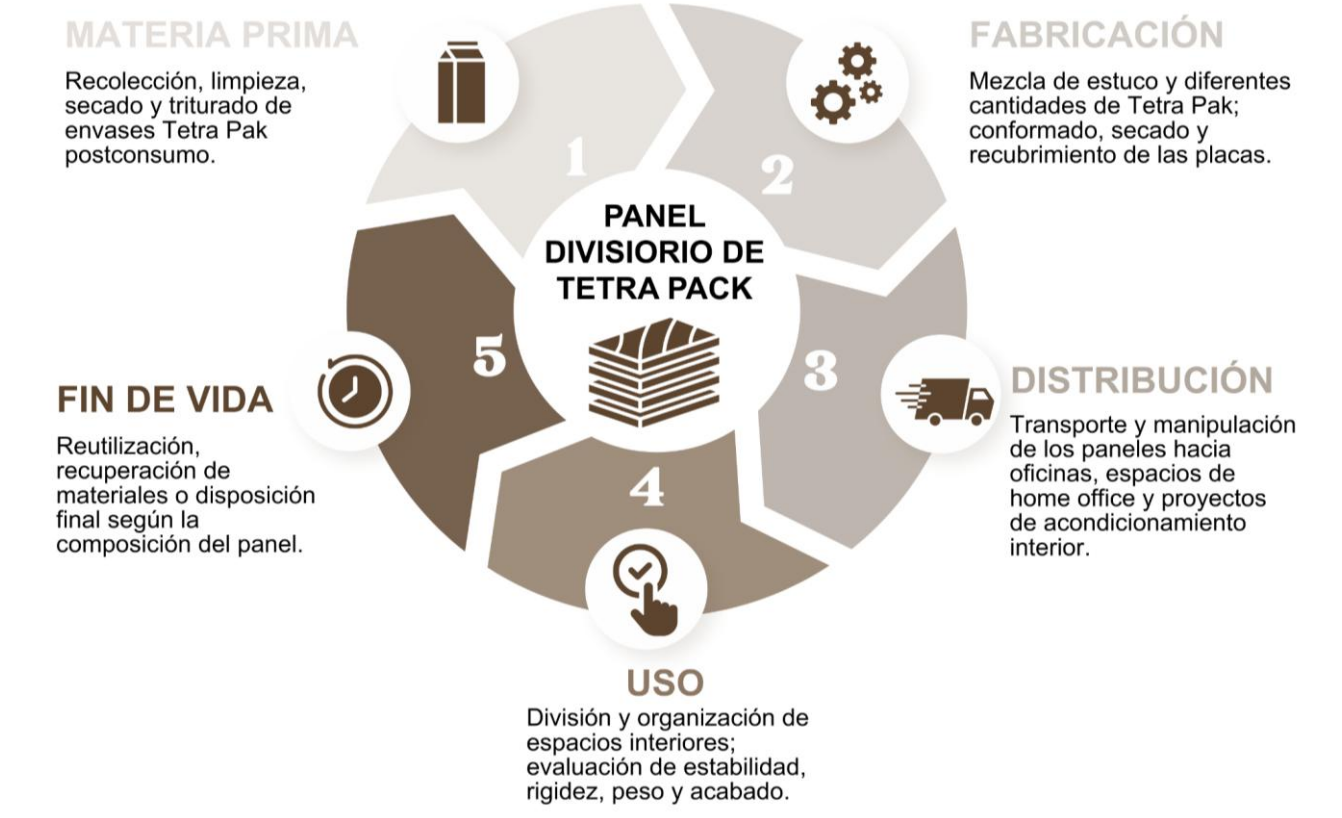


Figure 1. Schematic representation of the life cycle of the partition panel made from post-consumer Tetra Pak containers.

Note: Created by the author

Raw materials: It consists of post-consumer Tetra Pak packaging, which was collected, opened, cleaned, and dried before being incorporated into the experimental process. Subsequently, elements that were not part of the proposal, such as caps or other components, were removed, and the packaging was shredded into fragments of similar size. Stucco, water, and two layers of recycled cardboard were also used as part of the structure of the experimental panels. The amount of Tetra Pak was the main variable of the study, while the amount of stucco and the cardboard layers were kept constant across the five tests.

A stucco mixture was prepared with varying amounts of crushed Tetra Pak, using a mold measuring approximately 30×30 cm. The mixture was placed between two layers of recycled cardboard to form a sandwich-like structure. Five formulations were prepared:

P1: 90 g of stucco and 0 g of Tetra Pak.

P2: 90 g of stucco and 5 g of Tetra Pak.

P3: 90 g of stucco and 10 g of Tetra Pak.

P4: 90 g of stucco and 15 g of Tetra Pak.

P5: 90 g of stucco and 20 g of Tetra Pak.

In all tests, the size of the panels, the amount of stucco, the number of cardboard layers, the drying time, and the final coating were kept constant as much as possible. The volume of water was adjusted according to the workability of each mixture. After setting and drying, a water-based acrylic sealer and water-based paint were applied to both sides and edges of each panel.

- **Distribution:** The proposal is intended for offices, home office spaces, and other interiors that require the division and organization of work areas. At this stage, the panel's dimensions, weight, and ease of handling will be considered, as well as the conditions required for its transportation, storage, and installation.

- **Use:** The panel is proposed as an element for dividing and organizing interior spaces, especially office and home office areas. Its main function will be to create a physical or visual separation between work zones, contributing to a more adaptable spatial layout.

- **End of life:** At the end of its useful life, the possibility of dismantling the panel and recovering some of its constituent materials will be analyzed. Since the proposal combines Tetra Pak, stucco, recycled cardboard, sealant, and paint, it will be necessary to consider the difficulty of separating these components.

3. Eco-design Strategies

As the main strategy, the use of recycled material within a stucco matrix was proposed, maintaining a structure composed of two layers of recycled cardboard and a core made of stucco with different amounts of shredded Tetra Pak. To identify the most suitable proportion, five experimental formulations were developed, designated P1, P2, P3, P4, and P5.

Test P1 served as the control sample, as it did not incorporate Tetra Pak. The remaining tests progressively increased the amount of incorporated waste, while keeping the 90 g of stucco, the two layers of recycled cardboard, and the approximate dimensions of 30 × 30 cm constant (Table 3).

Test	Estuco (g)	Tetra Pak crushed(g)
P1	90	0
P2	90	5
P3	90	10

P4	90	15
P5	90	20

Table 3. Experimental formulations of stucco and crushed Tetra Pak.

Note: Prepared by the author. All formulations used 90 g of stucco and increasing amounts of crushed Tetra Pak.

The purpose of this experiment was to identify the amount of Tetra Pak that could be incorporated into the mixture without significantly compromising the rigidity, stability, and integrity of the panels. The selected formulation was subsequently determined by comparing the results obtained.

4. Design and Prototyping

The experimental panels were developed based on the formulations established in the previous phase. The process included the preparation of the Tetra Pak packaging, the preparation of the mixtures, panel forming, drying, and the application of a final coating.

As an initial reference, a panel measuring approximately 30 × 30 cm was proposed, consisting of two outer layers of recycled cardboard and a core of stucco with shredded Tetra Pak. This configuration made it possible to produce samples of controlled size and compare the behavior of the different formulations under similar conditions.

Manufacturing Process:

1. **Tetra Pak Collection and Preparation:** Post-consumer Tetra Pak packaging was collected. The packages were subsequently opened, emptied, washed, and completely dried. The caps and other elements that were not incorporated into the experimental material were removed.

2. **Material Shredding:** The prepared packages were cut and shredded into small fragments of relatively uniform size.

3. **Material Weighing:** For each formulation, 90 g of stucco and the corresponding amount of shredded Tetra Pak were weighed. Two sheets of recycled cardboard measuring approximately 30 × 30 cm were also prepared for each panel.

4. **Mold Preparation: A** mold or frame measuring approximately 30 × 30 cm was used and placed on a flat surface. A non-stick material was placed at the base to facilitate the removal of the panel once the setting process was complete.

5. **Mixture Preparation: T**he stucco was mixed with water until a homogeneous and workable consistency was obtained. The corresponding amount of shredded Tetra Pak for each formulation was then gradually incorporated and evenly distributed throughout the mixture.

6. **Panel Forming:** The first sheet of recycled cardboard was placed at the bottom of the mold. The stucco and Tetra Pak mixture was then poured and evenly distributed until an approximate thickness of 1.5 cm was reached. Finally, the second sheet of cardboard was placed over the mixture. The resulting structure consisted of:

recycled cardboard → stucco with shredded Tetra Pak → recycled cardboard.

7. **Pressure Application and Drying:** A flat board was placed over the assembly, and light, uniform pressure was applied to promote contact between the layers and keep the panel flat. The stucco was then allowed to set, and the panel was left to dry completely in a ventilated space protected from moisture.

8. **Preliminary Evaluation and Coating:** Once dry, each panel was observed and documented before applying the coating. Characteristics such as weight, thickness, cracks, deformations, detachment, and rigidity were recorded. Subsequently, a water-based acrylic sealant was applied to both faces and edges. Finally, water-based paint was used as a surface finish, aiming to maintain similar conditions across the five samples.



Figure 2. Preliminary design of the partition panel made from post-consumer Tetra Pak.

Note: Image generated using artificial intelligence to visually represent the preliminary product proposal.

Prototyping process:



Figure 3. Multilayer containers that have been recovered and cut up in preparation for shredding.



Figure 4. Tetra Pak material after the shredding process, showing visible fibers and multilayer fragments.



Figure 5. Manual preparation of a stucco mixture using crushed Tetra Pak cartons.



Figure 6. Visual comparison of the five formulations (P1–P5) after they were placed in the molds.

5. Evaluation and Improvement

Sample P1 was used as a reference and did not incorporate Tetra Pak. Starting with P2, the amount of waste was increased by 5 g per sample. The initial amount of water was 25 mL; however, as the amount of Tetra Pak increased, more water had to be added to achieve a consistency that could be distributed inside the mold. In P5, the final amount of water could not be determined precisely, so the estimated range observed during preparation was retained (Table 4).

The five samples were placed together for natural drying in the same location and under similar environmental conditions. Subsequently, demolding was carried out to observe the integrity of each panel. At the time of evaluation, some formulations with higher Tetra Pak content still retained moisture; therefore, the observations describe the actual behavior observed during demolding and should not be interpreted as a definitive mechanical characterization.

RESULTS AND DISCUSSION

Behavior During Mixing

The comparison of the formulations revealed a clear trend: as the amount of Tetra Pak increased, the mixture became more fibrous, voluminous, and difficult to work with using the initial amount of water (Table 4). P1 formed an almost continuous stucco surface. In P2, fibers and small particles appeared, although the stucco matrix remained predominant. In P3 and P4, the heterogeneous texture increased noticeably. In P5, with 20 g of Tetra Pak, the waste occupied a significant portion of the visible volume, and the presence of stucco between the particles was considerably lower.

Sample	Stucco	Tetra Pak	Water used	Observation During Mixing
P1	90 g	0 g	25 mL	A uniform, fluid mixture that is easy to spread.
P2	90 g	5 g	25 mL	More pasty and fibrous; the stucco still dominated the visual appearance.
P3	90 g	10 g	50 mL	Higher fiber content and irregular texture; required more water
P4	90 g	15 g	75 mL	A heterogeneous mixture with a high visible presence of Tetra Pak.
P5	90 g	20 g	62-87 mL*	The Tetra Pak dominated the visual appearance and reduced the apparent continuity of the stucco.

Table 4. Composition of the formulations and behavior observed during the preparation of the mixture.

Note: Prepared by the author. For P5, it was not possible to determine the final amount of water used with precision; therefore, an estimated range of 62 to 87 mL is presented.

The increase in the amount of water required to maintain workability was also a relevant result. While P1 and P2 could be prepared with 25 mL, P3 required 50 mL and P4 required 75 mL; for P5, the estimated range (62–87 mL) includes values close to those of P4. This showed that incorporating the fibrous material significantly altered the behavior of the mixture.

Demolding Results

P1 - Stucco only. The sample cracked almost completely when attempting to remove it from the plate/mold. The material was highly brittle, and it was not possible to preserve the piece intact.

P2 - 5 g of Tetra Pak. This was the sample that could be removed with the greatest integrity, coming out almost completely intact. However, it exhibited considerable flexibility and remained brittle.

P3 - 10 g of Tetra Pak. The sample was still moist during evaluation. It broke easily, and it was observed that the Tetra Pak was not completely enveloped by the stucco matrix.

P4 - 15 g of Tetra Pak. It had a grainy appearance and was still moist. Little bonding was observed between the components, so a consolidated slab was not obtained.

P5 - 20 g of Tetra Pak. The sample behaved similarly to P4. Cohesion was insufficient, and during demolding, the material came away in fragments.

Table 5 summarizes the comparison of the formulations during demolding.

Table 5: Comparison of the behavior of the formulations during demolding.

Test	Integridad al desmoldeo	Observed status	Apparent Cohesion	Results
P1	Very low	cracked	Low	Broke when removed
P2	Higher than the others	Almost flexible complete	Higher, but insufficient	Better relative performance
P3	Low	Moist and brittle	Low	Breaks apart, tetra pak not well wrapped
P4	Low	Moist and grainy	Very Low	Did not set properly
P5	Very low	Fragmented	very low	Came apart in pieces

Note: Prepared by the author. This evaluation is based on preliminary observations of apparent integrity and cohesion and does not constitute a mechanical characterization of the material.

Of the five formulations, P2 exhibited the most favorable relative behavior during demolding. It was the only sample made with Tetra Pak that could be removed almost entirely and retained greater cohesion than P3, P4, and P5. However, its flexibility and brittleness indicate that the formulation still requires optimization before it can be considered suitable for a partition panel.

The tests also showed that increasing the amount of Tetra Pak while keeping the 90 g of stucco constant did not result in a progressive improvement. Starting with P3, a reduced apparent ability of the matrix to envelop and bind the recycled material was observed. In P4 and P5, the residue occupied a considerable volume, and the mixture showed little continuity.

P1 demonstrated that unreinforced stucco alone did not solve the problem either, as it cracked during demolding. In contrast, the small amount of Tetra Pak added in P2 resulted in a piece with greater structural integrity, although it was still too flexible and brittle.

Since P3, P4, and P5 retained moisture at the time of evaluation, their poor performance cannot be attributed exclusively to the amount of Tetra Pak. Residual moisture may have influenced the observed behavior. Therefore, the results are considered an initial experimental approximation and not a definitive mechanical characterization.

The results partially agree with the reviewed literature. The incorporation of Tetra Pak fibers into gypsum matrices has been associated with improvements in flexural strength (Balti et al., 2024), although with long fibers rather than shredded fragments such as those used in this study, which is consistent with the greater integrity of P2 compared to the unreinforced control. Likewise, in Tetra Pak panels, a higher material content

reduces strength (Ayrilmis et al., 2016), a trend similar to the loss of cohesion observed in P3, P4, and P5. The greater water requirement is consistent with the loss of workability described when incorporating plastic aggregates into gypsum (Mourid et al., 2025) and may be related to the cellulose fraction of the packaging, which absorbs more water when the material is shredded (Macías Gallego et al., 2020). This relationship between fiber, water, and residual moisture reinforces the conclusion that the performance of P3 to P5 cannot be attributed solely to the amount of Tetra Pak.

It is worth noting that the control without Tetra Pak (P1) fractured and that increasing the amount of waste did not produce progressive improvements, but rather a relative maximum at 5 g. This suggests that the proportion between fiber, matrix, and water, rather than the amount of waste, is the critical variable. In practical terms, the manual procedure made it possible to produce the panels without specialized machinery, in line with the objective of accessible manufacturing, although they still lack sufficient properties for a partition panel. The literature review identifies as research gaps the limited experimentation with sandwich-type structures (cardboard, stucco core, and Tetra Pak) and the lack of optimization of the water/waste/matrix ratio; this study provides initial observations on both aspects, limited to one sample per formulation.

P2 was selected as the most promising starting point in this first experimental series, not because it achieved the required final properties, but because it presented the best relative combination of integrity and cohesion during demolding. The next stage should focus on optimizing the relationship between Tetra Pak and the stucco matrix, rather than continuing to increase only the amount of waste. One possibility for a new formulation is to maintain a moderate amount of Tetra Pak and increase the proportion of stucco to achieve better fiber encapsulation and greater rigidity. This formulation must be evaluated again before defining the panel's final material composition.

CONCLUSION

This preliminary study showed that shredded post-consumer Tetra Pak can be incorporated into a stucco core enclosed between two layers of recycled cardboard using accessible manual techniques. However, the amount of Tetra Pak strongly influenced the workability and cohesion of the mixture: increasing the proportion of waste did not improve the panels, and the formulations with higher contents showed lower apparent cohesion and required more water. The formulation with 90 g of stucco and 5 g of Tetra Pak (P2) showed the most favorable relative behavior at demolding, although it remained flexible and fragile and cannot be considered a definitive formulation for an interior partition panel.

From a practical perspective, the results offer a low-technology starting point for ecodesign-oriented panels that make use of a post-consumer waste that is difficult to recycle. From a conceptual perspective, they suggest that the proportion among the fibrous residue, the stucco matrix, and the water, rather than the quantity of waste alone, is the key design variable.

The study has limitations. It relied on direct observation of a single specimen per formulation, some samples (P3, P4, and P5) still retained moisture at evaluation, the water used in P5 could only be estimated, and no mechanical tests were performed. Therefore, the findings should be considered a first experimental approximation. Future research should improve the relationship among stucco, Tetra Pak, and water, replicate the formulations under controlled drying conditions, and evaluate stiffness, strength, moisture behavior, and overall performance before determining the suitability of the panel for interior partition applications.

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