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Obtaining particulate agglomerates from the recycling of multilayer containers and PET/Al/PE

Obtención de aglomerados particulados a partir del reciclaje de envases multicapa y PET/Al/PE

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Abstract

Sustainability makes the final use of waste reconsider, if it is possible to give it a new use and thus contribute to the planet. Therefore, in this work the physical and mechanical properties of particulate agglomerates from the recycling of multilayer containers (EM) and powdered milk (EL) are evaluated, the w/w ratio was varied. Agglomerates with a homogeneous matrix are obtained, hard to the touch, light, they can be cut, drilled, they are fireproof, they all have a prolonged elastic zone, when subjected to a load they do not show rupture, they support loads of 12 MPa. As the amount of EL increases, the density of the agglomerate increases and the apparent density decreases due to the compressibility of the materials, which contributes to reducing the degree of hygroscopicity. There is no relationship between the density and the properties of the agglomerates. The material that complies with the NMX-C-013-1978, ASTM D 1037-12 and NMX-C-036-ONNCCE-2013 standards, is the one with a p/p ratio of 70:30 (A6), it can be used in construction as a false wall; both outdoors and indoors. The other agglomerates could be used as catalytic supports for the degradation of dyes; because they show dimensional stability when in prolonged contact with water.

Sustainability, Particulate agglomerates, Catalytic supports

Resumen

La sostenibilidad hace que se replante el uso final de los residuos, si es posible darles un nuevo uso y así contribuir con el planeta. Por eso, en este trabajo se evalúan las propiedades físicas y mecánicas de aglomerados particulados a partir del reciclaje de envases multicapa (EM) y de leche en polvo (EL), se usaron diferentes proporciones p/p. Se obtienen aglomerados con matriz homogénea, duro al tacto, ligeros, se pueden cortar, taladrar, son ignífugos, todos poseen una zona elástica prolongada, al ser sometidos a una carga no muestran ruptura, soportan cargas de 12 MPa. Al aumentar la cantidad de EL aumenta la densidad del aglomerado y disminuye la densidad aparente debido aumenta la compresibilidad de los materiales lo que contribuye a disminuir el grado de higroscopicidad. No existe una relación entre la densidad y las propiedades de los aglomerados. El material que cumple con las normas NMX-C- 013-1978, ASTM D 1037-12 y NMX-C-036-ONNCCE-2013, es el de la relación p/p es 70:30 (A_6), puede ser usado en la construcción de muro falso; tanto en el exterior e interiores. Los demás aglomerados podrían ser usados como soportes catalíticos para la degradación de colorantes; debido a que muestran una estabilidad dimensional al estar en contacto prolongado con el agua.

Sustentabilidad, Aglomerados partículas, Soportes catalíticos

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Introduction

Poor disposal of urban solid waste (RSU), due to the fact that collection and disposal are not carried out efficiently; brings environmental and health risks to the city (Tchobanoglous, H., & VIgil, 1996), (Lechuga M. & Vargas H., 2016). That is why the initiative to do something with these types of waste arises, such as recycling (Raza C. & Acosta, 2022).

Being an initiative in academic and administrative areas, waste collection, recycling 77,447 kg of recoverable waste: 7,099 kg of PET containers, 12,829 kg of multilayer containers, 171 kg of aluminum cans, 10,487 kg of glass, 26,361 kg of paper and 20,500 kg of cardboard (Espinosa, y otros, 2013).

The waste is used in 32% of the total waste generated in high volume and 67.2% is sent to final disposal sites; that is 1,177.61 kg/day and 429.83 tons/year are recovered from PET, multilayer containers 591.80 kg/day and 216.01 tons per year, aluminum 290.58 kg/day, 106.06 tons/year, magazines and cardboard 4987.45 kg/day and 1820.42 tons /year (AICM, 2010).

Unfortunately, solid waste, such as multilayer packaging, is not fully used; In the world, more than 89,000 million cartons are produced for Tetra Pak beverages and it reports that they distribute 140 million liters of packaged beverages worldwide (UAM, 2009).

As of 2003, it is estimated that, in Mexico, every year 150 million portions of milk packaged in aseptic tetra brik are distributed to children, almost 3 million Tetra pak packages are consumed per day (Leander , 2003).

Local governments and businessmen have promoted the use of post-consumer packaging for the manufacture of panels, which can be used in the manufacture of furniture and construction of houses, for environmental protection (Chung, 2003).

Therefore, studies are beginning to be carried out on the use of these panels obtained by recycling wood or other materials, which can be reinforced, in order to replace wood as raw material (Center, 2018).

The company Primadera in Colombia uses urban wood or wood from recycling as raw material, contributes to caring for the environment and generates a positive social impact (Primadera, 2016).

In 2017 the physical-mechanical properties were determined and evaluated with the German standards German Institute for Standardization (DIN) and Venezuelan Vensolanza Commission of Industrial Standards (CONEVID) the manufacture of chipboard using Eucalyptus urophylla wood, complied with the MOR and adhesion properties, but the percentage of moisture absorption and thickness variation in some cases did not comply with the maximum values accepted by the standards, so they can be used in internal parts of furniture and cabinets, decorative material superimposed on other materials (Rangel L. , Moreno, Trejo, & Valero, 2017).

In 2019, they used ebony wood sawdust and adhesive (obtained from the shavings of a dye in leather tanning) in different proportions, they obtained a very resistant agglomerate for construction and represents an eco-friendly solution for the final disposal of the shavings (Valdez U., González G., Pariguana B., Lopez Guerra, & Dueñas, 2019).

In 2021, agglomerates were made with multilayer containers, they are reinforced with PEBD in different proportions, p/p, the physical-mechanical properties were evaluated, the materials obtained present a homogeneous matrix, they can be used in closed or open places for the construction of walls, are light, easy to machine, absorb 14.2% when submerged in water (Enríquez, Rosales, & Castrejón , 2021).

Also, the mechanical properties of agglomerates of multilayer containers reinforced with low-density polyethylene (PEBD) and polyethylene terephthalate (PET) post-consumer (ratio w/p 90:10) have been evaluated, the compaction and integration between the materials were improved and the density, decreases water absorption and volumetric variation; therefore, they are ecological agglomerates, do not generate waste and contribute to reducing RSU (Enríquez & Rosales, 2021).

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In this work, two types of RSU are being combined, powdered milk containers (polyester/aluminium/polyethylene PET / Al/PE)) and multilayer containers (cardboard, polyethylene and aluminum), controlling physical variables such as: temperature , pressure and time in the thermoforming process, for the elaboration of agglomerates of dimensions 24*12*2 cm, in addition the resistance to compression is analyzed, for its possible use in the construction of interior and exterior walls in homes, ceilings or false walls in residential houses or as catalytic supports for the degradation of pollutants. Contributing to reduce RSU, environmental risks and ecological aspects.

Methodology

For the elaboration of particulate agglomerates, multilayer containers (EM) and powdered milk containers (EL) were collected, washed and dried at room temperature.

The raw material is crushed with a mill, until a particle size of 5 mm EM and 1 cm EL; subsequently, the raw material is weighed. Table 1 shows the proportions w/w that were experimented to obtain the agglomerates.

Agglomerate	% EM	% EL
A_1	95	5
A_2	90	10
A_3	85	15
A_4	80	20
A_5	75	25
A_6	70	30

Table 1 Variation p/p between EM and EL
Source: Own Elaboration

The raw material is placed inside a mold with dimensions of 24*12*2 cm, which functions as a hot plate for thermoforming, manipulated by a control system. In thermoforming, agglomerates are obtained under the following operating conditions: heating time 60 min, pressure 4 tons of axial compression at 180°C; then the agglomerate is cooled to room temperature and removed. The described procedure has already been previously reported (Enríquez Pérez, Rosales Davalos, López Ramirez, & Castrejon Sanchez, 2017).

The physical-mechanical properties were carried out using the Standard NMX-C-013-1978 Plasterboard for dividing walls, ceilings and fire protection, ASTM D 1037-12 Standard Test Methods for Evaluating Properties of Wood-Base Fiber and Particle Panel Materials and Standard NMX-C-036-ONNCCE-2013 establishes the test method for the determination of the resistance to compression, applicable to blocks, partitions or bricks, partitions, lattices and paving stones of national manufacture and of import, that are marketed in national territory.

Analysis of results

The agglomerates are light materials, with a homogeneous matrix, hard to the touch, compact, with an average weight of 0.5 kg, figure 1 shows the physical appearance of the material.

The appearance of the material depends on the material used in the matrix and reinforcement, so that they can be integrated into a homogeneous matrix (Enríquez Pérez, Rosales Davalos, López Ramirez, & Castrejon Sanchez, 2017); the reinforcement used allows a good integration of the material regardless of the proportions.

Figure 1 Appearance of the agglomerates
Source: Own Elaboration

Table 2 shows the density of the materials obtained, when reinforcing them there is an increase in weight.

Agglomerate	Density Kg/m^3
A_1	620.9
A_2	775.9
A_3	756.1
A_4	873.2
A_5	905.8
A_6	915.1

Table 2 Density of the agglomerates.
Source: Own Elaboration

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In figure 2, the density vs relative humidity is plotted; as the density increases, the humidity decreases, the higher the weight there is a better compressibility between the material and the reinforcement, which contributes to reducing the degree of hygroscopicity (Zambrano, y otros, 2013).

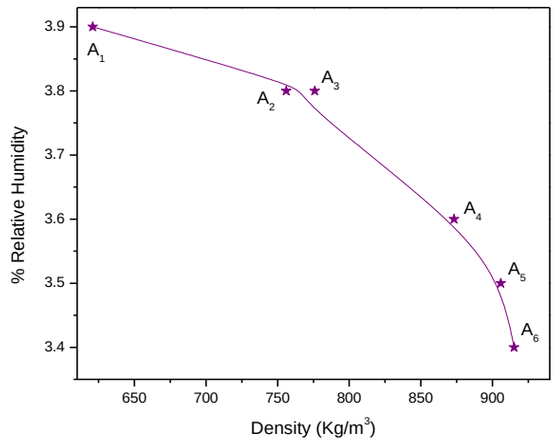

Figure 2. Percent Relative Humidity
Source: Own Elaboration

The water absorption is determined, when the material is submerged in water, for a period of time, in accordance with the ASTM D 1037 standard. Figure 3 shows the evolution of water absorption as a function of time (hours).

Some authors (Moreno P., y otros, 2005) (Zambrano, y otros, 2013), (Rangel, Moreno, Trejo, & Valero, 2017), assure that the increase in the density of the agglomerates produces a decrease in the absorption of water; this behavior is not presented by the materials obtained.

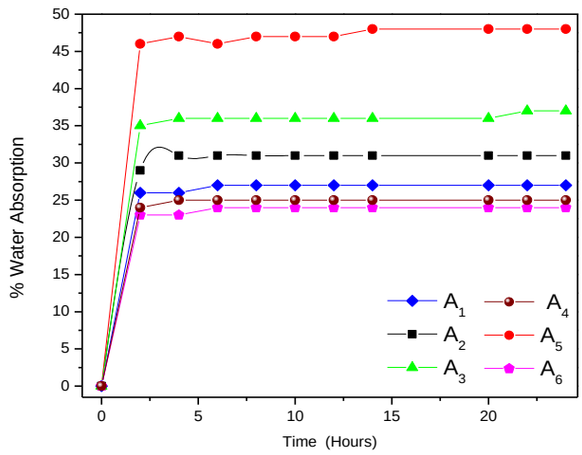

Figure 3 Percentage of water absorption.
Source: Own Elaboration

In the first two hours, the material absorbs the greatest amount of water, in a range from 23% to 46%, after that time there are no major variations in the percentage. This stability occurs when the agglomerates have little porosity and a good interaction between the particles and the reinforcement, which prevents the penetration of wáter (Rangel, Moreno, Trejo, & Valero, 2017).

Only A_4 and A_6 comply with the ASTM D 1037 standard, which indicates that the agglomerates can have an absorption between 25 and 60% between 2 and 24 hours. However, all comply at 24 H. Both A_4 and A_6 can be used outdoors, the others can be used indoors or as catalytic supports in the degradation of dyes (Enriquez P., Castrejon S., Rosales D., & Mendez R., 2019).

Figure 4 shows the variation of volume vs. time of immersion in water. The volume increase of the agglomerates ranges from 2.0 to 23.1%. When you have values lower than 30%, you do not reach a saturation of the fibers, so there is only an increase in weight, the volume remains practically constant (Volcuende, Parra, & Benlloch, 2005).

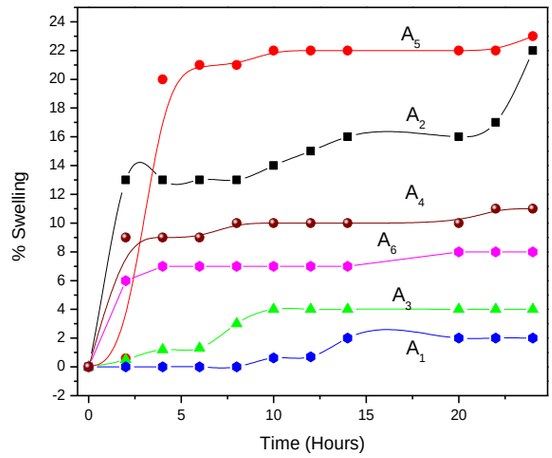

Figure 4 Swelling percentage
Source: Own Elaboration

A_5 was the material with the highest water absorption; therefore, it presents the greatest swelling. However, this tendency is not possessed by the other agglomerates, there is no correlation between swelling and density. The volume change in materials is not observed with the naked eye.

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The standard requests a variation of no more than 6% and 15% at 2 hours and 24 hours. The A_1, A_3 and A_6 comply with the standard. The material was dried in the sun, after three days under the sun's rays, they recover their initial weight, eliminating the absorbed water, without modifying their physical characteristics.

Table 3 shows the results of the compression test. All the blocks meet the required resistance according to the NMX-C-036-ONNCCE-2013 Standard, so they could be used as false walls. There is no relationship between density and strength in the material.

Aglgomerate	Force	
	Kg/m^2	MPa
A_1	122.1	11.98
A_2	122.4	12.00
A_3	122.0	11.97
A_4	122.2	11.99
A_5	122.4	12.01
A_6	122.3	11.97

Table 3 Compression test
Source: Own Elaboration

The material has good resistance to deformation, they have a prolonged elastic zone, when subjected to a load they do not show rupture, on the contrary, they have shape memory, when the load is removed after half an hour they return to their dimensions originals (see figure 5).

Figure 5 Appearance of the agglomerate after subjecting it to the compression test
Source: Own Elaboration

The agglomerates, independent of their composition, are: hydrophobic, fireproof, they do not spread heat, they only carbonize. They can be cut and tied, they support plugs, screws and nails, without presenting alterations in their structure.

Conclusions

In obtaining particulate agglomerates, the combination of EM and EL increases the cohesion of the material; by increasing the proportion of ELs, the density of the material increases and the relative humidity decreases; therefore, the compressibility between the matrix and the reinforcement is increased.

All the agglomerates comply with the NMX-C-036-ONNCCE-2013 standard; although not all comply with the ASTM D 1037 standard, which limits its use in construction. But, they are an alternative material to be applied as a catalytic support in the degradation of dyes. Because they can be cut, sanded, drilled, painted, submerged in water and exposed to the environment, without suffering a physical alteration.

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