Fire Resistance of Olive Leaf Panels with Fire Retardant Coatings: Preliminary Findings

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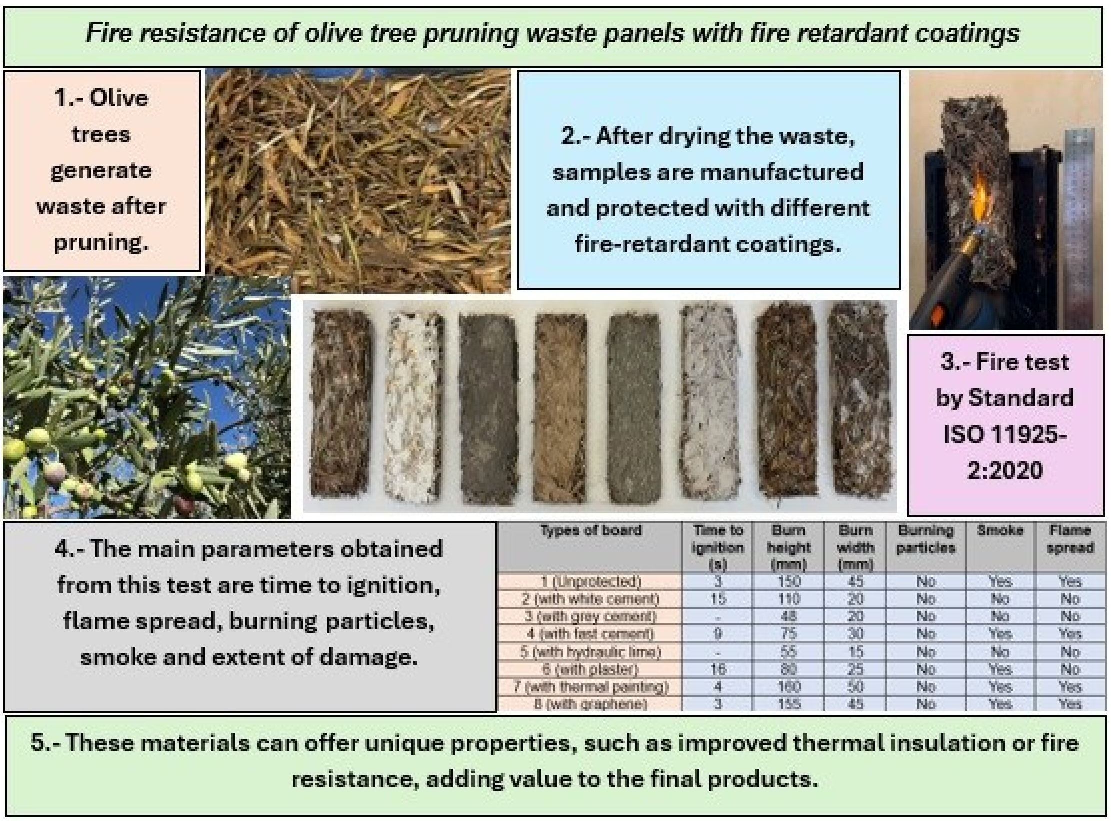
GRAPHICAL ABSTRACT



Types of board	Time to ignition (s)	Burn height (mm)	Burn width (mm)	Burning particles	Smoke	Flame spread
1 (Unprotected)	3	150	45	No	Yes	Yes
2 (with white cement)	15	110	20	No	No	No
3 (with grey cement)	-	48	20	No	No	No
4 (with fast cement)	9	75	30	No	Yes	Yes
5 (with hydraulic lime)	-	55	15	No	No	No
6 (with plaster)	16	80	25	No	Yes	No
7 (with thermal painting)	4	160	50	No	Yes	Yes
8 (with graphene)	3	155	45	No	Yes	Yes

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Olive tree pruning waste represents a significant agricultural byproduct in Mediterranean regions. It can be regarded as a sustainable and cost-effective alternative resource to other traditional materials for buildings. It is necessary to evaluate the flammability of these materials, according to building regulations. In this preliminary study, several fire-retardant coatings were applied to the materials obtained from olive leaves mixed with a natural adhesive. The coatings included cement-based layers, hydraulic lime, gypsum plaster, intumescent varnishes containing phosphate-based compounds, and graphene-based paints. Treated samples were subjected to flame spread tests to determine their fire resistance properties according to Standard EN ISO 11925-2. The potential of using olive leaves waste as a building material when combined with appropriate fire-retardant coatings is highlighted. The findings suggest that such treatments contribute to mitigating fires and promote the sustainable use of agricultural byproducts in buildings. By applying the coatings, the fire resistance increases significantly compared to untreated samples. The ceramic coatings provided the highest level of protection by reducing the flame spread rate and increasing the time to ignition. Additionally, the treated samples exhibited increased char formation, reducing heat transfer, and delaying combustion. Further research is recommended to optimize the formulations and application methods for large-scale implementation.

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Keywords: Fire resistance; Fire retardant coatings; Olive tree leaves; Pruning waste

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INTRODUCTION

Olive tree pruning waste, a byproduct of olive cultivation, represents a promising yet underutilized resource for the sustainable development of valuable materials (Martellotta *et al.* 2018). The Mediterranean region—particularly Spain—generates substantial quantities of this agricultural residue annually. This biomass can be valorized for various applications, including energy production and the development of eco-friendly materials (Martínez *et al.* 2006; Niaounakis and Halvadakis 2006; Niaounakis *et al.* 2006; Barreca and Fichera 2013; Bartocci *et al.* 2015; Yakout and Sharaf El-Deen 2016). Apart from pruning waste, other researchers have focused on extracting cellulose from olive solid waste for other commercial applications (Hamed *et al.* 2012).

Fire safety is a critical concern across multiple industries, especially in the construction sector. Conventional fire-retardant coatings often rely on halogenated compounds, which, despite their effectiveness, cause significant environmental and health threats. In response to growing sustainability demands, the research has increasingly focused on ecological fire-retardant coatings formulated from non-toxic, renewable materials such as cellulose, chitosan, and starch.

These coatings increase the fire resistance of organic substrates by forming a protective char layer that insulates the material from heat and oxygen, thereby slowing the combustion process. Recent advancements in fire-retardant technology have emphasized the development of environmentally friendly coatings suitable for a wide range of substrates, including wood and agricultural residues (Fatima and Mohanty 2011; Liang *et al.* 2021; Wang *et al.* 2020; Nasirzadeh *et al.* 2023) .

The fire-retardant mechanisms of ecological coatings typically involve several synergistic processes: (a) char formation, which reduces heat transfer and delays combustion; (b) endothermic reactions, which absorb heat and reduce the material's temperature; and (c) dilution of combustible gases, which decreases the probability of ignition.

Ecological fire-retardant coatings are applied across diverse sectors. In construction, they are used on wood, steel, and other materials to meet fire safety regulations. In transportation, they enhance fire resistance in automotive and aerospace components without significantly increasing weight. In the textile industry, they are employed to impart fire resistance to fabrics used in clothing, upholstery, and industrial applications. The olive leaves waste panels have previously been analyzed for their acoustic properties in previous studies by Belda *et al.* (n.d.). When applied in building acoustics, such materials must also demonstrate adequate fire resistance to prevent flame propagation.

The growing demand for sustainable and eco-friendly construction materials has prompted research into the fire resistance of natural materials. Among these, agricultural pruning residues have attracted attention because of their abundance, low cost, and environmental advantages. This study investigated the fire-resistant properties of materials derived from olive tree pruning waste, with a particular focus on their potential applications in the construction industry. Previous studies have shown that panels made from agricultural residues can meet minimum requirements for non-structural applications such as acoustic and thermal insulation boards (Ferrandez-Villena *et al.* 2020; Martellotta *et al.* 2018). Although structural applications require higher mechanical performance, research indicates that composites reinforced with natural fibers can achieve adequate strength for certain uses (Nguyen and Nguyen 2021; Ortega *et al.* 2020). Additionally, olive pruning residues are highly flammable due to their lignocellulosic composition, which underscores the need for effective flame-retardant treatments (Fatima and Mohanty 2011; Sienkiewicz and Czub 2020).

Regarding pruning activity, others investigated the thermal and fire-resistance properties of boards made from pruning of vine (Ferrandez-Villena *et al.* 2020). Natural fibers and agricultural residues have been widely studied for their fire resistance and thermal insulation capabilities. These materials offer renewable and biodegradable alternatives to conventional insulation products such as fiberglass and foam. The use of pruning waste addresses the dual challenges of waste management and resource efficiency.

The increasing frequency and intensity of wildfires in buildings have emphasized the urgent need for effective fire-resistant materials. In this context, pruning waste offers a sustainable and abundant resource that can be repurposed for various applications. However, its inherent combustibility presents a significant challenge for use in fire environments. To mitigate this issue, the application of fire-retardant coatings has emerged as a promising strategy to enhance the fire resistance of biomass-based materials.

Previous studies have demonstrated the effectiveness of various treatments in improving the fire resistance of wood. For example, Yokokawa *et al.* (2019) conducted a comparative study on the fire performance of wood treated with different ionic liquids (ILs). Their findings revealed that IL-treated wood enhanced fire resistance compared to untreated samples. Notably, choline dihydrogen phosphate ([Choline]PO_4) and 1,3-dimethylimidazolium dimethylphosphate ([MMIM]DMP) were particularly effective, as evidenced by higher residual weights and the absence of prominent exothermic peaks in thermal analyses.

Similarly, Miyafuji and Minamoto (2022) investigated the fire and termite resistances of wood treated with PF_6-based ILs. Their results showed that all IL-treated samples exhibited improved fire resistance, with tetrabutylammonium hexafluoro-phosphate ([TBP]PF_6) emerging as the most promising candidate due to its thermal stability. The study also highlighted the potential of ILs to enhance the dimensional stability and termite resistance of wood, demonstrating their multifunctional benefits.

In another study, Dos Santos *et al.* (2016) evaluated the fire resistance of wood treated with an emulsion derived from lignin. The treatment significantly increased ignition time and reduced mass loss, indicating the potential of lignin-based emulsions as effective fire retardants. Additionally, improvements in hardness and hydrophobicity were observed, suggesting added functional advantages.

Pries and Mai (2013) explored the use of cationic silica sol as a fire retardant for wood. Their research demonstrated that the treatment reduced both mass loss and burning duration, while completely preventing the flaming of the resulting char. The effectiveness of the treatment increased with higher weight percent gains, supporting its potential as a scalable fire-retardant solution.

Wu *et al.* (2023) investigated the fire resistance of pine wood treated with phenol-formaldehyde resin and phosphate-based flame retardants. Their findings indicated that the combined treatment significantly improved thermal stability and reduced flammability. Even after accelerated leaching tests, the treated wood maintained a substantial reduction in total heat release, highlighting the durability of the fire-retardant effect.

Lin *et al.* (2022) introduced guanyl-urea phosphate (GUP) into furfurylated wood to enhance fire resistance. The modified wood exhibited a marked reduction in heat release rate demonstrating that GUP incorporation can enhance fire performance without compromising mechanical properties.

Finally, Alves *et al.* (2023) examined the fire behavior of wood and wood-based composite panels, focusing on the development of fire-resistant multilayer systems. Their study emphasized the importance of material selection and layer configuration, showing that systems incorporating moisture-resistant MDF and rockwool insulation achieved significant improvements in fire resistance, with some configurations providing up to one hour of insulation fire resistance. Regarding thick wood-based boards, Harada *et al.* (2006) conducted fire resistance tests including plywood, particleboard, and medium-density fiberboard (MDF). Their findings indicated that insulation performance was closely related to board density, with higher-density materials exhibiting superior fire resistance. The study also demonstrated that cone calorimeter tests could effectively predict the fire performance of these materials.

Uddin *et al.* (2022) developed novel fire-retardant coatings for wood using a composite of casein, mica, and aluminum hydroxide. These coatings significantly improved fire resistance by reducing both the peak heat release rate and total heat release. The study highlighted multiple mechanisms contributing to fire retardancy, including the formation of an insulating surface layer and catalytic effects from the additives. Wang *et al.* (2020) investigated the influence of polydimethylsiloxane (PDMS) viscosity on silica fume-based geopolymer hybrid coatings for flame-retardant plywood. Their results showed that PDMS-modified coatings substantially enhanced fire resistance and smoke suppression, with optimal performance achieved at a PDMS viscosity of 350 cps.

To improve the fire behavior of birch plywood, Bekhta *et al.* (2016) evaluated the application of conventional flame retardants. Their research demonstrated that diffusive impregnation of moist veneer resulted in more homogeneous fire-retardant distribution. The treated plywood was reclassified from highly flammable to low-flammability material, confirming the effectiveness of conventional treatments.

Collectively, these studies underscore the potential of various fire-retardant strategies—including ionic liquids, lignin-based emulsions, cationic silica sols, phenol-formaldehyde resins, guanyl-urea phosphate, novel composite coatings, PDMS-modified geopolymers, and conventional flame retardants—to develop sustainable and effective fire-resistant materials. These approaches not only mitigate wildfire risks but also promote the valorization of agricultural waste.

In parallel, some research has also explored the development of environmentally friendly composites reinforced with natural fibers. One such study focused on banana fibers—sourced from banana tree bark in Vietnam—incorporated into epoxy resin (Epikote 240) at varying weight percentages (10% to 25%) after alkali pretreatment with 5% NaOH (Nguyen and Nguyen 2021). These results indicated that composites with 20 wt% banana fiber offered an optimal balance of mechanical strength and fire resistance, making them suitable for sustainable applications. Further investigations into natural fiber-reinforced polymer composites have examined the fire performance of banana fiber, banana-cotton blends, and linen (Ortega *et al.* 2020). Given the high combustibility of natural fibers, the study employed magnesium hydroxide as a flame retardant and alkali treatments to enhance fire resistance. While increased flame-retardant content, reduced flame propagation speed, it also compromised mechanical strength. Linen-reinforced composites exhibited the best mechanical properties, whereas banana nonwoven composites with 60% magnesium hydroxide achieved the highest fire resistance.

Sienkiewicz and Czub (2020) reviewed the fire sensitivity of biobased polymer composites, particularly those incorporating plant-based fillers, and emphasized the need to enhance their flame retardancy due to their growing use in practical applications. The review discussed commonly used flame-retardant compounds, including halogenated organics such as hexabromocyclododecane (HBCD) and polybrominated diphenyl ethers (PBDEs), which, despite known health risks, are still occasionally used in biocomposites.

Gernay (2021) investigated the fire performance of timber columns, focusing on their resistance during the burnout stage—a critical yet often overlooked stage in standard fire testing. The study highlighted that ensuring structural integrity throughout the entire fire lifecycle requires more than addressing combustibility or self-extinction; it demands comprehensive design strategies. Another study presented a numerical investigation into the fire resistance of reinforced concrete (RC) beams and slabs strengthened with natural fiber-reinforced polymers (FRPs), comparing them to conventional FRP systems (Kodur *et al.* 2023). The results showed that fire insulation significantly improved the fire performance of bio-based FRP systems.

Related to this research, a polyester-based composite incorporating marble waste powder and glass fiber was developed for building applications such as flooring and wall panels (Abenojar *et al.* 2021). The composite improved mechanical strength with the addition of marble and exhibited high fire resistance, including self-extinguishing behavior and structural integrity under fire conditions when mesh reinforced. A comparative analysis of flame-retardant additives—tris(2-chloroisopropyl) phosphate (TCPP), tris(1,3-dichloro-2-propyl) phosphate (TDCP), and aluminum trihydrate (ATH)—was conducted in rigid polyurethane foams (RPUFs) (Gürkan and Yaman 2023). The study addressed the high flammability of RPUFs and evaluated the effectiveness of each additive in enhancing flame retardancy.

An extensive review by other authors (Li 2023) provided a comprehensive overview of the current state of flame-retardant coatings. The review detailed recent advancements, mechanisms of action, and the influence of microstructure on fire resistance, offering valuable insights for both researchers and industry professionals.

Related to flame-retardant treatments (Lazar *et al.* 2020), there are several researchers who offer applications to sound absorption of fiberboards (Lee *et al.* 2023) and to textile materials as cotton fabrics (Thi *et al.* 2020).

This study investigated the fire resistance of olive tree leaf waste panels treated with ecological fire-retardant coatings. The development of such coatings has gained significant attention due to the increasing demand for sustainable and environmentally friendly fire protection solutions. This work explored the composition, mechanisms, and applications of eco-friendly fire-retardant coatings, emphasizing the integration of bio-based materials to enhance fire resistance while minimizing environmental impact. Ecological fire-retardant coatings offer a sustainable alternative to traditional fire protection methods. By using renewable materials and advanced technologies, these coatings may provide effective fire resistance with reduced ecological footprint. Continued research and innovation in this field will further improve their performance and broaden their applicability across various industries.

In this preliminary research, the goal is to examine the effectiveness of fire-retardant coatings applied to panels manufactured from olive tree leaves, aiming to ensure their safe use in building applications.

MATERIALS AND METHODS

The materials used in this research came from the agrifood industry, since they were obtained from the pruning of olive trees. The other materials used in this investigation are the polyurethane used as an adhesive and the fire-retardant coatings.

Natural Waste

The waste used to manufacture the boards were olive tree leaves (*Olea europea*). These leaves have been collected from a local oil mill and then completely dried for one month with a moisture content of 8%. The average dimensions of the whole leaves were in the range 10 to 15 mm wide and 40 to 50 mm long, with an average thickness of 0.5 mm (Fig. 1).

Fig. 1. Olive leaves dried

The leaves were mixed with polyurethane in a proportion of 20%.

Adhesives

Polyurethane

Polyurethane adhesives, often referred to as PU adhesives (Fig. 2), are highly versatile and widely used in various applications due to their strong bonding capabilities. The composition and types fell into two categories, as follows:

- *One-Component adhesives:* These are pre-mixed and ready to use. They cure upon exposure to moisture in the air.
- *Two-Component adhesives:* These require mixing of a resin and a hardener before application. The curing process is initiated by the chemical reaction between these two components.

Fig. 2. Polyurethane two-component on the left and one-component on the right

Regarding the properties of polyurethane, this adhesive provides strong, durable bonds that can withstand significant stress and strain; and it is resistant to chemicals, water and humidity, which enhances their durability in harsh environments.

Fire-retardant Coatings

To provide thermal resistance to the materials they have been tested with different fire-retardant coatings: white cement, grey cement, fast cement, hydraulic lime, plaster, thermal painting, and graphene.

White cement

White cement is known for its high reflectivity and lower thermal conductivity compared to other cements. This material contains Clinker of Portland cement and water-soluble chromium reducer less than 0.0002%. The components of this cement, as well as their proportions according to CEM I 52.5, are indicated in Table 1.

Table 1. White Cement Components (CEM I 52.5).

Raw Materials	Percentage (%)
SiO_2	22.5
Fe_2O_3	0.22
Al_2O_3	3.98
CaO	67.06
MgO	1.62
SO_3	2.48
K_2O	0.27
Na_2O	0.06
Cr	<0.0002

Grey cement

Grey cement has similar thermal properties to white cement but may have slightly different chemical compositions and additives. Its composition has chromium VI content below 2 parts per million (2 PPM). The used cement is CEM II / B-L 32,5 N – UNE-EN 197-1:2011. The Composition is shown in Table 2.

Table 2. Grey Cement Components

Grey Cement Componentes	Percentage (%)
Sulfate	<= 3.5
Chlorides	<= 0.1
Chromium	< 2 ppm*

**ppm: parts per million*

Fast cement

Fast-setting cement typically has additives that accelerate the curing process (Table 3).

Table 3. Fast Setting Cement

Properties	Mean Values
Density	1210 kg/m^3
Granulometry	0 to 600 µm (EN 1219-1)
pH mix	>= 12
Setting time	<= 3 min.

Hydraulic lime

Lime can be used as an insulating material, particularly when combined with other materials. Lime itself has moderate thermal insulation properties. It is not as effective as some modern insulation materials such as polyurethane foam or mineral wool, but it does provide a certain level of thermal resistance. Lime is considered environmentally friendly because it is produced at lower temperatures compared to cement, resulting in lower CO_2 emissions.

It is composed essentially of calcium hydroxide and, to a lesser extent, of calcium silicates and aluminates. Mix 3 parts of sand for each part of lime.

Table 4. Hydraulic Lime Properties

Properties	Mean Values (EN 459-1)
Name	NHL 3,5
Composition	100% Hydraulic lime
Free lime content	44 %
Density	590 kg/m^3
Setting time	> 4 h
Compression strength	5 MPa (approx.)

Plaster

Applying gypsum as a cover to improve the fire-resistance of wooden materials is a common practice in construction. This material presents multiple benefits such as thermal insulation (helping to regulate indoor temperatures), fire resistance, and providing acoustical insulation (reducing noise transmission). Table 5 shows some properties.

Table 5. Plaster Properties

Properties	Mean Values
Water/Plaster Ratio	0.75 l/kg
Purity Index	>= 92%
Start Setting Time	9 to 12 min
Final Setting Time	25 to 35 min
Granulometry	0.5 % > 0.2 mm 99.5% between 0 – 0.2
pH	7
Bending Strength	>3.5 MPa
Fire Resistance	Euroclass A1

Fire-resistance painting

Fireproof varnish, also known as fire retardant varnish, is a specialized coating designed to enhance the fire resistance of timber and timber-derived substrates (Table 6). Fireproof varnishes typically consist of a basecoat and an overcoat. The basecoat is often an intumescent varnish, which means that it swells when exposed to heat, forming an insulating layer that protects the underlying material. According to the manufacturer, the intumescent varnish consists of a combination of 3-iodo-2-propynyl butylcarbamate, hydroxyphenyl-benzotriazole derivative, methyl sebacate and a polymeric binder (polyurethane resin, polyvinyl acetate emulsion, acrylic resins).

Table 6. Thermal Painting Properties

Properties	Mean Values (EN 459-1)
Specific Weight	1030 kg/m^3
Solids in Weight	38%
Solids in Volume	37.5%
Viscosity	80 – 85 KU at 20 ºC

These varnishes are tested and certified to meet various fire safety standards. For example, they can achieve BS Class-1 and Class-0 for surface spread of flame, as well as EN Class-B s2 d0, which indicates limited contribution to fire growth and smoke production.

Graphene painting

Graphene varnish is an advanced coating that incorporates graphene, a single layer of carbon atoms arranged in a two-dimensional honeycomb lattice (Fig. 3). It consists of a polymer matrix infused with graphene nanoparticles (Table 7).

Fig. 3. Graphene varnish

The high thermal conductivity of graphene helps in dissipating heat, which can be beneficial in applications where temperature regulation is crucial.

Table 7. Graphene Painting Properties

Properties	Mean Values (EN 459-1)
Specific weight	1640 +/- 50 kg/m^3
pH	9.5 +/- 1
Viscosity	90 – 120 UK
Volume Solids	68 +/- 5%

METHODS

To conduct the test to determine the ignitability of the materials, the Standard ISO 11925-2: 2020 was used (European Committee for Standardization, 2020).

Test Specimen Preparation

The boards were manufactured with a target density of approximately 0.3 g/cm³. Olive leaves were mixed with polyurethane (PU) adhesive at a ratio of 20 g PU per 100 g leaves. The mixture was placed in molds measuring 250 mm × 90 mm × 20 mm and subjected to cold pressing at 0.05 MPa for 10 minutes. No heating was applied during pressing (Fig. 4).

Fig. 4. Olive leaves mixed with polyurethane

After molding, specimens were conditioned for 48 hours at 23 °C and 50 ± 5% relative humidity before testing. Finally, fire-retardant coatings were applied by brushing onto the surface after curing (Fig. 5).

Fig. 5. Mould and sample of olive leaves with polyurethane (250 x 90 x 20 mm)

Table 8 shows the proportions used and the fire-retardant materials applied.

Table 8. Types of Manufactured Boards

Type Of Board	Natural Waste (%)	Binder (%)	Cover Layer	Weight (g)	Density (g/cm^3)
1	80%	20%	Without coating	114.70	0.26
2			White cement	185.45	0.42
3			Grey cement	211.82	0.48
4			Fast cement	145.67	0.33
5			Hydraulic Lime	187.15	0.42
6			Plaster / Gypsum	154.90	0.34
7			Thermal paint	127.86	0.29
8			Graphene paint	116.03	0.26

Figure 6 shows the samples unprotected and with fire retardant materials.

Fig. 6. Preparation of samples with fire resistance coatings

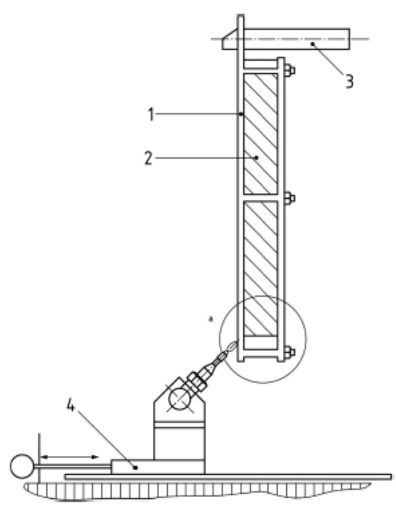

Fig. 7. Scheme of the experimental test according to the ISO 11925-2:2020

Test Procedure

The specimens were mounted vertically in a sample holder, and a single-flame source (propane burner) was used. The flame was 20 mm in length and was applied to the surface at an angle of 45º for 30 seconds to the edge of the specimen (Fig. 7).

In Fig. 7, item 1 is the sample holder; 2, is the sample; 3, is the support; 4, is the burner support. Figure 8 shows the chamber where the fire tests have been conducted and one of the samples during the test.

Fig. 8. Chamber for the test (left) and sample being tested (right).

RESULTS

The standard ISO 11925-2 provides a method for testing the ignitability of building products when exposed to a small flame. The main parameters obtained from this test are time to ignition, flame spread, burning particles, smoke, and extent of damage. After the tests have been completed and by means of the observation, one can determine when the specimen ignites and how the flame spreads, including the duration of burning (Fig. 9).

Fig. 9. Samples after testing

Table 9 shows the results obtained after the test.

The moisture content of the boards before coating was almost neglectable after six months drying, and the density ranged from 0.3 to 0.45 g/cm³ depending on the coating applied. Boards with higher density and lower moisture content tended to ignite more quickly, but coatings that increased surface mass (*e.g.*, cement layers) improved fire resistance by delaying heat spread.

According to the results, the sample without protection ignited after 3 seconds (s), which is something expected because of the lack of protection.

Table 9. Results of Flame Tests

Types of Board	Time to Ignition (s)	Burn Height (mm)	Burn Width (mm)	Burning Particles	Smoke	Flame Spread
1 (Unprotected)	3	150	45	No	Yes	Yes
2 (With White Cement)	15	110	20	No	No	No
3 (With Grey Cement)	-	48	20	No	No	No
4 (With Fast Cement)	9	75	30	No	Yes	Yes
5 (With Hydraulic Lime)	-	55	15	No	No	No
6 (With Plaster)	16	80	25	No	Yes	No
7 (With Thermal Painting)	4	160	50	No	Yes	Yes
8 (With Graphene)	3	155	45	No	Yes	Yes

With white cement protection, the high ignition time (15 s) and lack of smoke and flame spread suggest that white cement provided good fire resistance, reducing the heat transfer to the underlying material. Concrete is non-combustible and has a high thermal mass, which helps it withstand high temperatures for extended periods.

As for the grey cement, the board did not ignite, indicating excellent fire resistance. The grey cement layer effectively prevented the underlying material from reaching ignition temperature.

Regarding the fast cement, the moderate ignition time (9 s) and presence of smoke and flame spread suggest that while it provided some fire protection, it may not be as effective as other cement in preventing combustion.

Hydraulic lime is known for its breathability and moderate thermal insulation properties. The board did not ignite, indicating good fire resistance. The lime layer provided a protective barrier that prevents the underlying material from igniting.

Plasters have good fire-retardant properties, but cracks can appear under high heat. The relatively high ignition time (16 s) and lack of flame spreads suggest that plaster provided significant thermal protection, though it may not be as effective as cement-based coverings. Gypsum boards have a non-combustible core made of gypsum, which contains chemically bound water. When exposed to fire, this water is released as steam, helping to slow the spread of flames and providing a protective barrier.

Finally with paintings, the thermal paint is designed to reflect heat and provide a barrier against high temperatures. However, issues with paint dropping through pores can reduce its effectiveness. The very low ignition time (4 s) and high burn height and width indicate that the thermal paint was not effective in preventing ignition and flame spread in porous materials.

As for the graphene paint, which is known for its excellent thermal conductivity and strength, despite the low ignition time (3 seconds), the high burn height and width suggest that while graphene paint provided some thermal protection, it may not be sufficient to prevent rapid ignition and flame spread in this type of material with a high percentage of porosity.

As for the correlation with fire resistance, boards with higher density and coatings that added thermal mass (grey cement and hydraulic lime) showed the best performance with no ignition observed during the test. On the contrary, boards with lightweight coatings (thermal paint and graphene paint) retained similar density and moisture levels to uncoated boards, resulting in rapid ignition and extensive flame spread.

In summary, the effectiveness of the covering layers in preventing ignition and flame spread varied significantly. Cement-based coverings (white, grey, and fast cements) generally provided better fire resistance, while issues with the application of paint can significantly reduce its effectiveness in fibrous and porous materials.

This preliminary study highlights the potential of olive leaf panels with fire-retardant coatings for non-structural applications. Future work will focus on optimizing coating formulations, improving adhesion, and evaluating mechanical properties and durability under real building conditions.

CONCLUSIONS

This study explored the ignition and burning characteristics of boards made from olive tree leaves mixed with polyurethane and covered with various materials. The results revealed significant differences in fire resistance based on the properties and composition of the covering layers.

As for the materials used for protection, the results concluded that white cement, known for its high reflectivity, demonstrated excellent fire resistance properties. This resulted in a high ignition time of 15 s and no smoke or flame spread, indicating effective reduction of heat transfer to the underlying material.

The plaster, with its good fire resistance properties, showed a relatively high ignition time of 16 s and no flame spread. However, its effectiveness may be limited under high heat conditions due to potential cracking.

The paints, designed to reflect heat, were less effective due to dropping through pores. This resulted in a very low ignition time and significant burn height and width, indicating poor performance in preventing ignition and flame spread.

In summary, cement-based coverings (white, grey, and fast cement) generally provide superior fire resistance compared to other materials.

This research promotes the circular economy by utilizing agricultural waste apart from contributing to fire safety. Olive tree pruning generates a significant amount of biomass that would otherwise be considered waste. By repurposing this biomass into building materials, the use of available resources is enabled. The need for raw materials of non-renewable origin is reduced. Adding olive tree pruning waste into building materials for acoustic applications helps remove this biomass from landfills or incineration, thereby reducing environmental pollution and waste management costs.

The use of olive tree pruning waste in buildings, such as boards mixed with polyurethane and covered with various protective layers, creates sustainable products, mainly due to the use of those ceramic layers that protect recovery residue. These materials can replace conventional, less eco-friendly options, contributing to a more sustainable construction industry.

The development of new materials from olive tree pruning waste encourages innovation in the construction industry. These materials can offer unique properties, such as improved thermal insulation or fire resistance, adding value to the final products.

This approach aligns with the core principles of the circular economy, which aim to keep resources in use for as long as possible, extract the maximum value from them, and recover and regenerate products and materials at the end of their service life.

The future of ecological fire-retardant coatings lies in the continued exploration of novel bio-based materials and advanced nanotechnology. Research efforts are focused on improving the efficiency and durability of these coatings while ensuring they remain cost-effective and environmentally friendly. Additionally, the development of self-healing and recyclable fire-retardant coatings represents a promising area of innovation.

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Conflict of Interest

Authors do not have any personal interest or relationship that could potentially be affected by the publication of their manuscript.

Use of Generative AI

Authors have not used any AI tool to write this manuscript.

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