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Sunflower Stalk ASH: Prime Additive to Latex Paint for Fire Retardancy of Marine Plywood

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ABSTRACT

This research study investigates the use of sunflower stalk ash as a prime additive to latex paint for the fire retardancy of marine plywood. Its main goal was to assess the effectiveness of sunflower stalk ash paint in improving the fire retardancy of marine plywood. The researchers employed a simplified flame spread test to determine the effectiveness of the paint, and statistical analysis alongside observation were used to ascertain the ideal concentration required for the sunflower stalk ash paint. The findings revealed that the use of sunflower stalk ash paint can significantly improve the fire retardancy of marine plywood, with the most effective outcome observed in marine plywood that was coated thrice with 16% concentration of sunflower stalk ash in latex paint. This study suggests that utilizing agricultural waste like sunflower stalk ash could serve as an effective and efficient method for enhancing the fire retardancy of marine plywood.

Keywords:- *Sunflower Stalk Ash, Latex Paint, Marine Plywood, Concentration, Fire Retardancy.*

CHAPTER ONE
THE PROBLEM AND ITS SETTING

A. Introduction

Fire retardants or sometimes called as Flame retardants refer to a variety of substances that are added to combustible materials to help prevent fires from starting or to slow the spread of fire and provide additional escape time. When added to different products and materials, ranging from electronic devices to furniture, flame retardants can help prevent fires from starting or limit their spread. It provides consumers with a critical layer of fire protection and can be vital to reducing the risks associated with fire. (Chemical Safety Facts, October 2022). Although flame retardants can offer benefits when added to certain products, increasing scientific evidence shows that many of these chemicals may harm animals and humans. Adverse health effects may include endocrine and thyroid disruption, immunotoxicity, reproductive toxicity, cancer, and adverse effects on fetal and child development and neurobehavioral function. (National Institute of Environmental Health Sciences).

Hence, Paint is a liquid or semi-liquid substance that is used to add color to the surface of an object by covering it with a pigmented (colored) coating. Latex paint is the most popular type of paint for wood. It's easy to use and dries quickly, making it a great choice for beginners. It's also inexpensive and available in a wide range of colors. It's not as durable as oil-based paint, so it's not the best choice for high-traffic areas or exterior surfaces. But it’s perfect for projects like painting furniture or kitchen and bathroom cabinets where you want a beautiful, long-lasting finish. (Easy Reader and Peninsula Magazine).

Moreover, Chase Derousse (2021) stated that one advantage of latex paint, and a reason why it is becoming more popular than oil-based paint, is that it has fewer volatile organic compounds (VOCs). Fewer VOCs leads to non-toxic and environmentally friendly paint. In addition, this means latex paint has less of an odor, which means fewer lingering fumes even after the paint has dried. Latex paint is also non-flammable and not considered hazardous, making it easier to dispose of based on local regulations.

Fire retardant paint is formulated with special additives that help slow the spread of flames in the event of a fire. These additives are typically based on phosphorus or nitrogen compounds, which react when exposed to heat and flame, creating an oxygen-starved environment that slows down or stops the spread of fire. The fire triangle consists of Oxygen (O), fuel (wood or paper), and heat. All three components must be present for a fire to occur.

Fire retardant paint works by interrupting the fire triangle that consists of Oxygen (O), fuel (wood or paper), and heat. When exposed to heat, the phosphorus or nitrogen compounds in the fire-retardant coating react with oxygen and water vapor to create an insulating foam that delays the spread of flames. This insulating foam also creates an oxygen-starved environment, further reducing combustible materials' flammability.

Sunflower (*Helianthus annuus* L.) is an herbaceous plant mainly cultivated in China, USA, Russia, and Western Europe, whose seeds are used to gain oil. Russia had the highest projected production volume of sunflower seeds of any country in the world in the 2023 crop year. During that time period, Russia produced around 17 million metric tons of sunflower seeds. Ukraine is also a major producer of sunflower seeds worldwide, with a production volume of around 14 million metric tons in 2023. (M. Shahbandeh 2024). The sunflower stalk is then a waste product of its cultivation. Sunflower stalks, like other bio-based materials, have been studied for their potential use in construction and insulation applications due to their inherent properties. Sunflower stalks, a common agricultural byproduct, possess unique properties that make them a subject of interest in various applications. One of the most notable characteristics of these stalks is their high fiber content. Fibers, due to their structure and composition, are known to exhibit fire-resistant properties. This suggests that sunflower stalks could potentially contribute to fire resistance, making them a valuable resource in industries where fire retardancy is crucial. In addition to these properties, sunflower stalks are widely available as agricultural waste, making them a sustainable and environmentally friendly choice for various applications. Their use not only helps in waste management but also contributes to the conservation of resources. Furthermore, after harvesting, sunflower stalks have a low water content. This characteristic could potentially reduce their flammability, further enhancing their suitability in applications requiring fire resistance. The combination of high fiber content and low water content could potentially make sunflower stalks an effective natural fire retardant. (Arne Eschenhagen, Magdalena Raj et al. 2019).

According to Alexandra K. Harakas (2016), The innovative use of wood ash including sunflower stalk ash in wall paint is a breakthrough in fire safety. This ash, when mixed into paint and applied to drywall, significantly increases the time it takes for the drywall to ignite when exposed to fire. This delay in ignition is crucial in preventing rapid fire spread, providing extra time for occupants to evacuate and for firefighting services to respond. This strategy of adding wood ash to paint not only repurposes a waste material but also enhances the fire resistance of painted surfaces, potentially saving lives and property. Since there are very few studies carried out on sunflower stalks, and there is no existing study related to latex paint with sunflower stalk ash, collecting and comparing the data is very limited.

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Moreover, Potassium bicarbonate, which is present in wood ash such sunflower stalk ash, has the ability to release carbon dioxide (CO_2) when heated. The CO_2 acts as a fire suppressant by reducing the oxygen concentration around the material, thus slowing down and delaying the combustion. When the sunflower stalk ash is added to latex paint, the amount it takes for the painted surfaces, such as drywall, to catch fire can be prolonged and delayed. The fire-retardant properties of the wood ash such as sunflower stalk ash could improve the safety of the building and structure. (Cemal Ozcan, Mustafa Korkmaz et al. 2018).

Although sunflower stalk ash has a potential additive to latex paint for fire-retardancy, it is important to conduct and perform a comprehensive research and testing to evaluate its effectiveness and analyze the impact on the overall paint performance. Some important aspect that need to be considered include the compatibility of sunflower stalk ash with other paint components, the long-term durability of the fire-retardant properties and the sunflower stalk ash concentration in the paint.

Furthermore, it is essential to verify that sunflower stalk ash added in paints is safe for the environment and for human health. Therefore, it may involve testing for any possible toxicities or hazards and problems connected to the use of sunflower stalk ash in latex paint. Considering that sunflower stalk ash has a potential additive to latex paints for fire retardancy, additional investigation, testing and research are required to ascertain its efficacy and safety before using it. Given the harmful impacts of these chemicals, it becomes imperative to conduct research on safer fire retardants. Exploring alternative options is essential for promoting safety and minimizing risks. In this study, researchers will determine the effectiveness of sunflower stalk ash as a prime additive to latex paint for fire retardancy of marine plywood.

B. Conceptual Framework

The researchers developed a conceptual framework that will determine the efficacy of sunflower stalk ash as an innovative addition to latex or water-based paint.

When evaluating building materials for fire safety, many factors including ignition temperature, smoke toxicity and flame-spread are considered. Flame-spread, used to describe the surface burning characteristics of building materials, is one of the most tested fire performance properties of a material (Information on Construction Requirements). Flame spread rating is a designation that indicates how fast a certain material will burn and how far the flame will spread if caught on fire (TimberTech, 2022). The process of rating flame spread entails a number of steps, including sample preparation, controlled igniting, measurement of flame spread, index calculation, material classification, results documentation, quality assurance, and application of findings to safety regulations. The data will gather through concept:

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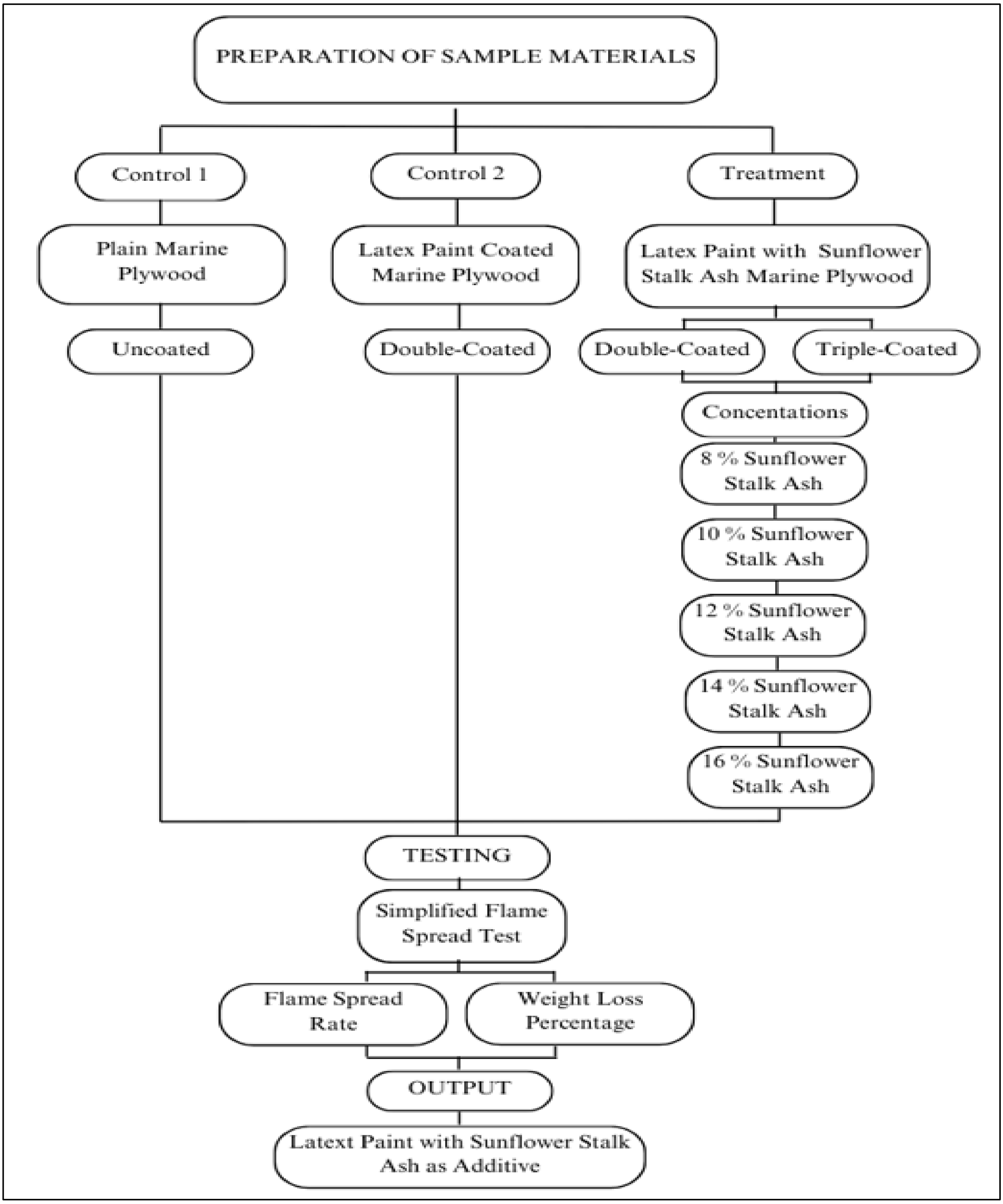

Fig 1: Conceptual Framework

Figure 1. shows the efficiency of Sunflower Stalk Ash as a prime additive to latex paint and will be evaluated through a series of tests. Researchers started by preparing the sunflower stalk ash by sun-drying the sunflower stalk and turning it into ash and cut the marine plywood. Sunflower stalk ash will be added to the latex paint and mix thoroughly. The mixture then applied to the PMP and wait until it dries. This process will be repeated for two and three times as per required. Researchers will also provide a sample of PMP without any paint coatings. Flame spread rate test and weight loss test will be using in this research to assess whether the sunflower stalk ash can be used as an additive to the latex paint.

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Based on the study of Volkan Gul entitled "Determination of Some Plant Nutrients in Sunflower Waste Ashes", the maximum amount of nutrient elements identified in the ash are potassium (37.69 g kg-1), calcium (26.64 g kg-1), magnesium (13.93 g kg-1), phosphorus (7.27 g kg-1) and boron (0.25 g kg-1). Sunflower stalk or sunflower plant waste ash can be used as a potential fire retardant when added to latex paint, however, more extensive research is needed on this subject.

C. Statement of the Problem

This study sought answer to the following questions:

➢ *Describe the Flame Spread Rate and Weight Loss Percentage of the Following:*

- Plain Marine Plywood (PMP)
- Latex Paint Coated Marine Plywood (LPCMP)
- Various Concentrations (Double-Coated and Triple-Coated with 8%, 10% 12%, 14% and 16%)

➢ *Determine if there is a Significant Difference Between PMP and LPCMP with SSAA in Terms of:*

- Flame Spread Rate
- Weight Loss (%)

➢ *Determine if there is a Significant Difference between LPCMP and LPCMP with SSAA in Terms of*

- Flame Spread Rate
- Weight Loss (%)

D. Hypotheses

- H_o: There is no significant difference between the PMP and LPCMP with SSAA in terms of Flame Spread Rate and Weight Loss percentage.
- H_o: There is no significant difference between the LPCMP and LPCMP with SSAA in terms of Flame Spread Rate and Weight Loss percentage.
- H_a: There is a significant difference between the PMP and LPCMP with SSAA in terms of Flame Spread Rate and Weight Loss percentage.
- H_a: There is a significant difference between the LPCMP and LPCMP with SSAA in terms of Flame Spread Rate and Weight Loss percentage.

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CHAPTER TWO
METHODS AND PROCEDURES

This chapter discussed the methods and procedures that the researchers utilized. It specifies the research design, research locale, research instrument, data gathering procedure, and the data analysis and technique that would be made based on the outcomes of the study.

A. Research Design

This research used an experimental approach to assess the effectiveness of adding sunflower stalk ash to latex paint. Experimental research, as described by Creswell (2012), involves manipulating independent variables to observe their impact on dependent variables. It falls under quantitative research, as it entails collecting numerical data and analyzing it statistically. The study's experimental design entailed establishing protocols for the experiment and focusing on obtaining relevant data to draw valid conclusions. The experimentation included treating different surfaces: PMP, LPCMP, and LPCMP with SSAA. These treatments were divided into two categories, the double-coated and triple-coated, each with different concentrations of sunflower stalk ash. Researchers conduct five samples in each category to obtain the average value.

➢ *Research Instrument*

The key methodology used by the researchers in this study was experimentation, with the simplified flame spread test forming the foundation of their investigation. Through this experimentation, the researchers collected data to assess the effectiveness of Sunflower Stalk Ash Paint. By using statistical analysis and observation, the researchers identified the optimal concentration required for the Sunflower Stalk Ash Paint.

➢ *Data Gathering*

To determine the effectiveness of sunflower stalk ash as an additive to paint, the following are necessary:

➢ *Materials*

Plywood (12x6 inches)	Latex paint
	
Sunflower Stalk/ Sunflower Stalk Ash	Paint Brushes (2inches)
	

<table>
<tr><td>Weighing Scale
</td><td>Measuring tape
</td></tr>
<tr><td>Hand Mixer
</td><td>Butane blow torch
</td></tr>
<tr><td colspan="2">Stainless Steel Strainer
</td></tr>
</table>

B. Parameters in Producing Sunflower Stalk Ash

After harvesting, the sunflower stalks were cut into smaller pieces ranging from 4 inches to 6inches long and split the sunflower stalk into half. The sunflower stalk then sun dried for 7 days. According to Hydrobuilder (2011), the plants will be done drying in around 7 to 10 days. This can be checked by applying pressure to the branches. If the branches snaps, then it is dry. On the other hand, if the branches just bends, then it still needs a bit more time.

The technique of pyrolysis can transform sunflower stalk into a component for fire-retardant paint. Sunflower Stalk are heated in pyrolysis, causing them to break down into char and gases without oxygen. This char, when finely ground, can be added to paint for fire resistance. Suneetha, M., & Reddy, B. S. (2017) outline various conditions necessary for producing high-quality sunflower stalk ash during controlled burning. The following are some crucial parameters:

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- Temperature: The temperature must be sufficiently elevated to ensure the thorough combustion of sunflower stalk during burning, yet it should not be excessively high to prevent the ash from merging. Typically, sunflower stalks are burnt at temperatures exceeding 100°C to generate ash.
- To ensure the thorough combustion of sunflower stalk and prevent incomplete burning, it's crucial to regulate the oxygen supply throughout the process. This can be achieved by using a furnace or a sealed container with controlled oxygen flow.
- Burning duration: It is essential to burn the sunflower stalk for a sufficient duration to achieve complete combustion. Depending on the size and moisture content of the sunflower stalk.
- Cooling Period: To avoid the fusion of ash particles, it's recommended to allow gradual cooling. It is advisable to let the material to cool.
- Particle size: A crucial determinant influencing the properties of the ash is its particle size. For various purposes, finely ground ash particles typically ranging between 100 to 1000 microns in size are commonly favored.
- Contaminants: Ensuring the purity of the ash necessities minimizing contamination during both the burning process and storage to maintain cleanliness and free from impurities.

By meeting these criteria, it is possible to produce sunflower stalk ash suitable for various applications, such as agriculture, construction, and as a fire retardant in paints.

C. Procedure in Making Sunflower Stalk ASH Paint

The procedures in making the paint with sunflower stalk ash will be the following:

- Step 1: Organize and arrange all the research materials that will be needed.
- Step 2: Before usage, remove the lid of the paint container and mix the paint thoroughly. Then, accurately measure out 250 grams of latex paint.
- Step 3: Weigh out different amounts of sunflower stalk ash in grams and put them in a container. These amounts will represent different proportions, (8%, 10%, 12%, 14%, and 16%) of sunflower stalk ash mixed with latex paint.
- Step 4: Blend and stir thoroughly using hand mixer until the desired texture is attained.

Table 1: The Applied Ratio and Proportion of Water-Based Paint and Sunflower Stalk Ash Paint

TREATMENT	**PAINT (g)**	**SSAA**		**NO. OF COATING**	**REPLICATION**
		(%)	**(g)**		
1	250	8	20	2	5
2	250	10	25		5
3	250	12	30		5
4	250	14	35		5
5	250	16	40		5
6	250	8	20	3	5
7	250	10	25		5
8	250	12	30		5
9	250	14	35		5
10	250	16	40		5

D. Procedure in Making the Sample

For sample with latex paint, sunflower stalk ash paint, and without paint.

- Step 1: Prepare the 12x6 in marine plywood. There will be 60 samples needed: 5, 5 and 50 samples for C1, C2, and T respectively.
- Step 2: For the C2 group, create samples coated twice with latex paint. For the Treatment group, prepare samples coated with five different concentrations of paint. Among the 50 samples, 25 samples will receive two coatings and the 25 samples with three coatings. Ensure each coat of paint dries completely before applying the next one. Based on the PPG Industries, Incorporations (2024), latex paint will dry in about 1 hour but can safely recoat after 4 hours.
- Step 3: For optimal results, ensure to apply the paint in a consistent direction. To achieve precise testing outcomes, ensure all surfaces are properly coated with paint.
- Step 4: After applying the paint, allow it to dry either under direct sunlight or outdoors.

➢ *Levels of Independent Variable*

- (C1) Control 1- Plain Marine Plywood (PMP)
- (C2) Control 2- Latex Paint Coated Marine Plywood (LPCMP)
- (T) TREATMENTS- Various Concentrations of SSAA in LPCMP

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E. Testing Procedures

The samples undergo simplified flame spread evaluations. A flame spread test is a method used to evaluate the burning characteristics of various materials, including building supplies, textiles, and coatings, across their surfaces. It measures the propagation of flames along the material's surface, assessing both the speed and extent of spread. Flame spread tests are essential for ensuring the fire safety of structures and construction materials.

According to Luna (2021), ASTM E119 considers the criteria for fire test responses, which are crucial for fire safety. Tests conducted according to ASTM E119 determine the length of time a particular material or installation can withstand a fire. This information is useful for insurance providers, contractors, and other stakeholders to understand what can be anticipated during a fire incident.

F. Procedure for Testing of Materials:

- Measure the weight of each sample before conducting the test.
- Set up a testing space Making sure to avoid any flammable substances with proper ventilation, then position the wooden sample on a heat-resistant surface.
- Light the butane blow torch at a moderate level and hold it at about a 180-degree angle to the paint surface, roughly 4 inches away from the sample's edge. Researchers use a blow torch 509C model having a 1300 °C. According to Anova Bois (2024), wood can properly burn starting at 500 °C.
- Measure the distance covered by the flame within 25 seconds, then continue exposing the sample surface to the flame for another 25 seconds, totaling 50 seconds of testing per sample.

According to Gould and Sullivan (2020), there are two methods commonly used to determine spread rate which are the cumulative spread rate, calculated as the total distance travelled by the fire divided by the total time of travel, and the interval spread rate, which is calculated using the maximum distance travelled by the fire and the minimum time or the desired time between observations.

Conduct the test five times each for Control 1, Control 2, and Treatment with double-coating and triple-coating. Record and organize the distance traveled by the flame, then weigh the sample again post-test.

➢ *Data Analysis and Techniques*

The researchers used quantitative data analysis to examine experimental data, chosen due to the numerical nature of the experimentation on sunflower stalk ash's effectiveness as a fire-retardant paint. The data will be stored and analyzed using the Statistical Package for the Social Sciences (SPSS). The researchers use the one-way ANOVA in SPSS to explore relationships between multiple dependent variables and one independent variable with varying levels. ANOVA is a statistical test used to determine whether there are statistically significant differences between the means of three or more independent groups. It's often used when comparing means across different treatments or conditions. Likewise, Dunnett will be use. Dunnett's Method or Dunnett's Multiple Comparison, evaluates the means of multiple experimental groups against the mean of a control group to determine if differences exist. In instances where an ANOVA test yields significant results, it does not indicate which specific pairs of means exhibit differences. Dunnett's Test can be applied subsequent to conducting ANOVA to pinpoint pairs showing statistically significant disparities. to pinpoint which group have significantly different means.

CHAPTER THREE
PRESENTATION, ANALYSIS AND INTERPRETATION OF DATA

This section discussed the results of a research project investigating the use of sunflower stalk ash in latex paint to improve the fire resistance of marine plywood. The researchers gathered data through experiments and observations, organizing it into tables to address specific issues identified during the study.

Table 2: Raw Data on Various Surface Treatment for PMP LPCMP

Various Surface Treatments	Replication	Initial Weight (grams)	Final Weight (grams)	Distance Travelled in 25s (inches)
Plain Marine Plywood (PMP)	1	94	78	11.0000
	2	94	80	11.5000
	3	93	77	12.0000
	4	94	79	12.0000
	5	89	74	12.0000
Latex Paint Coated Marine Plywood (LPCMP)	1	98	84	8.0000
	2	92	81	10.3750
	3	102	84	10.2500
	4	102	77	11.0000
	5	99	86	10.1875

Table 2 illustrates the core data regarding various surface treatments applied to both uncoated and latex-painted surfaces. This data encompasses measurements from five distinct trials, wherein the weight of the samples was recorded in grams at the commencement and conclusion of each trial to ascertain the extent of weight loss. Moreover, the table also incorporates the distance traveled by the samples in a 25-second flame test to evaluate their susceptibility to fire.

Table 3: Raw Data on Various Surface Treatment for Double-Coated Marine Plywood with Different Ash Concentrations

Sunflower Stalk Ash Paint				(Double Coated)
Various Surface Treatment (SSAA)	**Replication**	**Initial Weight (Grams)**	**Final Weight (Grams)**	**Distance Travelled in 25s (Inches)**
8%	1	97	91	6.6250
	2	93	83	8.2500
	3	96	89	9.1250
	4	104	98	8.2500
	5	96	80	9.0000
10%	1	100	90	9.0000
	2	96	84	8.8750
	3	96	89	9.0000
	4	93	83	7.8125
	5	96	86	8.5000
12%	1	95	90	8.8750
	2	99	93	7.1875
	3	95	91	7.3750
	4	95	91	7.2500
	5	88	83	5.5000
14%	1	94	85	7.8750
	2	100	94	8.3750
	3	100	94	5.1250
	4	95	90	7.7500
	5	96	88	6.6875
16%	1	92	86	8.0000
	2	94	86	8.3750
	3	94	85	7.6250
	4	91	85	5.6875
	5	97	91	5.5000

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Table 3 presents the original data concerning diverse surface treatments applied to double-coated marine plywood samples treated with sunflower stalk ash, with five repetitions for each of the five different concentrations of ash. The weight of the samples was gauged in grams at both their initial and final stages to calculate weight loss. Similarly, the table includes data on the distance covered by the samples during a 25-second test.

Table 4: Raw Data on Various Surface Treatment for Triple-Coated Marine Plywood with Different Ash Concentrations

Sunflower Stalk Ash Paint (Triple Coated)				
Various Surface Treatment (SSAA)	**Replication**	**Initial Weight (grams)**	**Final Weight (grams)**	**Distance Travelled in 25s (inches)**
8%	1	109	98	6.7500
	2	100	87	6.7500
	3	100	93	7.0000
	4	98	89	8.6250
	5	103	97	6.7500
10%	1	105	94	6.6875
	2	95	84	9.2500
	3	105	98	8.0000
	4	100	95	7.1250
	5	103	98	6.1250
12%	1	92	85	7.7500
	2	89	86	9.0000
	3	91	85	7.5000
	4	96	89	8.5000
	5	107	100	8.0000
14%	1	95	88	9.1875
	2	103	96	6.6875
	3	104	96	6.5000
	4	104	99	6.0000
	5	104	98	8.0000
16%	1	100	88	6.3750
	2	107	98	7.0000
	3	103	94	6.5000
	4	95	84	6.6875
	5	96	89	5.3125

Table 4 exhibits the primary data for various surface treatments applied to triple-coated marine plywood samples treated with sunflower stalk ash. The dataset comprises five repetitions for each of the five different concentrations of ash. Initial and final weights of the samples were recorded to calculate weight loss. Additionally, the table provides details on the distance traveled by the samples during a 25-second test to evaluate their flame spread rates.

Table 5: Distance Travelled in 25s (Inches) for Surface Treatment of PMP and LPCMP

Various Surface Treatments	**Replication**	**Distance Travelled in 25s (inches)**	**Flame Spread Rate (in/sec)**
Plain Marine Plywood	1	11.0000	0.4400
	2	11.5000	0.4600
	3	12.0000	0.4800
	4	12.0000	0.4800
	5	12.0000	0.4800
	AVERAGE:		**0.4680**
Latex Paint Coated Marine Plywood	1	8.0000	0.3200
	2	10.3750	0.4150
	3	10.2500	0.4100
	4	11.0000	0.4400
	5	10.1875	0.4075
	AVERAGE:		**0.3985**

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Table 5 displays the distance covered in 25 seconds, measured in inches, by different surface treatments applied to plain marine plywood and marine plywood coated with latex paint. The data was gathered through experimentation to assess the flame spread rate of the individual samples.

For PMP, the surface treatment resulted in samples reaching a distance of 11 in, 11.5 in, 12 in, 12 in and 12 in for 5 replications. Conversely, for LPCMP, the distance traveled were 8 in, 10.375 in, 10.250 in, 11 in and 10.1875 in, in separate replications. The average flame spread rates were calculated to be 0.48 inches per second for PMP and 0.457 inches per second for LPCMP, based on the distances traveled by the flame within the 25-second duration.

Table 6: Distance Travelled in 25s (Inches) of Independent Variable of Double-Coated Marine Plywood with Different Ash Concentrations

Sunflower Stalk Ash Paint (Double Coated)			
Various Surface Treatment (SSAA)	Replication	Distance Travelled in 25s (inches)	Flame Spread Rate (in/sec)
8%	1	6.6250	0.2650
	2	8.2500	0.3300
	3	9.1250	0.3650
	4	8.2500	0.3300
	5	9.0000	0.3600
	AVERAGE:		**0.3300**
10%	1	9.0000	0.3600
	2	8.8750	0.3550
	3	9.0000	0.3600
	4	7.8125	0.3125
	5	8.5000	0.3400
	AVERAGE:		**0.3455**
12%	1	8.8750	0.3550
	2	7.1875	0.2875
	3	7.3750	0.2950
	4	7.2500	0.2900
	5	5.5000	0.2200
	AVERAGE:		**0.2895**
14%	1	7.8750	0.3150
	2	8.3750	0.3350
	3	5.1250	0.2050
	4	7.7500	0.3100
	5	6.6875	0.2675
	AVERAGE:		**0.2865**
16%	1	8.0000	0.3200
	2	8.3750	0.3350
	3	7.6250	0.3050
	4	5.6875	0.2275
	5	5.5000	0.2200
	AVERAGE:		**0.2815**

Table 6 shows the information collected from the 25-second flame spread ability test to determine the flame spread rate of the variables. The samples that are coated in different ash concentrations, with a second coat applied to each sample. The table indicates that the flame spread rate of the samples are in inches per second (in/sec). The average flame spread rate in 8% SSAA in LPCMP is 0.3300in/sec. In 10% SSAA, the average flame spread rate is 0.3455 in/sec. The average flame spread rate in 12%, 14% and 16% SSAA are 0.2865 in/sec, 0.2865 in/sec and 0.2815 in/sec respectively.

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Table 7: Distance Travelled in 25s (Inches) of Independent Variable of Triple-Coated Marine Plywood with Different Ash Concentrations

Sunflower Stalk Ash Paint (Triple Coated)			
Various Surface Treatment (SSAA)	Replication	Distance Travelled in 25s (inches)	Flame Spread Rate (in/sec)
8%	1	6.7500	0.2700
	2	6.7500	0.2700
	3	7.0000	0.2800
	4	8.6250	0.3450
	5	6.7500	0.2700
		AVERAGE:	**0.2870**
10%	1	6.6875	0.2675
	2	9.2500	0.3700
	3	8.0000	0.3200
	4	7.1250	0.2850
	5	6.1250	0.2450
		AVERAGE:	**0.2975**
12%	1	7.7500	0.3100
	2	9.0000	0.3600
	3	7.5000	0.3000
	4	8.5000	0.3400
	5	8.0000	0.3200
		AVERAGE:	**0.3260**
14%	1	9.1875	0.3675
	2	6.6875	0.2675
	3	6.5000	0.2600
	4	6.0000	0.2400
	5	8.0000	0.3200
		AVERAGE:	**0.2910**
16%	1	6.3750	0.2550
	2	7.0000	0.2800
	3	6.5000	0.2600
	4	6.6875	0.2675
	5	5.3125	0.2125
		AVERAGE:	**0.2550**

Table 7 displays the data collected from the 25-second flame spread ability test to determine the flame spread rate of the variables. The samples that are coated in different ash concentrations, with a triple coat applied to each sample. The table indicates that the flame spread rate of the samples are in inches per second (in/sec). The average flame spread rate in 8% SSAA in LPCMP is 0.2870 in/sec. In 10% SSAA the average flame spread rate is 0.2975 in/sec. The average flame spread rate in 12%, 14% and 16% SSAA are 0.3260 in/sec, 0.2910 in/sec and 0.2550 in/sec respectively.

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Table 8: Means of Flame Spread Rate on Various Surface Treatment

CONTROL 1	
PMP	0.4680
CONTROL 2	
LPCMP	0.3985
TREATMENT (DOUBLE COATED)	
8% SSAA	0.3300
10% SSAA	0.3455
12% SSAA	0.2895
14 % SSAA	0.2865
16% SSAA	0.2815
TREATMENT (TRIPLE COATED)	
8% SSAA	0.2870
10% SSAA	0.2975
12% SSAA	0.3260
14% SSAA	0.2910
16% SSAA	0.2550

Table 8. illustrates the means of various surface treatment in flame spread test. The controlled variables are PMP and LPCMP with an average of 0.4680 in/sec and 0.3985 in/sec respectively. Treatments includes the double coated and triple coated marine plywood with an additive of 8%, 10% 12%, 14% and 16% sunflower stalk ash. The double coated has 0.3300 in/sec, 0.3455 in/sec, 0.2895 in/sec, 0.2865 in/sec and 0.2815 in/sec respectively. Moreover, triple coated has 0.2870 in/sec, 0.2975 in/sec, 0.3260 in/sec, 0.2910 in/sec and 0.2550 in/sec respectively.

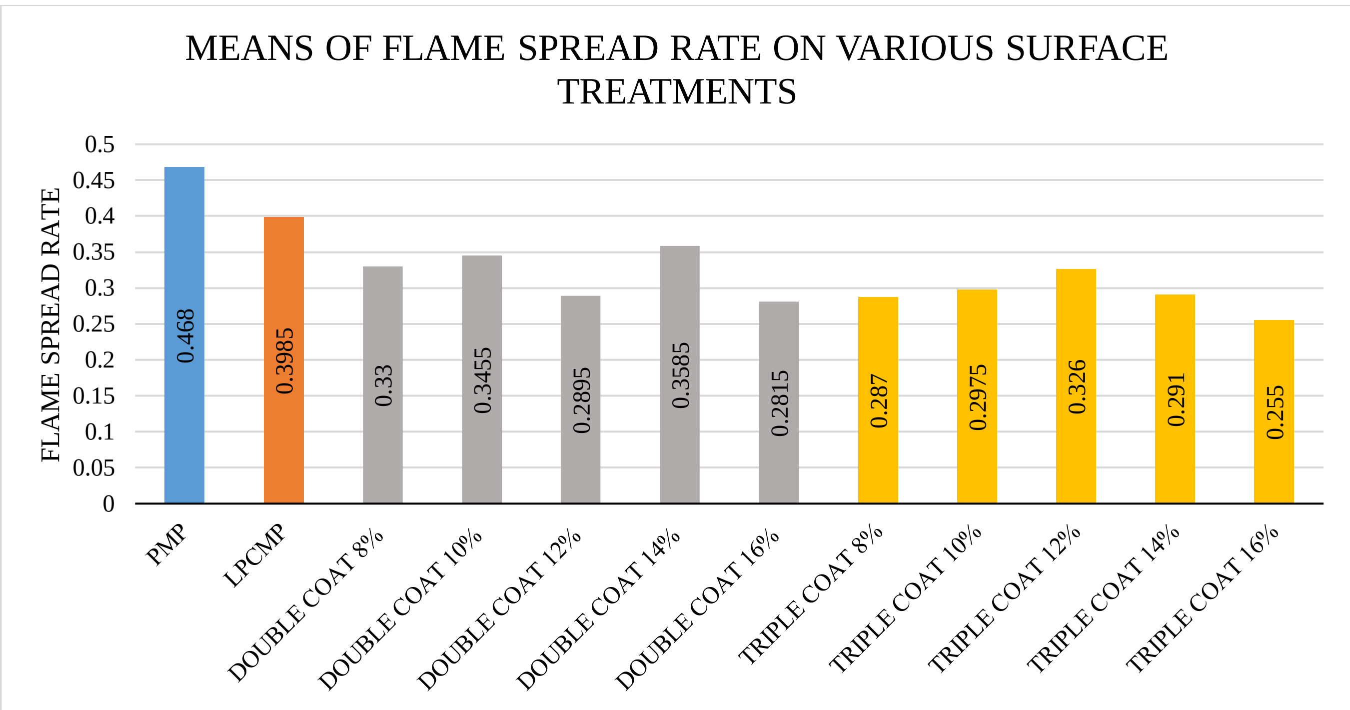

Fig 2: Means of Flame Spread Rate on Various Surface Treatment

Figure 2. displays the relationship between the mean of different surface treatments and the flame spread rate. It indicates that the lower the mean value results the slower the flame spread rate of the materials and the higher the value the faster the flame is spreading. The graph shows that the highest spread rate value is the PMP and the lowest mean value of spread rate is the triple-coated marine plywood with SSAA of 16%. Lower mean value means lower flame spread rate.

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According to the article in the USG (n.d.) entitled "Fire Performance", stated that "The low spread flame rating indicates a reduced probability of having a small fire develop into a room". In conclusion, when the spread of fire is low, it could imply a higher resistance against fire.

Table 9: Weight Loss of PMP and LPCMP on Various Surface Treatment

Various Surface Treatments	Replication	Initial Weight (grams)	Final Weight (grams)	Weight Loss (%)
Plain Marine Plywood	1	94	78	17.0213
	2	94	80	14.8936
	3	93	77	17.2043
	4	94	79	15.9574
	5	89	74	16.8539
			AVERAGE:	**16.3861**
Latex Paint Coated Marine Plywood	1	98	84	14.2857
	2	92	81	11.9565
	3	102	84	17.6471
	4	102	77	24.5098
	5	99	86	13.1313
	AVERAGE:			**16.3061**

Table 9 shows the initial and final weight of the sample in terms of grams. The sample were replicated five (5) times for each surface treatment for PMP and LPCMP.

The data was obtained by conducting experiments where the sample were weighed both before and after the test, and the information was utilized to compute the weight loss for each of the independent variables.

As shown on the table, there were five (5) replications on both independent variables to determine its weight loss. In PMP, the weight loss percentage are 17.0213%, 14.8936%, 17.2043% 15.9574% and 16.8539% having an average of 16.3861% from the replication 1,2,3,4 and 5 respectively. However, the weight loss in LPCMP are 14.2857%, 11.9565%, 17.6471%, 24.5098% and 13.1313% with an average percentage of 16.3061% from the replication 1, 2, 3, 4, and 5 respectively.

Table 10: Various Surface Treatment for Double-Coated Marine Plywood with Different Ash Concentrations

Sunflower Stalk Ash Paint (Double Coated)				
Various Surface Treatment (SSAA)	**Replication**	**Initial Weight (Grams)**	**Final Weight (Grams)**	**Weight Loss (Percent)**
8%	1	97	91	6.1856
	2	93	83	10.7527
	3	96	89	7.2917
	4	104	98	5.7692
	5	96	80	16.6667
	AVERAGE:			**9.3332**
10%	1	100	90	10.0000
	2	96	84	12.5000
	3	96	89	7.2917
	4	93	83	10.7527
	5	96	86	10.4167
	AVERAGE:			**10.1922**
12%	1	95	90	5.2632
	2	99	93	6.0606
	3	95	91	4.2105
	4	95	91	4.2105
	5	88	83	5.6818
	AVERAGE:			**5.0853**
14%	1	94	85	9.5745
	2	100	94	6.0000
	3	100	94	6.0000

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	4	95	90	5.2632
	5	96	88	8.3333
	AVERAGE:			**7.0342**
16%	1	92	86	6.5217
	2	94	86	8.5106
	3	94	85	9.5745
	4	91	85	6.5934
	5	97	91	6.1856
	AVERAGE:			**7.4772**

Table 10 displayed the initial and final weights of the samples, which are duplicated five (5) times for every independent variable of Double-Coated Marine Plywood with different concentrations. The average weight loss percentage in 8% SSAA in LPCMP is 9.3332%. In 10% SSAA, the average weight loss percentage is 10.1922%. The average weight loss percentage in 12%, 14% and 16% SSAA are 5.0853%, 7.0342% and 7.4772% respectively.

Table 11: Various Surface Treatment for Triple-Coated Marine Plywood with Different Ash Concentrations

Sunflower Stalk Ash Paint				**(Triple Coated)**
Various Surface Treatment (SSAA)	**Replication**	**Initial Weight (grams)**	**Final Weight (grams)**	**Weight Loss (percent)**
8%	1	109	98	10.0917
	2	100	87	13.0000
	3	100	93	7.0000
	4	98	89	9.1837
	5	103	97	5.8252
			AVERAGE:	**9.0201**
10%	1	105	94	10.4762
	2	95	84	11.5789
	3	105	98	6.6667
	4	100	95	5.0000
	5	103	98	4.8544
			AVERAGE:	**7.7152**
12%	1	92	85	7.6087
	2	89	86	3.3708
	3	91	85	6.5934
	4	96	89	7.2917
	5	107	100	6.5421
			AVERAGE:	**6.2813**
14%	1	95	88	7.3684
	2	103	96	6.7961
	3	104	96	7.6923
	4	104	99	4.8077
	5	104	98	5.7692
			AVERAGE:	**6.4868**
16%	1	100	88	12.0000
	2	107	98	8.4112
	3	103	94	8.7379
	4	95	84	11.5789
	5	96	89	7.2917
			AVERAGE:	**9.6039**

Table 11 shows the initial and final weights of the samples, which are duplicated five (5) times for every independent variable of Triple-Coated Marine Plywood with different concentrations. The average weight loss percentage in 8% SSAA in LPCMP is 9.0201%. In 10% SSAA, the average weight loss percentage is 7.7152%. The average weight loss percentage in 12%, 14% and 16% SSAA are 6.2813%, 6.4868% and 9.6039% respectively.

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Table 12: Means of Weight Loss Percentage on Various Surface Treatment

CONTROL 1	
PMP	16.3861
CONTROL 2	
LPCMP	16.3061
TREATMENT (DOUBLE COATED)	
8% SSAA	9.3332
10% SSAA	10.1922
12% SSAA	5.0853
14 % SSAA	7.0342
16% SSAA	7.4772
TREATMENT (TRIPLE COATED)	
8% SSAA	9.0201
10% SSAA	7.7152
12% SSAA	6.2813
14% SSAA	6.4868
16% SSAA	9.6039

Table 12 illustrates the means of various surface treatment in weight loss percentage. The controlled variables are PMP and LPCMP with an average of 16.3861% and 16.3061% respectively. Treatments includes the double coated and triple coated marine plywood with an additive of 8%, 10% 12%, 14% and 16% sunflower stalk ash. The double coated has 9.3332%, 10.1922%, 5.0853%, 7.0342% and 7.4772% respectively. Moreover, triple coated has 9.0201%, 6.2813%, 6.4868% and 9.6039% respectively.

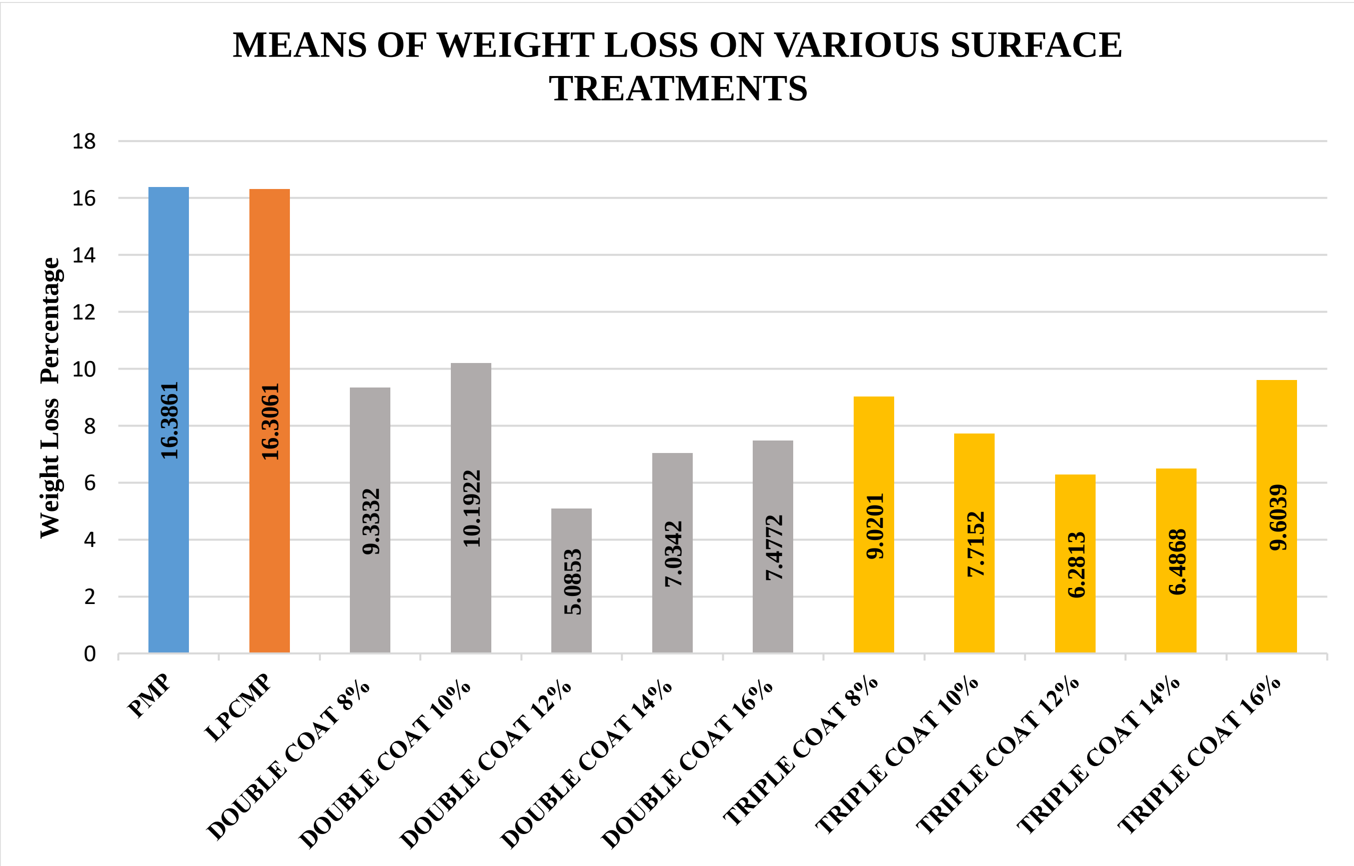

Fig 3: Means of Weight Loss on Various Surface Treatment

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Figure 3. displays the relationship between the mean of different surface treatments and the weight loss percentage. It indicates that a lower mean value results in a lower weight loss percentage of the materials and the higher the value the higher the weight loss percentage of the materials. The graph shows that the highest weight loss percentage value is the plain marine plywood and the lowest mean value of spread rate is the double-coated marine plywood with SSAA of 12%. Lower mean value indicates lower weight loss percentage.

According to Pavlo Bekha et al. (2016) in the research study entitled "Effect of different fire retardants on Birch plywood properties", states that "It is known that lower total weight loss implies higher resistance against thermal degradation of fire".

Moreover, the research study of Adelaida Fanfarova et al. (2016) entitled "Testing of Fire Retardants" stated that "The best results achieves the lowest value of weight loss and was able to withstand initiation of the combustion process longer".

Overall, when a material has a lower total weight loss when exposed to fire, it shows that it retains more of its original mass during the burning process and to take a longer time to start burning. It is an indicator of higher resistance against thermal degradation.

A. Correlation of Flame Spread Rate and Weight Loss Percentage

The correlation between the mean of the flame spread rate and weight loss percentage in which the values of the flame spread rate were accumulated by multiplying the mean by 100 and using the 1:3 ratio to establish the correlations of the variables. Based on the graph shows in the Figure 2 and 3, the consistent variation of surface treatment is the Triple-Coated Marine Plywood with SSAA of 16%. The Triple-Coated Marine Plywood with 16% SSAA has a mean of 25.5 inches per second and 28.8% in Flame Spread Rate and Weight Loss Percentage respectively.

B. One-Way ANOVA (Analysis of Variance)

Based in the Data Analysis and Techniques section, the researchers used the one-way ANOVA utilizing the Statistical Package for the Social Sciences (SPSS) to analyze the data gathered. The ANOVA method was selected to evaluate the impact of the various surface treatments on flame spread rate and weight loss.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
FlameSpreadRate2C	Between Groups	.125	5	.025	14.787	.000
	Within Groups	.041	24	.002		
	Total	.166	29			
FlameSpeadRate3C	Between Groups	.143	5	.029	22.230	.000
	Within Groups	.031	24	.001		
	Total	.174	29			

Fig 4: ANOVA Test Results for PMP VS SSAA on Flame Spread Rate

Figure 4 illustrates that one-way analysis of variance was performed to determine the significant difference between PMP and SSAA in terms of Flame Spread Rate. Results show that there is a significant difference between PMP and SSAA in terms of Flame Spread Rate both with double coated and triple coated. Post hoc analysis using Dunnett showed that the average flame spread rate in inch per second (in/sec) of PMP is significantly higher than the average flame spread rate of SSAA with double coated in 8%, 10%, 12%, 14% and 16%. Likewise, the average flame spread rate in inch per second (in/sec) of PMP is significantly higher than the average flame spread rate of SSAA with triple coated in 8%, 10%, 12%, 14% and 16%.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
WeightLoss2C	Between Groups	386.080	5	77.216	14.763	.000
	Within Groups	125.530	24	5.230		
	Total	511.610	29			
WeightLoss3C	Between Groups	349.530	5	69.906	15.470	.000
	Within Groups	108.454	24	4.519		
	Total	457.984	29			

Fig 5: ANOVA Test Results for PMP VS SSAA on Weight Loss

Figure 5 shows that one-way analysis of variance was performed to determine the significant difference between PMP and SSAA in terms of Weight Loss. Results show that there is a significant difference between PMP and SSAA in terms of Weight Loss both with double coated and triple coated. Post hoc analysis using Dunnett showed that the average weight loss percentage (%) of PMP is significantly higher than the average weight loss percentage of SSAA with double coated in 8%, 10% 12%, 14% and 16%. Likewise, the average weight loss percentage (%) of PMP is significantly higher than the average weight loss percentage of SSAA with triple coated in 8%, 10%, 12%, 14% and 16%.

To sum up, based on the results in Figure 4 and 5, it implies that SSAA with double coated and triple coated in terms of flame spread rate and weight loss percentage in all concentration percentage is more effective as an alternative organic fire-retardant paint than PMP. Therefore, the collected data are sufficient to reject the null hypothesis and accept the alternative hypothesis where:

- Null Hypothesis (H_o): There is no significant difference between the Plain Marine Plywood and Latex Paint with Sunflower Stalk Ash Coated Marine Plywood in terms of Flame Spread Rate and Weight Loss percentage.
- Alternative Hypothesis (H_a): There is a significant difference between the Plain Marine Plywood and Latex Paint with Sunflower Stalk Ash Coated Marine Plywood in terms of Flame Spread Rate and Weight Loss percentage.

Table 13: ANOVA Test Results for LPCMP VS SSAA on Flame Spread Rate

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
FlameSpreadRate2C2	Between Groups	.052	5	.010	5.232	.002
	Within Groups	.048	24	.002		
	Total	.100	29			
FlameSpreadRate3C2	Between Groups	.061	5	.012	7.684	.000
	Within Groups	.038	24	.002		
	Total	.099	29			

Table 13 shows that one-way analysis of variance was performed to determine the significant difference between LPCMP and SSAA in terms of Flame Spread Rate. Results show that there is a significant difference between LPCMP and SSAA in terms of Flame Spread Rate both with double coated and triple coated. Post hoc analysis using Dunnett showed that the average flame spread rate in inch per second (in/sec) of LPCMP is significantly higher than the average flame spread rate of SSAA with double coated in 12%, 14% and 16% but not in 8% and 10%. Likewise, the average flame spread rate in inch per second (in/sec) of PMP is significantly higher than the average flame spread rate of SSAA with triple coated in 8%, 10%, 12%, 14% and 16%.

Table 14: ANOVA Test Results for LPCMP VS SSAA on Weight Loss

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
WeightLoss2C2	Between Groups	380.397	5	76.079	8.151	.000
	Within Groups	224.007	24	9.334		
	Total	604.404	29			
WeightLoss3C3	Between Groups	343.846	5	68.769	7.976	.000
	Within Groups	206.930	24	8.622		
	Total	550.776	29			

Table 14 displays that one-way analysis of variance was performed to determine the significant difference between LPCMP and SSAA in terms of Weight Loss. Results show that there is a significant difference between LPCMP and SSAA in terms of Weight Loss both with double coated and triple coated. Post hoc analysis using Dunnett showed that the average weight loss percentage (%) of LPCMP is significantly higher than the average weight loss percentage of SSAA with double coated in 8%, 10%, 12%, 14% and 16%. Likewise, the average weight loss percentage (%) of PMP is significantly higher than the average weight loss percentage of SSAA with triple coated in 8%, 10%, 12%, 14% and 16%.

To sum up, based on the results in Table 13 and 14, it shows that SSAA with double coated in 12%, 14% and 16% concentration but not in 8% and 10%concentration; and triple coated in terms of flame spread rate in all concentration percentage is more effective as an alternative organic fire-retardant paint than LPCMP. Moreover, it also states that SSAA with double coated and triple coated in terms of weight loss in all concentration percentage is more effective as an alternative organic fire-retardant paint than LPCMP. Therefore, gathered data are sufficient to reject the null hypothesis and accept the alternative hypothesis where:

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- Null Hypothesis H_o: There is no significant difference between the Latex Paint Coated Marine Plywood and Latex Paint with Sunflower Stalk Ash Coated Marine Plywood in terms of Flame Spread Rate and Weight Loss percentage. Sunflower Stalk Ash when added to Latex Paint will increase fire-resistance.
- Alternative Hypothesis: H_a: There is a significant difference between the Latex Paint Coated Marine Plywood and Latex Paint with Sunflower Stalk Ash Coated Marine Plywood in terms of Flame Spread Rate and Weight Loss percentage. Sunflower Stalk Ash when added to Latex Paint will increase fire-resistance.

C. Post-Hoc Test (Dunnett's Test)

In this study, a Post-Hoc Test was conducted to provide a more detailed interpretation of the results gathered from the ANOVA analysis. The ANOVA analysis is used to determine if there is a significant difference between the groups under investigation. Hence, the Post-Hoc Test is necessary to identify whether a particular groups or conditions varied significantly from one another.

In the Appendix E section, the results of the Post-Hoc Test conducted after the ANOVA analysis is presented. The Figure shows the information about the mean differences, standard errors of differences, significance levels for each pair of groups and 95% confidence intervals. By examine the figures, the researchers can determine which specific groups differ significantly from each other and gain a deeper understanding of the differences observed in the ANOVA analysis.

D. Summary of Multiple Comparison of Flame Spread Rate from Post-Hoc Test (Dunnett's Test)

Referring to Appendix E, for example in Table 13 the result of post-hoc analysis using Dunnett showed that the average flame spread rate in inch per second (in/sec) of PMP is significantly higher than the average flame spread rate of SSAA with double coated in 8%, 10%, 12%, 14% and 16% Likewise, the average flame spread rate in inch per second (in/sec) of PMP is significantly higher than the average flame spread rate of SSAA with triple coated in 8%, 10%, 12%, 14% and 16% given that 16% is the most effective among all the concentration.

Therefore, based on the results, the researchers can conclude that there are significant differences in the Flame Spread Rate between various Surface Treatment. The findings suggest that the Flame Spread Rate in various concentration is more effective in preventing or delaying the spread of fire.

E. Summary of Multiple Comparison of Weight Loss Percentage from Post-Hoc Test (Dunnett's Test)

Referring to Appendix E, for example in Table 14 the results of Post-hoc analysis using Dunnett showed that the average weight loss percentage (%) of PMP is significantly higher than the average weight loss percentage of SSAA with double coated in 8%, 10%, 12%, 14% and 16%. Likewise, the average weight loss percentage (%) of PMP is significantly higher than the average weight loss percentage of SSAA with triple coated in 8%, 10%, 12%, 14% and 16% given that 12% is the most effective among all the concentration.

Therefore, based on the results, the researchers can conclude that there are significant differences in the Weight Loss percentage between various Surface Treatment, but not all of them. The findings suggest that the Weight Loss Percentage in various concentration is more effective in preventing or delaying the spread of fire.

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CHAPTER FOUR
SUMMARY OF FINDINGS

This research explored the use of sunflower stalk, a byproduct of agriculture, as an additive in latex paint to enhance the fire resistance of marine plywood. Sunflower Stalk was harvested at Ver's Sunflower Farm in Barangay Talipapa, Cabanatuan City. Subsequently, Sunflower Stalk ash was created and mixed into latex paint at various concentrations. The fire-retardant properties of the sunflower stalk ash latex paint were evaluated using the simplified flame spread rate.

The resulting sunflower stalk latex paint exhibited improved fire retardancy, as shown in flame spread tests, indicating reduced flame spread and weight loss. As regards to flame spread rate, the sunflower stalk ash additive of 16% has the lowest flame spread rate. Hence, in terms of weight loss percentage, the sunflower stalk ash additive of 12% has the lowest weight loss percentage. Altogether, the study identified 16% as the optimal concentration of sunflower stalk ash, balancing fire resistance with maintaining plywood mechanical properties. This approach offers a cost-effective and eco-friendly alternative to traditional fire retardants, underscoring the potential of agricultural waste in sustainable construction materials. Future investigations could explore sunflower Stalk ash's efficacy with other building materials and in different environmental conditions.

A. Conclusion

Based on the research results and collected data, the researcher reached several conclusions. Statistical analysis revealed significant differences among the three independent variables concerning weight loss and flame spread rate, with flame spread rate being influenced solely by the distance the flame traveled in 25 seconds on the coated surface. Marine plywood coated with sunflower stalk ash paint exhibited lower fire retardancy. Additionally, marine plywood coated thrice with a 16% concentration of sunflower stalk ash in latex paint showed the most consistent results, balancing flame spread rate and weight loss.

Based on ANOVA test and Post-Hoc Test (Dunnet's Method) drawn from the analysis on SSAA, both double coated and triple coated, exhibits superior performance over PMP and LPCMP in terms of both Flame Spread Rate and Weight Loss across various concentration percentages. Therefore, SSAA appears to be a more effective alternative organic fire-retardant paint compared to PMP and LPCMP.

B. Recommendation

Here are the recommendations based on the findings regarding the use of sunflower stalk ash in latex paint for enhancing the fire resistance of marine plywood:

- Further exploration is needed to determine how effective sunflower stalk ash is as a fire retardant in other wood products like particleboard and medium-density fiberboard.
- More research should be conducted to find the optimal amount of sunflower stalk ash that maintains fire resistance while preserving the mechanical properties of plywood.
- Long-term durability tests are necessary to assess how sunflower stalk ash-coated marine plywood withstands various environmental conditions and exposure to weather and moisture.
- Additional studies should focus on generating ash in a more efficient and appropriate manner.
- To maintain a consistent flame intensity, the butane in the blow torch should be inspected and replaced as necessary, or after every 10 to 15 samples.

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