

Developing Fire Resistant Compound from Household Material

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Abstract

This technical paper addresses the escalating global demand for fire-resistant materials by investigating a compound synthesized from commonplace household ingredients: corn-starch, baking soda, and PVA glue. The primary objective is to develop an effective fire-resistant compound with a focus on specific goals. Firstly, the study explores the workability of fire-resistant compounds using only three ingredients. Secondly, it measures the influence of varying material ratios on the compound's properties. Thirdly, it aims to identify the optimal concentration of materials for crafting a reliable fire-resistant material. The methodology involves meticulous sample preparation, ensuring high-quality ingredients and precise measurements. Two types of samples are crafted for distinct tests, covering thermal conductivity and fire resistivity. The control sample undergoes comprehensive testing, including wet and dry weight difference analysis, thermal conductivity tests, and fire resistivity experiments. Results indicate intriguing trends, with corn-starch showcasing hygroscopic behaviour and baking soda acting as a thermal conductor with a positive correlation to concentration. Corn-starch, as an insulator, demonstrates a negative correlation, while PVA glue introduces complexities in constraining thermal conductivity. In fire resistivity experiments, elevated baking soda concentrations enhance fire resistivity, aligning with its role as a flame retardant. Corn-starch consistently contributes to increased fire resistivity due to its insulating properties, and PVA glue emerges as a vital binding agent fortifying the compound against combustion. The delicate balance observed among these components highlights the nuanced interplay necessary for crafting an effective fire-resistant compound. This research not only contributes empirical data but also sets the stage for ongoing exploration, encouraging the refinement of formulations and the continuous evolution of fire-resistant materials. As the paper concludes, it marks not an endpoint but a transformation into new avenues of exploration and innovation.

1. Introduction

In response to the escalating global demand for fire-resistant materials, this technical paper explores formulating a compound using commonplace household ingredients—cornstarch, baking soda, and PVA glue. The principal components undergo meticulous analysis to unravel their synergies and impacts on crucial material properties. Initiating with a detailed examination of wet and dry weight differences, intriguing trends emerge, notably with corn-starch playing a pivotal role, showcasing consistent increases indicative of its hygroscopic nature. This observation lays the groundwork for understanding the moisture absorption characteristics of the compound, providing empirical insights into its behavior under different compositional conditions.

The subsequent thermal conductivity study unfolds intricate relationships within the compound. It positions baking soda as a thermal conductor, showcasing a positive correlation with increasing concentrations. In contrast, corn-starch, acting as an insulator, exhibits a negative correlation, influencing the compound's heat dissipation capabilities. The introduction of PVA glue introduces nuanced dynamics to thermal conductivity. The careful examination of these elements deepens our understanding of the material's behavior and hints at the delicate balance required for optimal performance.

The exploration extends further into the realm of fire resistivity, revealing compelling insights into each component's contribution. Baking soda emerges as a robust flame retardant, accentuating fire resistivity with elevated concentrations. Corn-starch, with its insulating prowess, aligns with increased fire resistivity, providing a layered approach to fire protection. PVA glue's role as a binding agent prominently fortifies the compound against combustion. These findings contribute to empirical knowledge and set the stage for broader implications in material science.

Simultaneously, the study addresses specific objectives aimed at developing an effective fire-resistant compound from readily available household materials. The primary goals involve preparing and investigating the workability of these compounds, measuring the impact of varying material ratios, and identifying optimal concentrations for reliable fire resistance through a comprehensive comparison of samples. By methodically addressing these objectives, the research aspires to significantly contribute to developing an effective fire-resistant compound, offering a practical and accessible solution to enhance fire safety in residential and commercial settings.

2. Methodology

This methodology centers on the comprehensive analysis of a fire-resistant compound formulated from commonplace household ingredients—corn-starch, baking soda, and PVA glue. The initial phase involves scrutinizing wet and dry weight differences, employing meticulous measurements to capture the hygroscopic nature of corn-starch, which exhibits consistent increases. The thermal conductivity study follows, where concentrations of baking soda, corn-starch, and PVA glue are systematically varied. Baking soda emerges as a thermal conductor, showing a positive correlation with increasing concentrations. In contrast, corn-starch, acting as an insulator, exhibits a negative correlation, influencing heat dissipation. PVA glue introduces nuanced dynamics, constraining thermal conductivity with rising concentrations. The investigation extends to fire resistivity, assessing the flame-retardant capabilities of baking soda, the insulating prowess of corn-starch, and the binding strength of PVA glue. The study utilizes established fire resistivity testing methods, observing the compound's response to varying ingredient concentrations. This methodology integrates multiple techniques, including wet and dry weight measurements, thermal conductivity assessments, and fire resistivity testing, offering a holistic understanding of the formulated compound's behavior under different conditions. The results obtained from these varied analyses contribute to a nuanced understanding of the compound's multifaceted properties, facilitating the formulation of recommendations for optimizing fire-resistant materials crafted from common household ingredients. The methodology ensures precision through systematic variations, employing established testing methods, and adhering to stringent cleaning procedures during each characterization process.

2.1 Sample Preparation

The preparatory phase involves carefully selecting and procuring high-quality corn-starch, baking soda, and PVA glue. For the thermal conductivity test, the dry materials are precisely mixed using the Kakuhunter Planetary Centrifugal Mixer. The glue is then measured and incorporated into the dry mix using a mortar and pestle, resulting in a putty with a consistency akin to modeling clay. Subsequently, the mixtures are molded into cuboidal forms measuring 2.54 cm (1 inch) in length, 2 cm in width, and 0.5 cm in thickness. Simultaneously, for the naked butane flame test, the prepared mixtures are shaped into discs with a diameter of 7.62 cm and a thickness of 0.5 cm, as illustrated in Figure 3.1[3]. The samples are then left to dry in a Memmert oven at 30°C for 48 hours. This comprehensive process ensures uniformity in sample preparation, a prerequisite for the ensuing thermal conductivity and fire resistivity tests.

2.2 Wet and Dry Weight Difference

In the weight difference experiment, samples are initially weighed, and these measurements serve as the baseline. Subsequently, the samples are placed in the Memmert oven for 48 hours. After the designated time, the samples are reweighed. The weight differences between the initial and final measurements are then calculated and meticulously recorded for analysis.

2.3 Thermal Conductivity Test

In the thermal conductivity experiment, samples are positioned on a heated surface, connected to a power supply with a specified voltage (10 V) and current (0.5 A), and subjected to controlled conditions [3]. Temperature changes are measured over time using thermocouples at key points. To ensure efficient heat transfer, a layer of thermal paste is applied between the sample and the heated surface. The experiment involves recording temperature variations, allowing the assessment of how well the material conducts or insulates heat. The goal is maintaining steady temperatures for precise measurements, contributing to a comprehensive understanding of thermal conductivity properties.

2.4 Naked Flame test

In the fire resistivity test, samples undergo exposure to a naked butane flame for a predefined duration [3]. One side of the specimen is directly exposed to the flame, while temperature measurements are recorded on both exposed and unexposed sides. The resulting carbon layer and its peak temperature are measured and documented. This test helps evaluate the material's ability to resist and inhibit heat penetration, providing insights into its performance under fire-like conditions. The recorded data aids in understanding how different concentrations of components, such as baking soda, PVA glue, and corn-starch, influence the material's resistance to combustion and heat propagation.

3. Results and Discussion

In addressing the surging global demand for fire-resistant materials, this study meticulously explores a compound formulated from commonplace household ingredients — corn-starch, baking soda, and PVA glue. The analysis delves into their synergies and impacts on crucial material properties, commencing with examining wet and dry weight differences, revealing corn-starch's hygroscopic nature. The subsequent thermal conductivity study unveils intricate relationships, identifying baking soda as a thermal conductor and corn-starch as an insulator, with PVA glue introducing nuanced dynamics. Extending to the fire resistivity test, baking soda emerges as a robust flame retardant, corn-starch aligns with increased fire resistivity, and PVA glue fortifies the compound against combustion as a binding agent. This paper contributes empirical insights into household materials under fire-resistant considerations, laying the foundation for broader implications in material science. The delicate balance observed between moisture absorption, thermal conductivity, and fire resistivity opens avenues for refining formulations and advancing fire-resistant materials, fostering innovation in crafting safer environments.

3.1 Wet and Dry Weight Difference Analysis

Meticulous investigation into wet and dry weight differences is pivotal to unraveling the behavior of the compound under varying compositional conditions. The process begins with careful sample preparation, introducing controlled concentrations of corn-starch, baking soda, and PVA glue. Rigorous adherence to systematic measurements and precise mixing protocols ensures the reliability and repeatability of the experiments. The observed trend in Fig. 3.1, showcasing an increase in weight difference with rising corn-starch concentrations, underscores the hygroscopic nature of corn-starch. This empirical insight becomes foundational in understanding how the compound responds to differing moisture-absorption characteristics. As baking soda concentrations increase, Fig. 3.2 reveals a noteworthy decrease in the wet and dry weight difference, suggesting a potential correlation between higher baking soda content and reduced moisture retention. Conversely, the rising wet and dry weight difference with elevated PVA glue concentrations, as depicted in Fig. 3.3, emphasizes the adhesive nature of PVA glue, contributing to increased water retention within the compound. These detailed observations refine our understanding of the intricate interplay of compositional elements, offering nuanced insights into the compound's responsiveness to varying concentrations of its core components.

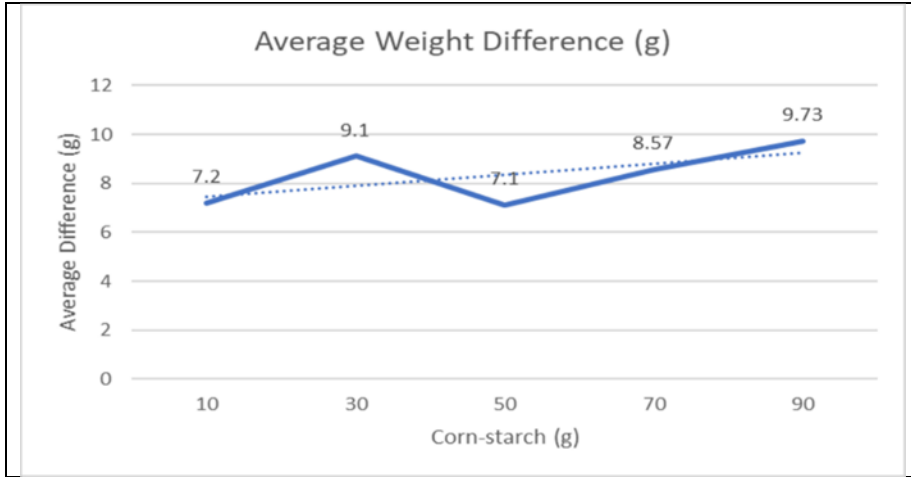


Fig. 3.1 Average Weight Difference When Corn-Starch Is Increased

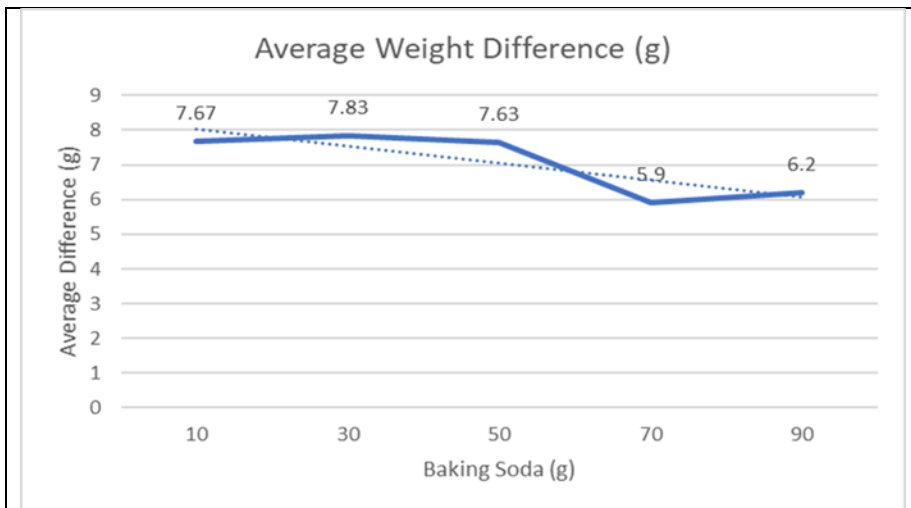


Fig. 3.2 Average Weight Difference When Baking Soda Is Increased

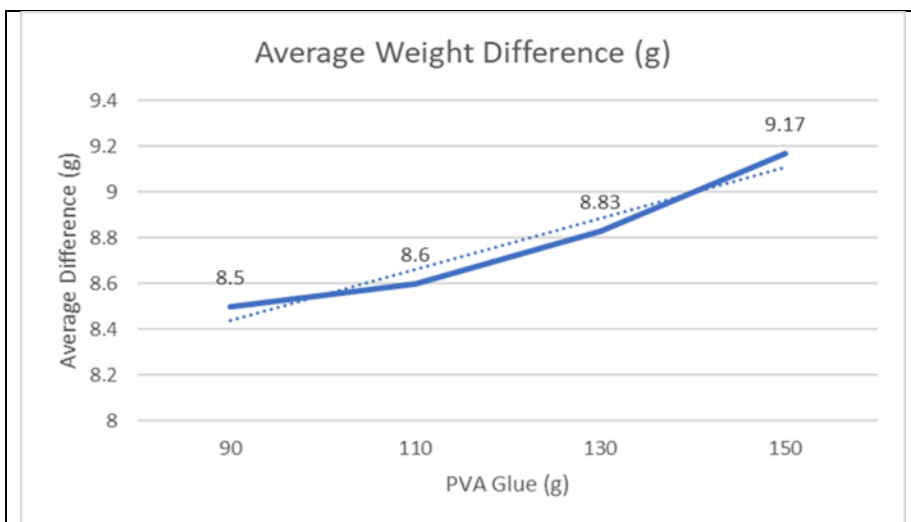


Fig. 3.3 Average Weight Difference When PVA Glue Is Increased

3.2 Thermal Conductivity Analysis

The exploration into thermal conductivity, detailed in Section 3.2, unravels intricate relationships between the compound's composition and its heat dissipation capabilities. Each core component — corn-starch, baking soda, and PVA glue — plays a distinctive role in shaping the thermal conductivity of the compound, offering valuable insights for potential applications. Corn-starch, acting as an insulator, demonstrates a negative correlation with thermal conductivity, as revealed in Fig. 3.4. This indicates that as concentrations of corn-starch increase, the compound's ability to conduct heat decreases, aligning with the material's role in impeding heat transfer and contributing to the overall thermal insulating properties. In contrast, as baking soda concentrations increase, a positive correlation with thermal conductivity is observed, as illustrated in Fig. 3.5. This phenomenon aligns with baking soda's role as a thermal conductor, suggesting that higher concentrations enhance the compound's ability to dissipate heat efficiently. The figure shows the compound's improved thermal conductivity with higher baking soda content. Interestingly, increasing concentrations of PVA glue introduce a nuanced dynamic, constraining thermal conductivity, as depicted in Fig. 3.6. This reveals that higher amounts of PVA glue restrict heat transfer within the compound, shedding light on the adhesive nature of PVA glue and its role in shaping the compound's heat-related properties. This comprehensive thermal conductivity analysis provides nuanced insights into how specific components contribute to the overall thermal behavior of the compound, laying the foundation for optimizing its application in contexts requiring controlled heat dissipation.

3.2.1 Equations

The formula for thermal conductivity as shown in equation 3.1 is a fundamental expression used to quantify the ability of a material to conduct heat.

$$\text{Thermal Conductivity, } K = \frac{Q(W) \cdot L(m)}{A(m^2) \cdot \Delta T(^{\circ}C)} \quad (3.1)$$

Each term in the formula has a specific significance:

K; Thermal Conductivity

This is the parameter we are trying to measure. It represents the ability of a material to conduct heat. Materials with high thermal conductivity transfer heat more effectively than those with low thermal conductivity.

Q; Heat Transfer

This is the amount of heat transferred per unit time. The unit for heat is watts (*W*). The formula shows that the thermal conductivity is directly proportional to the heat transfer. If the thermal conductivity of a material increased, it will transfer more heat.

L; Length of Material

The length of the material through which heat is being conducted. The longer the path for heat conduction, the more resistance the material offers to heat flow. This is why it's in the denominator of the formula.

A; Cross-Sectional Area

The cross-sectional area of the material. It represents the area through which heat is conducted. Larger cross-sectional areas enhance heat transfer, and this is why it's in the numerator of the formula.

T; Temperature Difference

This represents the difference in temperature across the material. Heat naturally flows from areas of higher temperature to lower temperature. The greater the temperature difference, the more heat is conducted. Using the following formula will result in Table 3.3.

Table 3.1 Thermal conductivity;K(W.mK)

Material Amount (g)			Thermal conductivity;K (W.mK)
Corn	Soda	Glue	
100	10	110	0.8788
100	30	110	0.9063
100	50	110	0.8759
100	70	110	0.8980
100	90	110	0.9764
10	100	110	1.4120
30	100	110	1.3295
50	100	110	1.2986
70	100	110	1.1912
90	100	110	1.1323
100	10	90	0.9442
100	10	110	0.8936
100	10	130	0.8814
100	10	150	0.8536

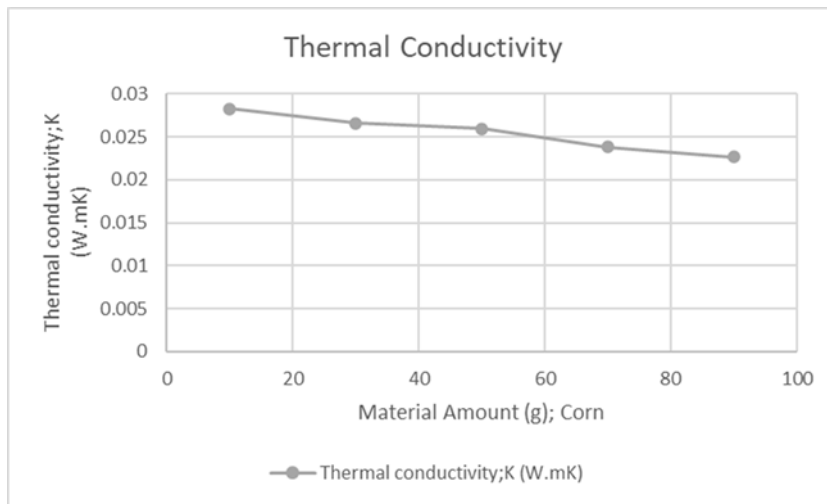


Fig. 3.4 Average Thermal Conductivity for Increasing Corn-starch (g)

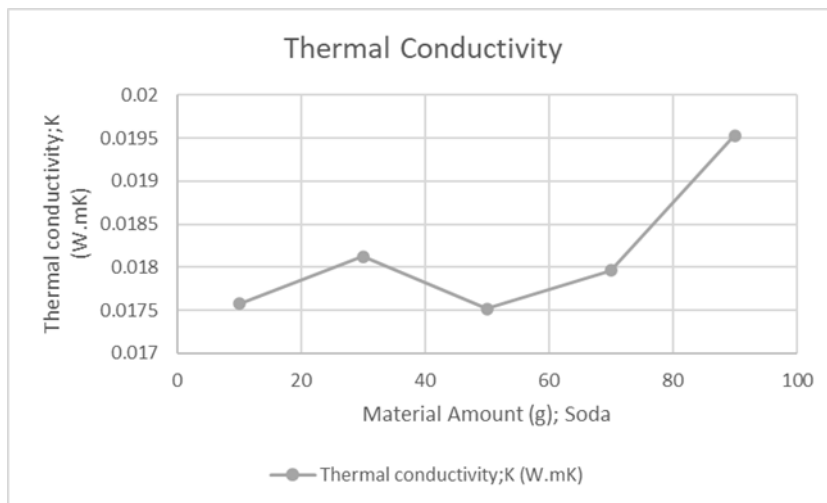


Fig. 3.5 Average Thermal Conductivity for Increasing Baking Soda (g)

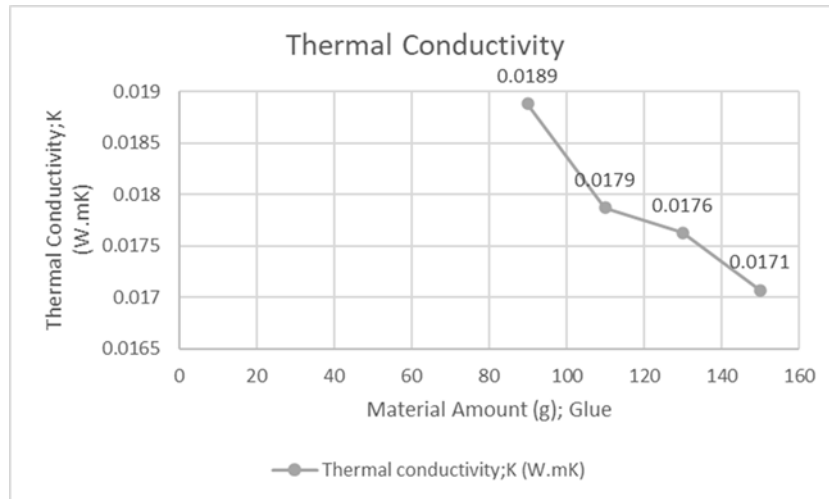


Fig. 3.6 Average Thermal Conductivity for Increasing Baking Soda (g)

3.3 Naked Flame test

The Naked Flame Test, detailed in Section 3.3, serves as a pivotal examination of the material's response to a naked butane flame, providing essential insights into its protective characteristics. This test reveals significant correlations between increased concentrations of specific components and heightened fire resistivity. Notably, baking soda emerges as a robust flame retardant, showing a pronounced positive correlation with improved fire resistivity as depicted in Table 3.2 and Fig. 3.7. This implies that higher concentrations of baking soda fortify the material against combustion and heat penetration. Similarly, elevated levels of PVA glue showcase a pronounced positive correlation with enhanced fire resistivity, leveraging its adhesive properties to augment the material's overall heat resistance, as illustrated in Table 3.3 and Fig. 3.8. In contrast, corn-starch, known for its insulating qualities, positively contributes to fire resistivity with increased concentrations, forming a barrier that limits heat penetration resistance, as portrayed in Table 3.4 and Fig. 3.9. The combined impact of these components results in a material demonstrating superior fire resistivity, showcasing an enhanced ability to withstand heat, inhibit flame propagation, and maintain structural integrity. These observed trends offer valuable insights for formulating effective fire-resistant compounds from common household materials, guiding future formulations toward optimal concentrations for superior fire-resistant properties.

Table 3.2 Naked Flame Sample Composition (Increased Baking Soda)

Series	Material Amount (g)		
	Corn	Soda	Glue
1	100	10	110
2	100	30	110
3	100	50	110
4	100	70	110
5	100	90	110

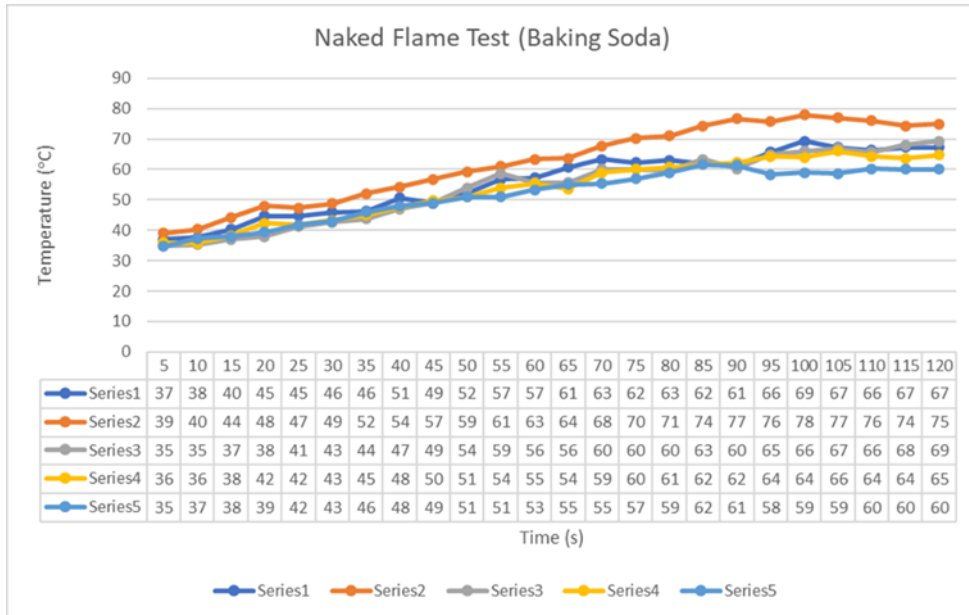


Fig. 3.7 Naked Flame Test for Increasing Baking Soda (g)

Table 3.3 Naked Flame Sample Composition (Increased PVA Glue)

Series	Material Amount (g)		
	Corn	Soda	Glue
1	100	10	90
2	100	10	110
3	100	10	130
4	100	10	150

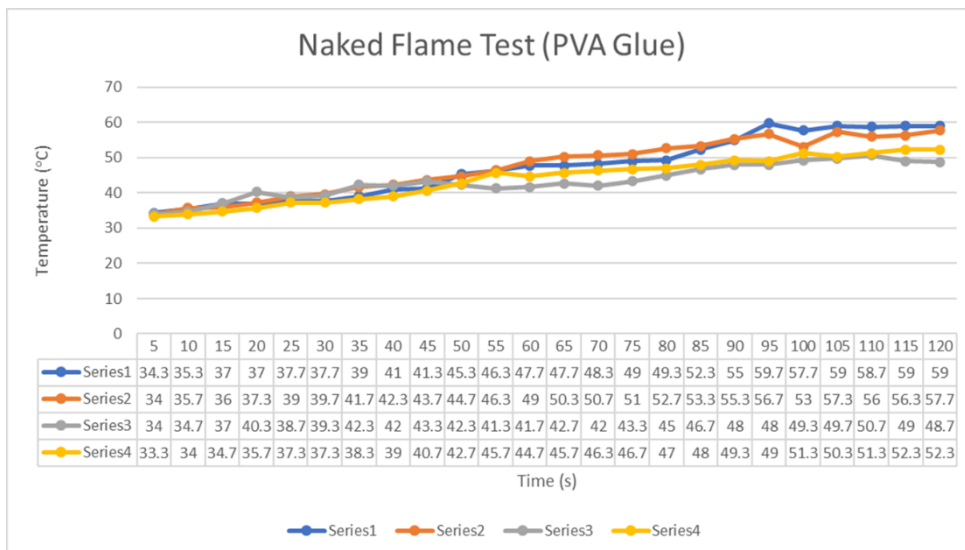


Table 3.4 Naked Flame Sample Composition (Increased Corn-Starch)

Series	Material Amount (g)		
	Corn	Soda	Glue
1	10	100	110
2	30	100	110
3	50	100	110
4	70	100	110
5	90	100	110

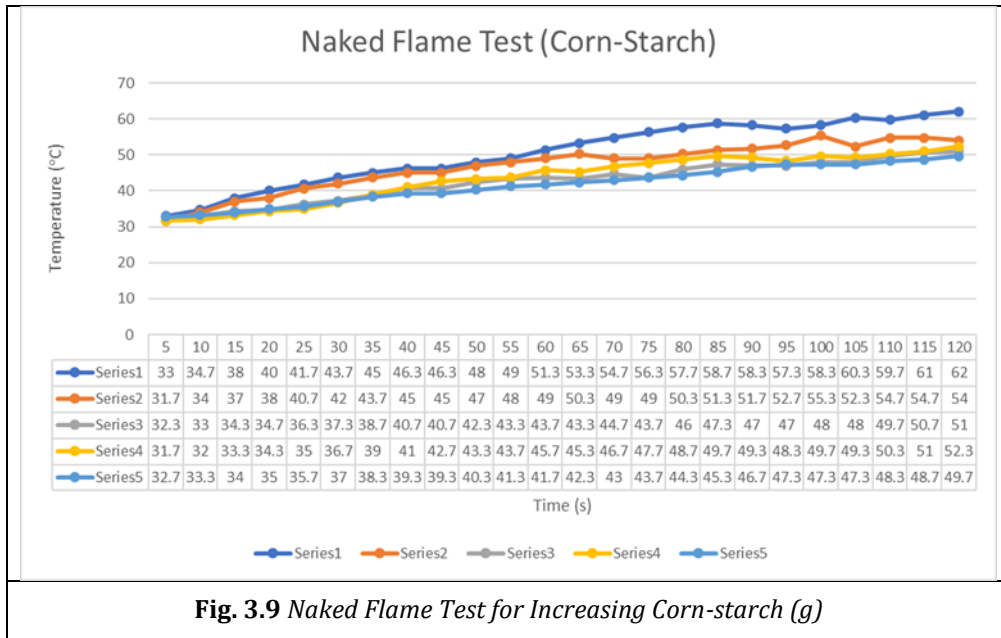


Fig. 3.9 Naked Flame Test for Increasing Corn-starch (g)

4. Conclusion

Concluding our exploration of fire-resistant compounds derived from household ingredients, we distill vital insights from our comprehensive study. The dynamic interplay among corn-starch, baking soda, and PVA glue significantly influences wet and dry weight differences, thermal conductivity, and fire resistivity. Baking soda emerges as a notable thermal conductor, amplifying heat dissipation, while corn-starch, serving as an insulator, tempers the compound's thermal behavior. The nuanced dynamics introduced by PVA glue in thermal conductivity enhance the complexity of our findings. In the realm of fire resistivity, each component plays a pivotal role — baking soda proves to be a robust flame retardant, corn-starch elevates resistivity, and PVA glue fortifies against combustion. This research not only deepens our understanding of these household materials but lays a foundation for crafting advanced fire-resistant solutions. As we conclude this chapter, it encapsulates a trail of significant insights, urging the scientific community to optimize these ingredients for creating safer environments. This culmination of our journey is not an endpoint but a prelude to further exploration and innovation in the realm of fire protection.

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Conflict of Interest

There is no conflict of interests regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design, data collection, methodology, analysis and interpretation of results:** Luqman Al Hakim Mohd Asri and Mohamad Zaky Noh. All authors reviewed the results and approved the final version of the manuscript.*

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