

THERMAL PROTECTIVE FORMULATION FOR FLAME-RESISTANT TEXTILES FROM HYDROXYAPATITE DERIVED FROM MILKFISH BONES

Afifah Azima*, Ikbal Syukroni

Pangkep State of Polytechnic Agricultural, Pangkep City

*Corresponding author: affahazima1@gmail.com

Abstract

Firefighters are always faced with the threat of hazardous working conditions, which necessitates protection in the form of FFPC (firefighter protective clothing). Firefighter protective clothing with excellent fire resistance and thermal protection performance, as well as being lightweight, is crucial in fire environments that firefighters constantly encounter. The development of additives in the production of fire-resistant textiles responds to the design of multi-layer firefighter protective clothing that has a heavy weight and increases movement difficulties. On the other hand, fish by-products, specifically milkfish bones, have calcium potential that can be applied as a material for producing hydroxyapatite (HAp), which contains a high phosphorus component. This high phosphorus content can produce components that effectively inhibit the spread of fire, making it a potential fire-retardant agent. This research aims to develop an innovative product from fishery by-products, namely milkfish bones, as a solution for creating thermal protective formulations for fire-resistant textiles. The stages of this research include the production of HAp starting with grinding the fish bones, followed by a sintering process, and then XRD testing to observe the highest crystallinity properties formed. After that, HAp is mixed with aerogel using biopolymer derived from seaweed due to its excellent thermal insulation properties with low thermal conductivity and high fire resistance. The mechanism of mixing these two materials involves the seaweed-derived biopolymer aerogel trapping HAp, thereby enhancing HAp's function as a fire-retardant agent that can be applied as a thermal protective formulation for fire-resistant textiles.

Keywords: Aerogel, FFPC, Flame-resistance textile, HAp, Thermal protective.

INTRODUCTION

Firefighters are always faced with constant threats due to dangerous working conditions so they need appropriate protection against such dangerous situations. During heat exposure, firefighters are exposed to dangerous environments such as hot climates, intense heat radiation, and contact with hot objects (Bajaj & Sengupta, 1992; Keizer & Rossi, 2008). It is well known that firefighting protective clothing with excellent fireproof and thermal protective performance is essential for various activities, especially in the fire environment that firefighters are constantly exposed to. Typically, conventional firefighting protective clothing contains a multi-layered structure, which ensures that firefighters are safe from threats such as external heat flux as well as fire (Naeem *et al.*, 2018; Chou *et al.*, 2008; Hu Y *et al.*, 2012). According to (Lawson, 1997, Rajkishore, Shadi, & Rajiv Padhye, 2014) firefighting protective clothing (FFPC) is multi-layered clothing that ensures that firefighters are safe from threats such as external radiation heat flux, chemical spills, flames, provides thermal balance of the human body and avoids possible burns to the skin. Firefighting protective clothing consists of an outer shell, a moisture barrier and a thermal barrier (Lu, Hong & Yoon, 2013). Unfortunately, the multi-layer design of firefighter protective clothing itself has a high weight and increases the difficulty of movement. Therefore, it is urgent to develop new lightweight materials with

durable fireproof and thermal protective functions, which are able to minimize thermal stress and provide better safety for firefighters in hot and humid environments (Easson *et al.*, 2020) because when it comes to firefighter protection performance, time is the key parameter. Improved thermal protection increases the amount of time firefighters can carry out their activities without significant injury. As a result, firefighters can spend more time dealing with the major risks posed by fires without injuring themselves (Soon, 1996; Holcombe, 1983; Schacher, Adolphe, & Drean, 2000; Tolera, 2015).

According to Panuluh S. *et al.* (2016) SDGs (Sustainable Development Goals) is a global initiative that aims to make human life better in social and economic aspects and can be in synergy with the environment. Implementation of the SDGs is based on a holistic approach and strategy between economic development, social inclusion and environmental sustainability that appropriately prioritizes the characteristics and priorities of the country. This encourages the development of innovations based on flame retardant materials in the form of preparations thermal protective using the basic ingredient hydroxyapatite so that it can minimize obstacles to movement and increase security. Chen and Zhu (2016) also explained that the inorganic composite which apparently has high thermal stability is hydroxyapatite. Akaki *et al.* (2012) also stated that hydroxyapatite contains a phosphorus component which is a fire retardant agent. This HAp can be obtained from the synthesis of fish bones from milkfish by-products.

Milkfish (*chanos chanos* foris) is a type of fish that has lots of bones and can live in fresh water, brackish water and sea water. According to statistical data from the Ministry of Maritime Affairs and Fisheries (KKP), in 2021 milkfish production in Indonesia will reach 784,941.13 tons. For the South Sulawesi region, milkfish production according to KKP data in 2020 was 87,396.97 tons.

Abundant milkfish production will produce a lot of waste. One of the milkfish waste is fish bones. Fish bones are fishery waste with an amount reaching 15% of the fish's body weight consisting of 70% inorganic minerals, 20% organic material and 10% water. Elyda's research found that the content of milkfish bone meal is: 25.54% protein, 17% phosphate, 5.52% water, 3.80% fat, 1.80% fiber and 46.34% calcium. The potential calcium content from milkfish bones can be applied as an ingredient in making HAp (Amelia *et al.*, 2013) So the idea in this paper is the potential for utilizing milkfish bone waste as a preparation thermal protective for flame retardant textiles in FFPC manufacturing materials.

LITERATUR REVIEW

The data used in writing this work is through collecting sources from library studies, originating from journals and electronic books. Literature searches were carried out using online search instruments such as Google Scholar, Science Direct, accredited national journals and accredited international journals.

RESULTS AND DISCUSSION

WellFirefighter protective clothing (FFPC) has a very important role in ensuring the safety of firefighters so that they do not suffer injuries when carrying out their duties related to extreme heat and other temperatures. So with the 5.0 era, innovation must be developed in the form of materials that have high thermal stability so that they can increase firefighting resistance. One thing that can be utilized is milkfish by-products, namely bones, because milkfish bones contain inorganic material

in the form of hydroxyapatite which has the ability to resist fire so it can be manufactured to create fire-resistant materials.

Hydroxyapatite (HAp) with the chemical structure $\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$ is a calcium phosphate derivative compound which has the properties *biocompatible* which is better than other derivative compounds. HAp has begun to be widely applied in modifying fire resistance by combining several polymers, such as *poly (methyl methacrylate)* (PMMA), *polycarbonate* (PC), polyester from epoxy resin (Wahabi *et al.*, 2018). Akaki *et al.* (2012) stated that hydroxyapatite contains a phosphorus component which is a fire retardant agent. The phosphorus component contained in HAp is much higher than the phosphorus content in fire retardant additives sold commercially, such as *triphenyl phosphate* (TPP). This high phosphorus content can produce components that can effectively inhibit the spread of fire (Elbasuney & Maraden 2019). Fish bones contain inorganic compounds that reach 60-70%, with the main elements consisting of calcium phosphate and hydroxyapatite (Euglen *et al.*, 2014). Other ingredients contained in it include protein or bone collagen, amino acids, non-protein nitrogen compounds and other soluble compounds (Albrektsen *et al.*, 2018). Peaks *et al.* (2007) stated that the inorganic compound components contained in fish bones are dominated by calcium (135-233 g/kg), phosphorus (81-113 g/kg) and zinc (70-233 g/kg) dan sedikit Mg, Fe, Cr, Na, K, Se, I, Cl, F, As, Cd, Hg, Pb dan Cu.

The process of making hydroxyapatite according to Venkatesan *et al.* (2011) begins with grinding fish bones using *disc mill* with a speed of 5700 rpm for 20 minutes with a size of 60 mesh, efficiency 85%. *Sintering* done using *electric furnace* at a temperature of 900 °C with a heating speed of 10 °C/minute for 5 hours. The sample is then cooled to room temperature. After that, the sample was subjected to a characterization process with XRD parameters (*X-Ray Diffraction*).

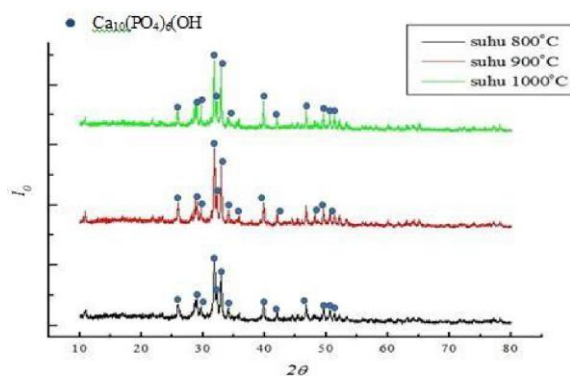


Figure 1. Graph of XRD test results of milkfish bone samples varying sintering temperature (Zulfalina, *et al.*, 2022)

Based on Zulfalina's *et al.* (2022) hydroxyapatite with the highest crystallinity is formed at a sintering temperature of 1000thC. This is visible at a temperature of 1000thC peak intensity formed was the highest compared to the sintering temperature of 800thC and 900thC. The highest peak in the sample diffraction pattern at a temperature of 1000thC is found at an angle of $2\theta = 32.9137^{\text{th}}$ with an intensity of 100 and an angle of 31.7772° with an intensity of 98.

Making preparations *thermal protective* for flame retardant textiles, this is done by mixing HAp with airgel which can be obtained from seaweed biopolymer. According to Berglund *et al.* (2021) Airgels derived from seaweed solid waste, especially cellulose nanofibers, have demonstrated excellent thermal insulation properties with low thermal conductivity and high fire resistance. This is

also supported by the thermal line research mentioned by Subham *et al.* (2023) that airgel can significantly improve the thermal protection of clothing, as it exhibits efficient thermal insulation (Yu *et al.*, 2023) from its heat-absorbing and storing properties, providing a thermal buffer during exposure to high temperatures.

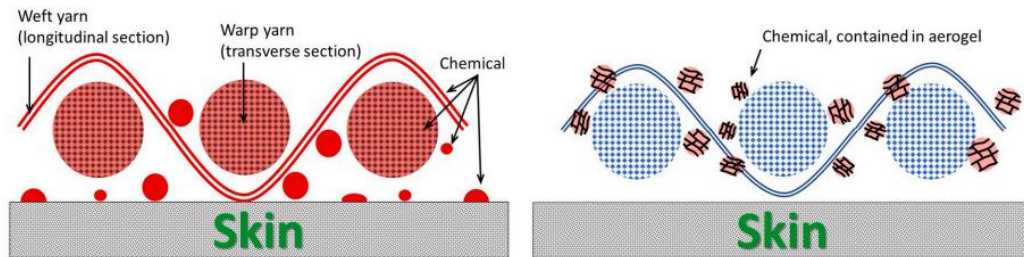
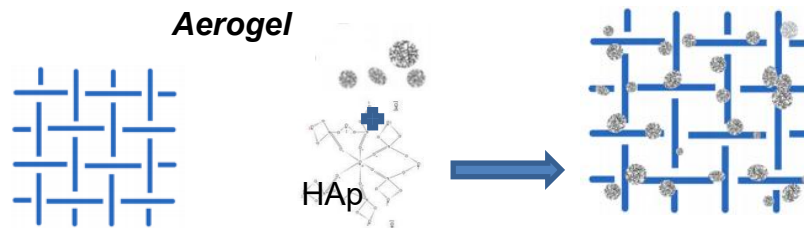


Figure 2. Illustration of airgel increasing fabric protection against chemicals
Source: Steven & Honey (2022)

Based on research from Steven and Honey (2022), fabric with the addition of airgel can increase the effectiveness of fire resistance as proven by tests carried out. In this research, there are also several studies which state that airgel can be considered as a material to prevent or reduce the entry of chemicals into protective clothing textiles because it has strong resistance through high chemical absorption resistance and has high modulus and elasticity which can be insulated. thermal.

a. HAp Formulation with Airgel Mixing as Preparation Thermal Protective



Source: Steven & Honey (2022); Agrawal *et al.*, (2011); Elkayar *et al.* (2009)

HAp is a material with promising flame retardant properties has the potential to be used as a preparation *thermal protective* which is made by mixing airgel from seaweed biopolymer because it has good temperature resistance and mechanical properties against heat/fire. Akaki *et al.* (2012) and Elbasuney and Maraden (2020) stated that hydroxyapatite contains phosphorus components which are fire retardant agents where the high phosphorus content in HAp can produce components that can effectively inhibit the spread of fire. The addition of airgel from seaweed biopolymer itself helps HAp as a fire-resistant material by trapping HAp so that it can help in its function of resisting heat/fire.

CONCLUSION

HAp is an inorganic material that can be used as a fire retardant agent because it has a high phosphorus content. Making HAp can be done using milkfish bone by-products. The high calcium content from milkfish bones could have the potential to be applied as a material for making HAp. Making HAp as a thermal protective preparation for flame retardant textiles is carried out by mixing airgel obtained from seaweed biopolymer. Where airgel can increase the effectiveness of fire resistance because it has excellent thermal insulation properties with low thermal conductivity and high fire resistance. So it can be concluded that mixing airgel with HAp can strengthen the function of HAp itself as a fire retardant agent which can be applied as a preparation. *thermal protective* for flame retardant textiles.

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