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Sustainable Forensic Application of Crab Shell Waste: Development of Eco-Friendly Fingerprint Powder for Non-Porous Surfaces

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Abstract: Most crime scenes contain fingerprints, which are among the most crucial pieces of identification evidence. For the creation of latent fingerprints on various surfaces, including porous, non-porous, and semi-porous surfaces, various kinds of fingerprint powders are utilized. Developing efficient, economical, and ecologically conscious methods for latent fingerprint visualization on non-porous surfaces remains challenging. In this work, off-white and grey powders derived from crab shells, an abundant marine waste material, were used to develop a novel fingerprint powder for latent fingerprint visualization. White powder from crab shells was prepared by cleaning, boiling, drying, crushing, and sieving. Grey powder from crab shells was prepared by using muffle furnace it using analytical techniques in order to assess its particle size, shape, and chemical properties. The material was tested for its viability in visualizing fingerprints on non-porous surfaces by using various deposition techniques, such as TV glass, Polished wood, Metal door, mobile glass, plastic covers. The developed fingerprints were evaluated for contrast, clarity and ridge detail. Results show that crab shell powder has good affinity with sweat and oil residues left in latent fingerprints and produces clear and well-defined ridge patterns. The results suggest that crab shell ash can be a low-cost, eco-friendly and efficient alternative for latent fingerprint visualization. This research adds to the field of forensic science, as well as demonstrates the potential to use marine waste for sustainable technology.

Index Terms: Latent fingerprints, Crab shell Powder and Ash, Non-porous surfaces, Semi- porous surfaces, Eccrine Fingerprints, Sebaceous Fingerprint, Eco-friendly fingerprint powder.

INTRODUCTION:

The goal of the current study was to create calcined grey and off-white fingerprint powders from crab shell waste and assess how well they visualized latent fingerprints on a range of semi-porous and non-porous surfaces. Many substances and techniques, including powder dusting, superglue fuming, multi-metal deposition, and fluorescent dyes, have been used over the ages to create latent fingerprints (Errington & Benjamin,2016). The traditional procedure is powder dusting. This technique is the most popular for improving latent fingerprints since it simply takes a basic toolkit and sufficient operator preparation. The fingerprint powder adheres to the components that remain in a fingerprint when it is applied to an area(Fatin et al., 2021).

Conventional fingerprint powders, such as those made of carbon and aluminium, have demonstrated promise, but they are frequently linked to health issues, environmental issues, and comparatively high costs. They have spurred studies toward eco-friendly fingerprint development alternatives(Kishankumar & Sabu, 2025). In recent years, there has been more interest in making long-lasting, cheap, and environmentally friendly alternatives from natural waste materials. A lot of research has shown that biogenic powders, like eggshells and clamshells, can leave latent fingerprints on non-porous surfaces that are just as clear and have ridge characteristics that are just as clear as commercial powders, if not better(Fatin et al., 2021).

A viable substitute for revealing latent fingerprints is crab shell powder, a marine biowaste rich in chitin and calcium carbonate (CaCO3). Crab shell powder's small particle size and inherent physicochemical characteristics should improve its adhesion to fingerprint remnants, particularly sebaceous secretions. This should enhance the ridge detail and contrast. Similar natural powders have produced obvious and distinctive ridge patterns on surfaces such as metal, glass, and plastic.

Additionally, natural shell-based powders have demonstrated stability in a variety of environmental settings, including soil, water, and sunlight, particularly when they are first beginning to age. Because they are inexpensive, abundant, naturally decompose, and non-toxic, they are excellent for long-term forensic use.

When people eat seafood, they make a lot of crab shells. These shells are mostly made of mineralized chitin fibers and are high in calcium carbonate ($CaCO_3$). These materials are a major source of pollution because they break down slowly and are thrown away in the wrong way. Using marine waste for scientific purposes is a sustainable way to follow the rules of a circular economy(Nwaeju et al., 2025).

Crab shell powder has unique structural and chemical properties that make it a good choice for developing latent fingerprints. These properties include its small particle size, large surface area, and attraction to lipid-rich residues. Natural powders high in calcium carbonate have been shown to stick well to fingerprint residues, which makes the ridges clearer and more distinct(Fatin et al., 2021). This study investigates the potential use of crab shell debris as a novel fingerprint powder in response to the growing demand for inexpensive, non-toxic, and environmentally friendly forensic materials. It examines the chemical composition and form of crab shell particles and evaluates their ability to reveal hidden fingerprints on various surfaces.

MATERIALS AND METHODS:

3.1 Materials

The primary raw material was discarded crab shells collected from nearby seafood restaurants. They cleaned with distilled water. The basic lab equipment used included beakers, stainless steel trays, heating devices, mixer grinders, cotton cloth for screening and airtight storage containers. The powder was heated in a muffle furnace.

3.2 Preparation of Off-White Crab Shell Powder

The crab shells collected were first thoroughly washed under running water to remove any organic matter adhering to them, such as tissues, dirt and other contaminants. This was an important step in making sure the final powder was pure, and that nothing would interfere with the development of fingerprints. We washed the shells then boiled them for about 15 minutes, to help get rid of any remaining bacteria and proteins. The shells were boiled and rinsed in fresh water to remove any residual dirt. Then the washed shells were left out in the sun for 2 to 3 days to dry out completely. It is important to dry things well so that moisture does not build up. This can affect their grind and stability. his can affect the grinding efficiency and the stability of the powder.

Then the dried shells were ground mechanically in a mixer grinder to a coarse powder. The ground material was passed through a thick cotton cloth to improve the efficacy and uniformity of the powder. This only let the smaller particles through and kept back the larger pieces. The powder that came out was mostly white because it had calcium carbonate in it. This powder was then collected and stored in air tight containers to prevent it from becoming wet or contaminated before it is used to develop latent fingerprints.

3.3 Preparation of Grey (Calcined) Crab Shell Powder

The crab shell powder prepared previously was subjected to thermal treatment for modification of its physical and chemical properties. The powder was heated in a muffle furnace at 550 °C for 1 h. And since it has to be cooled to room temperature inside the furnace to avoid thermal shock, the sample was kept warm owing to cooling exerted during calcination. It was again ground (if required) and passed through cotton cloth to get it into fine grey coloured powder. This powder had only been thermally treated to study the effect of calcination on fingerprint enhancement.

3.4 Substrate preparation:

Plastic sheets, metal plaques, glass doors, mobile glass, TV glass, and polished wood surfaces were selected and carefully wiped with 70% ethanol and thereafter dried in order to avoid any impurities and background residue.

3.5 Fingerprint Deposition

A donor was requested to gently touch the thumb on a cleaned surface for getting eccrine fingerprints and the donors were asked to touch their fingertips on the nose or forehead before touching the prepared surfaces in order to help the natural production of sweat and oils to get sebaceous fingerprints. The volunteers were not requested to apply any force by doing this standardize deposition of traces.

3.5 Powder Application Method

A soft, fine camel hair brush was gently used to dust the prepared crab shell powder, which is either off-white or grey, onto the latent fingerprints. To avoid any smudging or distortion, the powder was applied lightly in a circular motion over the print area. The same brush was then used to delicately sweep away any extra powder.

3.6 Visualization and Documentation

A high-resolution digital camera or mobile camera was used to capture images of the fingerprints, ensuring the lighting was consistent. We assessed the quality of the prints based on ridge clarity, contrast, background interference, and the visibility of the patterns. Under the same conditions, we compared the effectiveness of crab shell powder (off-white or grey) with that of standard commercial White and Grey fingerprint powders. We made sure to follow safety protocols by wearing the appropriate PPE (gloves, masks, and lab coats) in a well-ventilated environment.

RESULT:

We looked into the effectiveness of off-white and grey crab shell powders for revealing eccrine and sebaceous latent fingerprints on a range of non-porous and semi-porous surfaces. The findings were quite encouraging, showing that these powders adhere well to fingerprint residues, resulting in clear ridge patterns on most of the surfaces we tried.

Table 1: Eccrine Fingerprint Developed Using Crab Shell Powder

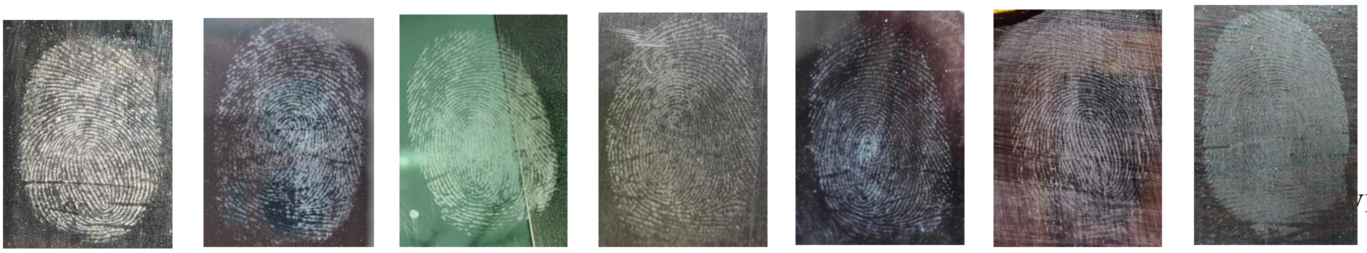
Surfaces	Powder Type	Ridge Clarity	Ridge Continuity	Background Contrast	Suitability for Identification
TV Glass	Off-White	High	High	High	Suitable
TV Glass	Grey	High	High	High	Suitable
Mobile Glass	Off-White	High	High	High	Suitable
Mobile Glass	Grey	High	High	High	Suitable
Kitchen Glass Door	Off- White	High	High	High	Suitable
Kitchen Glass Door	Grey	High	High	High	Suitable
Metal Cap Surface	Off- White	High	High	High	Suitable
Metal Cap Surface	Grey	High	High	High	Suitable
Sunglass Plastic lens	Off-White	Moderate	Moderate	Moderate	Partially Suitable
Sunglass Plastic lens	Grey	High	High	High	Suitable
Metal plaque/Metal surface	Off-White	High	High	High	Suitable
Metal plaque/Metal surface	Grey	High	Moderate	High	Suitable
Polished Wood (Semi-Porous)	Off-White	Moderate	Moderate	High	Partially Suitable
Polished Wood (Semi-Porous)	Grey	Moderate	Moderate	High	Partially Suitable

As shown in Figure 1, the off-white crab shell powder produced striking ridge patterns that displayed excellent clarity, continuity, and contrast on various surfaces, including TV glass, mobile glass, metal caps, and metal plaques. On the other hand, moderate-grade fingerprints were noted on polished wood and the plastic lenses of sunglasses.

[I] [II] [III] [IV] [V] [VI] [VI]

Figure 1. Eccrine Fingerprints Developed Using Off-White Powder: [I] TV Glass [II]Mobile Glass [III] Kitchen Glass Door [IV]Metal Cap[V]Sunglass Plastic Lens [VI] Metal Plaque [VII] Polished wood

As shown in Figure 2, the grey crab shell powder worked wonders, generating clear ridge features on a range of surfaces like TV glass, mobile glass, metal caps, plastic sunglasses lenses, and metal plaques.



VII]

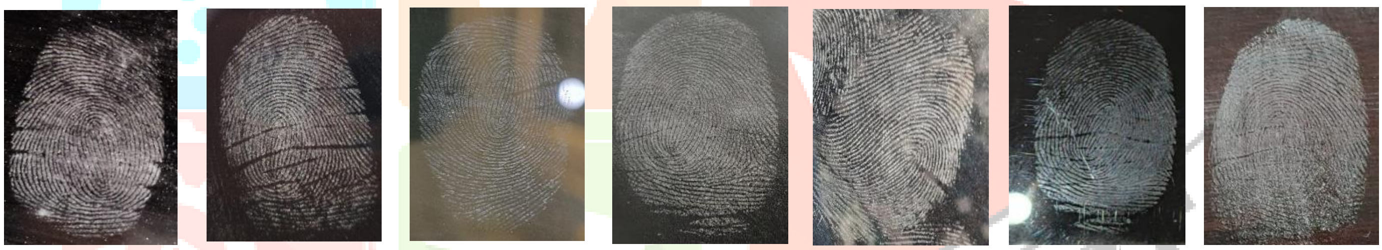
Figure 2. Eccrine Fingerprints Developed Using Grey Powder: [I] TV Glass [II]Mobile Glass [III] Kitchen Glass Door [IV]Metal Cap[V]Sunglass Plastic Lens [VI] Metal Plaque [VII] Polished wood

Comparing the off-white powder to the grey powder, the grey one generally showed better contrast and visibility on plastic surfaces. On polished wood, both powders had a moderate performance, indicating that their effectiveness on semi-porous substrates was lessened. In general, on most of the non-porous surfaces we tested, the fingerprints produced were adequate for forensic identification.

Table 2: Sebaceous Fingerprint Developed Using Crab Shell Powder

Surfaces	Powder Type	Ridge Clarity	Ridge Continuity	Background Contrast	Suitability for Identification
TV Glass	Off-White	Excellent	Excellent	Excellent	Suitable
TV Glass	Grey	Excellent	Excellent	Excellent	Suitable
Mobile Glass	Off-White	Excellent	Excellent	Excellent	Suitable
Mobile Glass	Grey	Excellent	Excellent	Excellent	Suitable
Kitchen Glass Door	Off-White	Excellent	Excellent	Excellent	Suitable
Kitchen Glass Door	Grey	Excellent	Excellent	Excellent	Suitable
Metal Cap Surface	Off- White	High	High	High	Suitable
Metal Cap Surface	Grey	High	High	High	Suitable
Sunglass Plastic lens	Off-White	Excellent	Excellent	Excellent	Suitable
Sunglass Plastic lens	Grey	Excellent	Excellent	Excellent	Suitable
Metal plaque/Metal surface	Off-White	High	High	High	Suitable
Metal plaque/Metal surface	Grey	High	High	High	Suitable
Polished Wood (Semi-Porous)	Off-White	High	High	High	Suitable
Polished Wood (Semi-Porous)	Grey	Excellent	High	High	Partially Suitable

Figure 3, illustrates sebaceous latent fingerprints created with off-white crab shell powder on different surfaces, including TV glass, mobile screens, kitchen glass doors, metal caps, sunglass lenses, metal plaques, and polished wood. Most of these non-porous surfaces showed impressive ridge detail, highlighting the powder's capability for effective latent fingerprint development.



[I] [II] [III] [IV] [V] [VI] [VII]

Figure 3. Sebaceous Fingerprints Developed Using Off-White powder: [I] TV Glass [II]Mobile Glass [III] Kitchen Glass Door [IV]Metal Cap [V]Sunglass Plastic Lens [VI] Metal Plaque [VII] Polished wood

Figure 4, presents sebaceous latent fingerprints developed with grey crab shell powder on different surfaces, including TV glass, mobile glass, kitchen glass doors, metal caps, sunglass lenses, metal plaques, and polished wood. The results on most non-porous surfaces were striking, with excellent ridge growth and contrast, demonstrating the effectiveness of calcined crab shell powder for visualizing latent fingerprints.

[I] [II] [III] [IV] [V] [VI] [VII]

Figure 4. Sebaceous Fingerprints Developed Using Grey Fingerprints: [I] TV Glass [II]Mobile Glass [III] Kitchen Glass Door [IV]Metal Cap [V]Sunglass Plastic Lens [VI] Metal Plaque [VII] Polished wood

By comparing both types of powder revealed that sebaceous fingerprints had clearer ridges, better continuity, and more contrast than eccrine fingerprints. Interestingly, grey crab shell powder outperformed the off-white powder, particularly on semi-porous and plastic surfaces. Among all the conditions tested, sebaceous fingerprints developed with powdered grey crab shell stood out as the best option for forensic identification.

DISCUSSION:

The findings from this study revealed that latent fingerprints can be effectively developed on various surfaces using both off-white and grey crab shell powders. Non-porous materials like glass, metal, and plastic showed enhanced visibility of fingerprints, showcasing clear ridge details and strong contrast. Since sebaceous residues contain a higher lipid content, which helps the powder stick better, sebaceous fingerprints displayed greater clarity and continuity compared to eccrine fingerprints. Notably, the grey (calcined) crab shell powder outperformed the off-white powder, especially on plastic and metal surfaces. The research suggests that crab shell powders could serve as a cost-effective, eco-friendly, and sustainable alternative to traditional fingerprint powders in forensic science. However, further studies with larger sample sizes and instrumental analysis are necessary to validate their effectiveness in forensic applications.

CONCLUSION:

The research focused on the effectiveness of off-white and grey fingerprint powders derived from crab shell waste for detecting latent fingerprints. Both powders successfully revealed fingerprints on various surfaces, with non-porous materials such as glass, metal, and plastic showing the best results. It was observed that eccrine fingerprints were less developed than sebaceous ones, and the grey powder had a slight advantage over the off-white powder. These findings highlight the potential of converting crab shell waste into a practical and eco-friendly fingerprint development material. Utilizing crab shell powder supports both forensic applications and sustainable waste management, offering a low-cost, non-toxic, and environmentally friendly alternative to traditional fingerprint powders. To enhance its application in forensics, further studies using advanced characterization techniques and real crime scene conditions are recommended.

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