



To Explore The Eco-Friendly And Biodegradable Potential Of Clam And Worm Shell Powders In Finger Print Development

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I.ABSTRACT:

The present study explores the eco-friendly and biodegradable potential of clam and worm shell powders as alternative materials for latent fingerprint development, offering a sustainable solution to traditional chemical and synthetic powders that pose environmental and health hazards. The research focuses on the physical and chemical properties of these natural shell powders, evaluating their particle size, adherence capability, contrast quality, and effectiveness on various non-porous and semi-porous surfaces. Through comparative analysis with conventional fingerprint powders, clam, and worm shell powders demonstrated promising results in terms of ridge clarity, background contrast, and surface compatibility, particularly on glass, plastic, and metal substrates. The study also emphasizes the non-toxic and biodegradable nature of these biomaterials, which not only reduce environmental impact but also ensure safety for forensic personnel during crime scene investigations. Further more ,the use of shell waste from marine organisms aligns with the principles of circular economy and waste valorization ,transforming discarded natural resources into valuable forensic tools. This innovative approach paves the way for the integration of green materials in forensic science, promoting sustainable practices without compromising efficiency and reliability in criminal investigations.

KEYWORDS:

Latent fingerprint development, Clamshell powder, Worm shell powder, Eco friendly forensic techniques, Biodegradable fingerprint powder, Sustainable forensics, Non-toxic materials, Green forensic science, Marine waste utilization, Circular economy

II.INTRODUCTION:

Fingerprints are the impressions made by the papillary ridges on the ends of the fingers and thumbs. "Every Contact Leaves Traces" – The basic Principle of Exchange by Sir Edmond Locard makes us realize that fingerprints play a crucial role in the field of forensic science. Fingerprints afford an infallible means of personal identification because the ridge arrangement on every finger of every human being is unique and does not alter with growth or age. Fingerprints reveal an individual's true identity and, in recent times, are key to everything. In forensic science, fingerprints are a tool for criminal investigation and have been the gold standard for person identification in the forensic community

for more than a hundred years. Fingerprints are commonly used to understand the individuality of a person to reveal their identity. Prints are left on anything touched and cannot be covered up because human fingerprints are unique, difficult to alter, and durable over the life of an individual, making them suitable as lifelong markers of human identity.

FUNDAMENTAL PRINCIPLES OF FINGERPRINTS

- No two fingers of the same person also no two same people have identical ridges design on the fingertips. Fingerprints are absolutely unique more unique than DNA the genetic components of a human being. Even identical twins with the same DNA sequence do not have the same ridge pattern.
- The fingerprints remain the same throughout life:the ridges pattern of the fingerprints starts forming during the fetal stage of human life and remains the same with no alterations during a person's life span. It is only after death the fingerprint ridges are destroyed during the time of body decomposition.
- Fingerprints can be classified for record-keeping:the fingerprint bureau keeps the record of biometrics of almost every individual, hence when a crime occurs the fingerprints as evidence collected from the scene,these records help the police and forensics to investigate and identify the suspect to be the proved criminal.

CHEMICAL COMPOSITION OF FINGERPRINT

Fingerprints are composed of complex mixtures of substances that originate primarily from skin secretions and environmental contaminants. The three major sources contributing to the chemical makeup of fingerprint residue are eccrine glands, sebaceous glands, and apocrine glands. Eccrine secretions, found throughout the body and especially on the palms and soles, consist mostly of water and contain inorganic ions (like chloride and sodium), amino acids, and small organic molecules. Sebaceous glands, concentrated on the face and upper body, secrete lipids such as triglycerides, wax

esters, and free fatty acids, which add a greasy or oily consistency to fingerprints. Apocrine glands, found in specific body areas like armpits, release a protein-rich fluid that mixes with bacteria to create unique scent markers. Additionally, fingerprints can also contain exogenous substances such as food oils, cosmetics, smoke residues, or environmental dust, making each print chemically unique. Advanced analytical techniques, such as Fourier Transform Infrared Spectroscopy (FTIR) and Liquid Chromatography-Mass Spectrometry (LC-MS), are now used to study the chemical profiles of fingerprints in detail. These profiles can help estimate donor characteristics like age, diet, or medication use, offering a powerful complementary tool to traditional ridge pattern analysis.

CLASSIFICATION OF FINGERPRINTS

Fingerprints are classified into seven major categories: arch, tented arch, loop, double loop, radial loop, and ulnar loop, where the algorithm extracts singular points (cores and deltas) in a fingerprint image and performs classification based on the number and locations of the detected singular points. ARCH the fingerprint ridges that form hills, some arches look like they have a pointed tent shape. Arches are the least common type of fingerprint.



Figure 1: Arch

TENTED ARCH - When two independent ridges come together and form an angle, the resulting pattern may be called a tented arch, it should have at least two of the three basic requirements of a good loop pattern (sufficient recurve, delta, and ridge count across a looping ridge).



Figure 2: Tented Arch

LOOP - A Loop is a pattern in which one or more ridges recurve run back on their previous course, making a half turn or more around the core, having a delta and at least one ridge intervening between the inner and outer terminal.



Figure 3: LOOP

DOUBLE LOOP - A type of print pattern that consists of two separate loop formations with two separate and distinct sets of shoulders and two deltas.



Figure 4: Double Loop

RADIAL LOOP - Radial loops, in which the pattern flows in the direction of the radius bone of the forearm (i.e., toward the thumb).

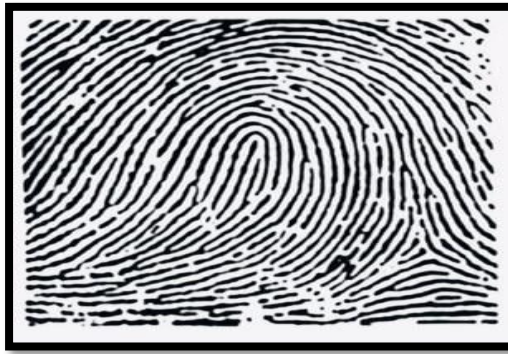


Figure 5: Radial Loop

ULNAR LOOP- Ulnar Loop is where the pattern flows in the direction of the ulna bone of the forearm (i.e., toward the little finger).



Figure 6: Ulnar Loop

DEVELOPMENT OVER DIFFERENT POROUS, NON-POROUS, SEMIPOROUS SURFACES

Fingerprint analysis has long been a cornerstone of forensic science, serving as a reliable method for personal identification due to the unique ridge patterns present on human fingers. The ability to effectively develop latent fingerprints largely depends on the type of surface on which the print is deposited. These surfaces are generally categorized into three types: porous, non-porous, and semi-porous, each requiring different development techniques due to their distinct physical properties.

Porous surfaces—such as paper, cardboard, and certain fabrics—contain microscopic cavities capable of absorbing moisture, including the sweat and oil secretions left behind by fingertips. While these surfaces readily absorb fingerprint residues, the prints are often vulnerable to degradation through handling or environmental exposure. Over time, absorption can reduce the visibility and integrity of the

print, making recovery more challenging. Forensic scientists commonly employ ninhydrin, which reacts with amino acids to produce a purple or blue colour, and physical developer, which utilizes silver nitrate, for enhancing latent prints on porous materials.

In contrast, non-porous surfaces—such as glass, plastic, and metal—do not absorb moisture or residues. Fingerprints deposited on these surfaces typically remain on the exterior, making them easier to detect and develop. Visualization techniques include the application of fingerprint powders, cyanoacrylate fuming (super glue method), and small particle reagents (SPR). Powders adhere to the moisture or oil in the fingerprint, providing good contrast on smooth surfaces. Cyanoacrylate fuming forms a polymer layer along the ridges, while SPR is particularly effective for wet or previously submerged surfaces.

Semi-porous surfaces, like wood, leather, and certain coated papers, exhibit intermediate absorption characteristics. These surfaces may partially absorb fingerprint residues, posing moderate challenges for print development. Techniques such as DFO (1,8-diaza uoren-9-one) and Acid Yellow 7 are commonly used, as they react with amino acids in the residue to render the prints visible under specific lighting conditions.

In conclusion, the successful development of latent fingerprints depends on the surface type and the environmental conditions under which the print was deposited. Each category—porous, non-porous, and semi-porous—requires tailored development methods to maximize clarity and detail. A forensic examiner's understanding of surface properties and appropriate reagents is critical for accurate fingerprint recovery and identification.

In forensic investigations, the relationship between the criminal, the victim, and the crime scene can be firmly established marks (1). Over the centuries, through the detection of latent finger there were many reagents and methods have been sought for the development of latent finger marks, such as powder dusting, superglue fuming, multi-metal deposition, and fluorescent dyes (2). The powder dusting method is the conventional technique. This method is the most widely practiced for the enhancement of latent finger marks because it only needs adequate preparation for operators and requires a simple toolset. When the finger mark powder is applied over a region, the powder affixes to the constituents left in a finger mark.

Regular powders for fingerprint development include a resinous polymer such as starch, kaolin, and silica gel for adhesion, as well as a colorant made up of inorganic or organic compounds for better visualization (3). The commercial fingerprint powder contains inorganic salt of heavy metals such as mercury, cadmium, titanium, lead, and manganese, which cause health hazards to the users. Therefore, instead of commercial methods used to develop latent finger marks, there are also alternative ways that researchers have previously investigated to achieve a non-toxic and successful approach to latent finger mark development. Turmeric powder, for example, has been tested to develop latent finger marks on different surfaces (4). Turmeric or *Curcuma longa* is a rhizomatous herbaceous perennial plant of the

ginger family Zingiberaceae. The functional use of curcumin, a component in turmeric, gives colour as a food additive. The powdering method was implemented using a few grams of commercially available turmeric powder. The powder has been demonstrated to be efficient for finger mark visualization, especially on contrasting backgrounds.

Seerat et al. (5) conducted comparative studies of various natural resources for the development of latent fingerprints on non-porous surfaces by using red chili, turmeric, marigold, black charcoal powders, and mustard oil soot. They concluded these natural powders produced well and clear results for the development of latent finger marks on non-porous substrates, for example, plastic and glass. The powders are also less expensive, simple, readily available, and could be simply used successfully on various non-porous surfaces. For instance, due to the small size of the carbon-rich mustard oil soot, it only adheres to the fingerprint, not all over the surface, and thus, less amount of it can be applied and produce the best result. Hence, less amount of soot is sufficient for developing the latent print.

Another study reported that Durian seed powder has successfully developed a natural latent finger mark with a better visualization (6). plentiful in starch and produces white powder The seed of Durian is which adheres to the deposited fingerprint residues. The good interaction may be due to the structure of hydrogen bonds between the fatty acids/glycerides of sebum and the carbonyl and hydroxyl group of the components in the seed powder. This natural powder is also not poisonous, un harmful, and readily obtainable a s compared to the currently available chemical powders, that offer potential health hazards.

Sari et al. (7) had sought an alternative cheap and natural fingerprint powder from gambir plants. The studies discovered that gambir powder is efficient for latent finger marks visualization on dry, non-porous surfaces. Gambir is the dried aqueous extract from the leaves and twigs of Uncaria gambir Roxburgh plants, used as a traditional medicinal material, which is native to India, Sri Lanka, Indonesia, and Malaysia. Further study revealed that the coarse gambir powder was preferable for latent finger marks on glass slides and transparent plastics, meanwhile, finer particles were significantly better for plastic cups, compact discs, and aluminum foils. In another similar study, marine biomasses were reported to be effective for finger marks the enhancement of latent fingerprints [8].

The previous study also reported the use of rice husk as a nano carbon powder (NP) that presented sustainable efficient, and eco-friendly alternatives for visualizing latent finger marks deposited on various non-porous and semi porous surfaces (9). The accumulation of rice husk waste, which is the aftermath of rice milling that is produced in billions of tonnes annually, would be significantly minimized. Findings revealed that the rice husk NP offers good clarity of finger mark ridges and has proven to outweigh commercial black powder due to the simple synthesis method and its low toxicity content of the powder.

Thakur et al. (10) investigated the application of Fuller's earth as an alternative powder for developing latent finger marks. Fuller's earth was grounded into a fine powder, and the powder was sprinkled over the latent finger marks without using any brushes as the tip of the brush might interfere with the ridge

patterns of the finger marks. The overspill powder was cleared by tapping. The method produced clear images of developed finger marks on the majority of tested substrates.

The present study focuses on the potential of naturally occurring marine shell wastes—specifically clam shells and worm shells—as sustainable materials for latent finger print development. These shells are abundant by products of coastal and aquaculture industries, often discarded without utilization. Clamshells, predominantly composed of calcium carbonate (CaCO_3), are known for their rigid, layered structure, comprising an outer calcite-based layer and an inner nacreous layer rich in aragonite. This aragonite contributes to the shell's lustrous appearance and offers desirable mechanical properties, including ne particle formation, smooth texture, and biocompatibility, making it suitable for fingerprint powder. Worm shells, typically secreted by marine polychaete worms such as Serpulidae, also consist largely of calcium carbonate and exhibit a coiled, tubular form. Though structurally different from clam shells, worm shells possess a porous and fragile composition which, when processed into powder, provides fine particle size and unique surface properties favourable for fingerprint adherence. Both clam and worm shell powders, once ground and refined, offer excellent adherence to latent fingerprint residues without smudging. Their ne particle size allows for precise deposition along the ridges and furrows of the print. Additionally, these materials are non-toxic, biodegradable, and environmentally friendly, positioning them as viable alternatives to conventional fingerprint powders. The study investigates the adhesion behaviour, contrast quality, and overall effectiveness of these natural powders on non-porous substrates such as glass, plastic, and metal. This approach not only supports sustainable forensic practices but also promotes the valorization of marine waste, aligning with green chemistry and circular economy principles.

OBJECTIVES :

1. To create an eco-friendly and low-cost method for developing fingerprints.
2. To apply fingerprints on different non-porous and semi-porous surfaces.
3. To check if ridge details and minutiae are clearer using clam or worm shells.
4. To compare this method with traditional fingerprint techniques.

In the present Review of the literature

1."The effectiveness of natural indigo/kaolinite composite powder in the development of latent finger marks" (2024)

This study introduced a green composite of natural indigo and kaolinite, demonstrating comparable or superior efficiency to commercial powders in developing latent fingerprints.

2. "Development of latent fingerprints using non-conventional powder methods" (2024)

Researchers evaluated unconventional powders like turmeric and talcum for fingerprint development on various non-porous surfaces, highlighting their effectiveness and safety.

3. "Green Composites from Thiophene Chalcones and Rice Husk Lignin: An Alternative of Powder for Latent Finger mark" (2022)

This work developed a cost-effective green composite from rice husk lignin and thiophene chalcone, yielding clear fingerprint images with minimal background staining.

4. "Zero Waste Latent Finger mark Developing Nano powder from Eggshells" (2024)

The study synthesized calcium oxide nano powder from eggshell waste, demonstrating high sensitivity and clarity in latent fingerprint development across multiple surfaces.

5. "A study on the development of fingerprint powders using natural sources for latent fingerprint visualization on non-porous surfaces" (2024)

Natural powders like betel leaf and turmeric were assessed for fingerprint visualization, with findings supporting their potential as eco-friendly alternatives to traditional powders.

6. "Enhancement of latent fingerprint using dyed eggshell powder" (2021)

This research explored the use of dyed eggshell powder as a sustainable material for enhancing latent fingerprints on various surfaces.

7. "A Comprehensive Review of Fingerprint Development: Exploring Unconventional Powder-Based Techniques" (2024)

The review analyzed various natural substances, including turmeric and durian seed powders, for their efficacy in fingerprint development, emphasizing environmental benefits.

8. "Nano carbon powder for latent finger mark development: a green chemistry approach" (2018)

Amorphous nano carbon powder derived from rice husk acid digestion was evaluated, showing high selectivity and performance comparable to commercial powders.

9. "Development of latent fingerprints using Clitoria ternatea and Curcuma longa powders" (2023)

Non-toxic plant-based powders from Clitoria ternatea and Curcuma longa were effective in developing clear ridge patterns on various non-porous surfaces.

10. "Peels to Prints: Exploring Natural Peels for Development of Latent Fingerprints – A Review" (2024)

The review discussed the potential of natural peels, such as orange and banana, as sustainable materials for latent fingerprint development.

11. "Bio friendly Waste Shell Powders/Polylactic Acid Composites for Antibacterial Engineering Applications" (2022)

This study investigated the use of waste shell powders in polylactic acid composites, highlighting their antibacterial properties and potential forensic applications.

12. "Recycling of Nanosilica Powder from Bamboo Leaves and Rice Husks for Forensic Applications" (2021)

Nanosilica powders derived from agricultural waste were explored for forensic applications, including fingerprint development, emphasizing sustainability.

13. "Exploring sustainable forensics: silica nanoparticle powder derived from rice husk waste for aged finger mark development and the chemistry of surface interactions" (2024)

Silica nanoparticles from rice husk waste were assessed for developing aged finger marks, showcasing their effectiveness and eco-friendly nature.

14. "Development of submerged and successive latent fingerprints: a comparative study" (2019)

This comparative study evaluated methods for developing latent fingerprints exposed to various conditions, contributing to the understanding of fingerprint recovery techniques.

15. "Techniques for fingerprint recovery on vegetable and fruit surfaces used in Slovenia - A preliminary study" (2008)

The research explored fingerprint recovery techniques on unconventional surfaces like fruits and vegetables, expanding the scope of forensic methodologies.

III. METHODOLOGY:

MATERIALS AND INSTRUMENTS:

- Clam shells
- Worm shells
- Clean cloth
- Mortar and pestle
- 600W personal blender
- Fingerprint brush
- Sieve
- Tins with lids

Shell Powder Preparation

Step 1: Collection of Shells

Clamshells and worm shells were collected from natural sources and thoroughly washed with tap water to remove all dirt, debris, and impurities from the surface.

Step 2: Sterilization of Shells

The cleaned shells were boiled in tap water at 100°C for 15 minutes to sterilize and eliminate any microbial or organic contaminants.

Step 3: Drying of Shells present.

After sterilization, the shells were removed from the boiling water and placed in clean cloths. They were then left to dry completely under natural sunlight.

Step 4: Primary Crushing

Once fully dried, the clam shells and worm shells were individually crushed into small pieces using a traditional mortar and pestle.

Step 5: Fine Grinding

The small shell fragments were then ground into a fine powder using a 600W personal blender. This step was repeated several times to ensure uniform particle size.

Step 6: Sieving the Powder

The ground powder was passed through a sieve to remove coarse particles and to obtain a fine, uniform texture.

Step 7: Collection and Storage

The sieved clam and worm shell powders were carefully transferred into separate tins and sealed tightly with lids to avoid contamination and moisture absorption. A fingerprint brush was used to handle the powders delicately during this process..



Figure 7, 8: The collected clam and worm shells were boiled in distilled water



Figure 9,10: Clam and Worm shells are kept under sunlight for drying

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Figure 11,12: Clam and worm shells were ground using a 600W personal blender

IV. RESULT:

The fingerprints developed using the prepared powder are detailed below.

Finger print developed using Calm shell powder:

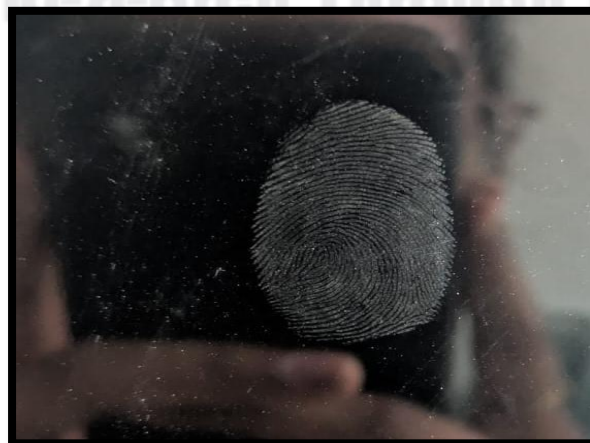


Figure 13: Fingerprint developed on the Glass Surface

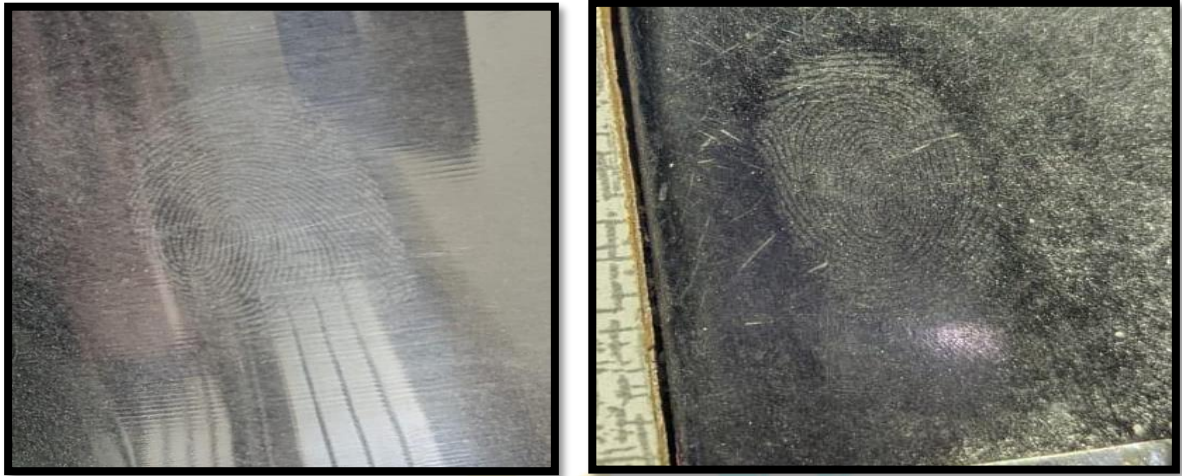


Figure 14, 15 : Finger print developed on the Steel surfaces



Figure 16 : Finger print developed on the Wood surface



Figure 17 : Finger print developed on the Plastic Surface

Finger Print developed using Worm shell Powder:



Figure18 : Finger print developed on the Glass surface



Figure 19: Finger print developed on the Steel Surface



Figure 20: Finger print developed on the wood surface



Figure 21: Finger print developed on the plastic surface

This study presents an eco-friendly and low-cost method for developing latent fingerprints using clamshell and worm shell powders. The powders were prepared from naturally available clam and worm shells, making them biodegradable and non-toxic alternatives to traditional chemical fingerprint powders. The study focused on developing fingerprints on non-porous and semi-porous surfaces such as glass, steel, plastic, and wood. Fingerprints developed using both clamshell and worm shell powders showed good clarity and visibility on these surfaces. The ridge characteristics and minutiae details were clearly visible, especially on glass and wood surfaces, indicating the effectiveness of both powders in enhancing fingerprint patterns. However, it was observed that on plastic surfaces, the clarity of fingerprints developed with clamshell powder was slightly lower compared to those developed with worm shell powder. This suggests that the surface texture and adherence properties of the powders may vary slightly, affecting the development quality of certain materials. Despite this minor difference, both powders demonstrated reliable performance in visualizing latent fingerprints, highlighting their potential for practical forensic use. The use of natural materials not only provides a sustainable option for forensic investigations but also reduces dependency on commercially manufactured powders that may pose environmental or health risks.

V .DISCUSSION:

This study demonstrates that clamshell and worm shell powders are viable, eco-friendly alternatives to traditional fingerprint powders used in forensic science. Their natural origin makes them biodegradable, cost-effective, and safe for both the environment and the user, aligning with the growing demand for sustainable forensic practices. The ability of these powders to develop clear fingerprints on non-porous and semi-porous surfaces such as glass, steel, wood, and plastic is significant, as these materials are commonly encountered in real crime scenes. The consistent visibility of ridge characteristics and minutiae on most surfaces, especially glass and wood, suggests that the particle size and surface adhesion properties of the powders are well-suited for forensic application. The slightly reduced clarity observed with clamshell powder on plastic surfaces could be attributed to differences in surface interaction or

particle texture, indicating a potential area for further refinement of the powder preparation process. This variation also highlights the importance of surface compatibility in fingerprint development techniques. While traditional powders may offer consistent results due to synthetic composition and controlled production, the use of natural powders requires an understanding of their behaviour on different substrates. Nevertheless, the overall performance of both powders was satisfactory and suggests that with further standardization, they could be reliably used in forensic laboratories and field investigations. Moreover, this study opens the door to further exploration of other natural materials for fingerprint development, potentially expanding the toolkit of eco-friendly forensic methods. The findings emphasize not only the practical benefits but also the environmental responsibility of adopting such green alternatives in criminal investigations.

VI. CONCLUSION:

In conclusion, this study has successfully demonstrated that clam shell and worm shell powders can serve as effective, eco-friendly, and low-cost alternatives to conventional fingerprint development powders used in forensic science. By utilizing natural and biodegradable waste materials, this approach not only addresses the pressing need for sustainable solutions in forensic investigations but also promotes the innovative reuse of biological waste, contributing to environmental conservation. The powders prepared from clam and worm shells were found to be effective in developing latent fingerprints on a variety of non-porous and semi-porous surfaces such as glass, steel, plastic, and wood—surfaces commonly encountered at crime scenes. The results showed that both powders provided good clarity and visibility of ridge details and minutiae characteristics, particularly on glass and wood surfaces. Although there was a slight decrease in fingerprint clarity on plastic surfaces with clam shell powder compared to worm shell powder, both types still produced satisfactory results overall. This confirms the practicality and applicability of these natural powders in real-world forensic scenarios. Their performance, when compared to that of commercial powders, underscores their potential to be integrated into routine forensic practice, especially in regions where resources are limited and cost-effective materials are needed. Furthermore, this study opens up new avenues for the exploration of other natural and waste-derived substances that could be used in forensic applications, potentially leading to a broader shift toward environmentally conscious practices in forensic laboratories. With continued research and refinement, clam and worm shell powders could be standardized and adopted widely, making a significant contribution to the advancement of green forensic technologies. This research thus lays a strong foundation for future innovations in sustainable forensic science and demonstrates the immense value of repurposing natural waste into functional, scientifically valuable resources.

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