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Application of Indian Barnyard Millet as a Sustainable Natural Powder for Latent Fingerprint Development

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ABSTRACT

Fingerprint visualization forms a key component in crime scene investigation. Till now, the primary method of fingerprint development is the use of synthetic or usually the chemical powders which can be potentially harmful to both the environment and to the human health. While there has been a lot of focus on the ecological impact of forensic activities and in an effort to develop various eco-friendly forensic methods, this paper deals with the testing of the Indian barnyard millet powder - a completely biodegradable and therefore a renewable material for the first time in the fingerprint detection on different surfaces. Usually, millets are considered to be one of the most nutrient dense and environmentally friendly crops that grow well in difficult conditions. They are mainly used for food and is edible in nature but their physical and chemical properties have not been much examined for forensic purposes.
The findings in our study suggest that the barnyard millet powder is a powerful latent fingerprint powder which is capable of producing high-quality fingerprints along with well-defined ridge features. The prints developed with the use of the barnyard millet powder produced high contrast without the loss of much fingerprint details. The fact that this powder is biodegradable is an environmentally friendly feature which helps to reduce the chemical waste and also prevents human exposure to toxic elements during the process of forensic analysis.

Keywords: Indian Barnyard Millet, Latent Fingerprints, Porous Surfaces, Non-Porous Surfaces, Forensic Science, Fingerprint Development.

INTRODUCTION

The field of forensic science is fundamentally rooted in the Locard's Exchange Principle, which asserts that "every contact leaves a trace." [1] In the multifaceted world of the criminal investigation, there is perhaps no trace more vital or enduring than the human fingerprint. Fingerprints have remained the definitive gold standard for the biometric identification for over a century due to its two unique properties that is permanence and uniqueness. [2] From the moment of the fetal development until later after a person has passed away these ridge patterns always remain unchanged. Also, the mathematical probability of the two individuals including even the identical twins sharing the same fingerprint is so not possible that it is considered a universal constant in global law enforcement. [3] When a finger comes into contact with a surface, it leaves behind what is known commonly as a "latent" print. The term "latent" is derived from the Latin word for "hidden" which is a fitting description as these impressions are usually and typically invisible to the naked eye. [4] They are composed of a complex chemical mixture secreted by the eccrine and the sebaceous glands located on the fingertips. This residue primarily consists of mainly in most situations water, sodium chloride, and potassium alongside organic compounds such as the amino acids, lipids and fatty acids. [5] Because these prints are invisible, they must undergo a process of "development" or "enhancement" to be documented. The most traditional and the most widely utilized method for this is powder dusting. [6] This process involves the mechanical application of the fine particles that adhere to the oily and moist remnants of the ridge patterns. While the concept is simple, the physics of adhesion requires a powder with a precise balance of particle size, shape, and surface energy. If a powder is too heavy, it fails to adhere and if the powder is too light, it disperses and then if it is too "sticky" it adheres to the entire surface hence resulting in destroying the necessary contrast between the ridges and the background. [7]

The history of fingerprinting is a fascinating journey that spans over several centuries, moving from the ancient cultural practices to the high-tech laboratories of the 21st century. While ancient civilizations in India and China used the thumbprints on clay tablets and silk to authenticate legal documents, the modern scientific era of the fingerprints began in the late 19th century. [8] Pioneers such as Sir William Herschel, who utilized fingerprints to prevent the pension fraud in colonial India and Dr. Henry Faulds, who recognized their potential for solving crimes laid the groundwork for modern dactyloscopy. [9] Eventually, the scientific method provided by Sir Francis Galton and the administrative framework developed by Sir Edward Henry led to the creation of the first systematic classification systems allowing law enforcement to organize and search through thousands of records for the first time. [10]

As the identification systems evolved, so did the physical methods used to recover prints at the crime scenes. Early investigators were resourceful but they also often relied on substances that were considered hazardous and dangerous. It was common to see the use of "anthracene" or various types of lead based powders, which provided excellent contrast but were also extremely hazardous to the health of the investigator. [11] Over time, the forensic industry developed standardized commercial powders such as carbon black and the magnetic powders. While these are currently the industry standard even then they possess significant flaws. Most commercial powders are synthetic and contain heavy metals or chemical resins that pose "occupational hazards" to the forensic technicians. [12] Technicians who spend years processing the crime scenes are frequently exposed to these fine dust particles which can lead to chronic respiratory diseases or even systemic toxicity when inhaled or absorbed. [13] Furthermore, these synthetic powders are also non-biodegradable. When a crime scene is processed these large quantities of powder are left behind or washed away into the local environment hence contributing to the microplastic pollution and chemical contamination. [14] This historical baggage has created a "research gap" and a pressing need for an eco-friendly solution. The shift toward natural powders like the Barnyard Millet proposed in this study is a necessary evolution to protect both the forensic practitioners and the nature. [15]

There are two types of Barnyard Millet, the Indian Barnyard Millet (Also known as “Mordhan”) and the other known as the Japanese Barnyard Millet. The choice of Indian Barnyard Millet as a subject for forensic research is highly significant for several environmental, economic and scientific reasons. In recent years, there has been a global resurgence of interest in the millets as highlighted by the "International

Year of Millets".[16] These "nutri-cereals" are known for their incredible resilience since they require very little water and virtually no synthetic pesticides to thrive in the harsh and arid climates. From a sustainability perspective the Barnyard Millet is a carbon sequestering "C4" crop that grows rapidly and leaves a minimal environmental footprint. [17] By repurposing this agricultural product into a forensic reagent we are moving toward a greener alternative where the natural resources are maximized and the waste is minimized.

The primary objective of this research is to synthesize and evaluate an eco-friendly and non-toxic fingerprint dusting powder derived from the Indian Barnyard Millet (*Echinochloa frumentacea*) for the visualization of the latent fingerprints. The study seeks to investigate the adhesion properties and the ridge-detail clarity of the millet based powder across various porous and non-porous surfaces also while assessing its efficiency as a sustainable and cost-effective substitute for the conventional synthetic chemical powders in forensic investigations.

LITERATURE REVIEW

Sara Moreno et al. (2021) This study investigated the impact of the chemical, physical and the morphological characteristics on the effectiveness of the six various different black fingerprint powders. Utilizing advanced analytical techniques such as the SEM, XPS and Raman spectroscopy the researchers determined that the powders consisting primarily of carbon and oxygen with the spherical particles approximately 50nm in size yielded the highest quality ridge detail. The results indicated that smaller and uniform particles significantly outperform larger and irregularly shaped alternatives. Furthermore, the research highlighted that the specific particle aggregation within perspiration residues can actually facilitate better print lifting hence providing critical insights into the optimization of commercial powder formulations for forensic use. [18]

Lifeng Ding et al. (2021) This study detailed the development of a bifunctional magnetic composite powder designed for the high-contrast enhancement of latent fingerprints using the carbon dot fluorescence. By employing a layer-by-layer assembly technique to create a core-shell structure the researchers then successfully mitigated the fluorescence quenching hence resulting in an intense blue emission under UV light. The powder's unique hydrophilic surface properties not only improved the chemical bonding with fingerprint residues but also served a safety function by absorbing the moisture to prevent the inhalation of airborne dust by forensic practitioners. Experimental results confirmed that this nanocomposite provides exceptional selectivity and sensitivity, allowing for the clear visualization of Level 2 and Level 3 ridge details while maintaining a user-secure application process. [19]

Vartika Khare and Anu Singla (2022) This review article evaluated the evolving landscape of forensic investigation by shifting focus from traditional pattern recognition to the chemical analysis of latent fingerprint residues. The researchers discussed how individual chemical profiles are influenced by external and internal factors, such as age, occupation, lifestyle, and environmental exposure. By synthesizing advancements in analytical instrumentation over the past decade, the study argued that identifying specific chemical constituents can provide crucial evidentiary value when ridge patterns are blurred or incomplete. The work concluded that while significant progress has been made in elucidating fingerprint composition, further research is essential to standardize the identification of individual donors and determine the precise aging kinetics of latent prints. [20]

Sneha Lohar et al. (2022) This research investigated an eco-friendly and economical approach to forensic identification by utilizing powders derived from plant-based waste materials, specifically orange and lemon peels. The study focused on the application of these natural, non-toxic powders to develop latent fingerprints on both porous and non-porous substrates using a standard camel hairbrush technique. The findings revealed that these organic powders successfully enhanced ridge characteristics with sufficient contrast for photographic documentation. By repurposing biological waste into reliable forensic tools, the authors demonstrated a sustainable alternative to synthetic chemicals that is both effective for crime scene investigations and safe for the environment. [21]

Harshita Niranjan et al. (2022) This study evaluated the effectiveness of various unconventional powder dusting techniques as a viable alternative to traditional forensic methods for identifying suspects. The researchers explored the use of widely available, non-toxic everyday materials that can be applied to porous, non-porous, and semi-porous surfaces using glass fiber or camel hair brushes. The paper emphasized that these cheaper, safer alternatives are highly useful for visualizing "chance" fingerprints found at crime scenes, which are typically invisible to the naked eye. By providing a collective review of existing unconventional materials, the authors demonstrated that these accessible substances can produce reliable ridge impressions while minimizing the cost and toxicity associated with conventional laboratory-grade powders. [22]

Francisco M. Gomes et al. (2023) This review article synthesized the historical and scientific progression of dactyloscopy, focusing on the core principles of uniqueness and immutability that underpin human identification. The authors discussed the fundamental chemical interactions, such as hydrogen bonding and Van der Waals forces, that occur between latent residues and various developers like ninhydrin and cyanoacrylate. Notably, the study highlighted a shift toward socio-environmental sustainability by exploring low-toxicity natural developers derived from seaweed and spices. Furthermore, the research emphasized the emerging role of mass spectrometry in analyzing the chemical composition of latent prints, which can reveal specific lifestyle details including the use of medications, lubricants, or illicit substances, thereby providing a multi-dimensional perspective for modern criminal. [23]

Yaling Li et al. (2023) This study introduced a "green" and biodegradable forensic reagent utilizing polydopamine nanospheres (PDA NSs) for the long-term visualization of latent fingerprints. By leveraging the abundant catechol and amine functional groups, the researchers developed a powder that adheres strongly to fingerprint residues through supermolecule interactions on challenging surfaces, such as leather, wood, and curved substrates. The research demonstrated that the PDA-based powder can successfully detect prints aged for over 90 days with a remarkably low detection limit and high contrast, as verified by gray value analysis. Ultimately, this harmless nanomaterial provides a highly competitive and sustainable alternative to commercial black magnetic powders for modern criminal investigations. [24]

David Nugroho et al. (2023) This research investigated the dual-purpose application of fluorophore-rich powders derived from four medicinal plant species Zingiber montanum, Solanum indicum L., Rhinacanthus nasutus, and Euphorbia tirucalli for forensic detection. The study focused on creating a safer, natural alternative to toxic chemical dusts that pose inhalation risks to investigators. By utilizing the inherent fluorescence of these botanical substances, the researchers successfully visualized latent fingerprints on multi-colored, non-porous surfaces with higher clarity than conventional powders. Furthermore, the study employed a "turn-on-off" fluorescent sensing mechanism to detect trace amounts of cyanide, demonstrating that these eco-friendly materials provide a high-potential, multi-functional tool for identifying both physical evidence and hazardous substances at crime scenes. [25]

Soumalya Roy et al. (2023) This research presented a cost-effective method for visualizing latent fingerprints by utilizing carbon powder derived from candle flame soot. The study focused on the development of invisible prints unconsciously left by perpetrators on various porous and non-porous surfaces. By collecting the black carbon mass and applying it through the traditional powdering technique, the authors demonstrated that this accessible material yields clear ridge patterns suitable for forensic identification. The findings highlight the importance of fingerprint enhancement for criminal investigations, providing a simple yet effective alternative to commercial reagents for establishing a definitive link between a suspect and a crime scene. [26]

Krushnai J. Parkale and Manjushri S. Bagul (2024) This review evaluated the transition from conventional, often toxic and expensive fingerprint powders to those derived from accessible natural materials. The authors contrasted traditional agents like titanium oxide and Rhodamine B dye with everyday substances categorized as food powders, minerals, and plant-based materials. The study emphasized that these organic alternatives offer a quick, cost-effective, and nontoxic method for developing latent fingerprints on both porous and non-porous substrates. By synthesizing research on various natural preparations, the work highlighted that these ecofriendly powders provide the necessary adhesion and contrast for reliable criminal identification without compromising the health of forensic practitioners. [27]

Peng Li et al. (2024) This research introduced a novel white fluorescent fingerprint powder developed by proportionally blending a carbazole-based dye (G-D) with other primary dyes and the montmorillonite (MMT). The resulting powder demonstrated exceptional performance in visualizing the latent fingerprints across a variety of challenging substrates including tin foil, marble and the painted wood while significantly minimizing background interference in dark environments. A key finding of the study was the powder's ability to successfully recover aged fingerprints up to 30 days old with high resolution. The authors concluded that this high contrast and wide applicability fluorescent medium serves as a highly competitive tool for real time criminal investigation and fingerprint replication. [28]

Rajdeep Kaur and Prabhpreet Singh (2024) This research presented the development of a multi-purpose yellow fluorescent powder ($2SiO_2$) synthesized by adsorbing a hydroxy benzothiazole-based derivative onto silica. The study leveraged the synergistic effects of the Aggregation-Induced Emission (AIE) and Excited State Intramolecular Proton Transfer (ESIPT) to achieve high solid-state fluorescence which enabled the visualization of Level 1 to 3 ridge details in both latent fingerprints and glove prints. The powder demonstrated robust binding affinity with sweat components such as Dglucose, urea, and lactate hence facilitating effective imaging on varied porous and non-porous surfaces without requiring post treatment. Furthermore, the authors validated the powder's practical utility by successfully developing aged and stained prints across different temperatures, underscoring its efficiency for high fidelity forensic documentation. [29]

Ying Fang et al. (2024) This study introduced a specialized fluorescent powder called DFF-MMT created by integrating a cyclic chalcone dye with montmorillonite for the advanced visualization of latent fingerprints. The researchers highlighted a unique color-changing property where the fluorescence shifts from orange to bright yellow upon contact with the sebaceous residues hence providing exceptional contrast on challenging backgrounds like LED screens and marble. The findings demonstrated that the developed prints maintain high fidelity for over 21 months and remain stable under the diverse environmental stressors including aquatic and the thermal conditions. Notably, the powder is non-destructive to DNA and cost-effective while offering a high-resolution and real-time solution for sophisticated forensic investigations on uneven or static prone surfaces. [30]

Bhoomi Aggarwal (2024) This research conducted a comparative analysis between traditional fingerprinting methods and the innovative use of Silica Gel G powder for latent fingerprint visualization. The study detailed how the hydroxyl (–OH) groups on the surface of the silica particles interact with glandular secretions including sebaceous, apocrine, and eccrine sweat to develop clear imprints on multiple substrates. The author emphasized that Silica Gel G, commonly used in thin-layer chromatography offers a highly precise and effective alternative to the conventional techniques. The findings underscore the significance of this material in enhancing ridge detail and providing forensic experts with a more versatile and detailed approach to identifying latent remnants during criminal investigations. [31]

Manaswini Karsharma et al. (2025) This review article provided a comprehensive evaluation of the historical and the contemporary advancements in luminescent and fluorescent materials used for latent fingerprint development. The authors detailed how organic and inorganic fluorescent compounds selectively bind to the sweat pore components on frictional ridges to render invisible prints visible under the specific light sources. The study particularly highlighted the emerging phenomena such as aggregation-induced emission (AIE) as a means to overcome traditional brightness limitations. By analyzing the properties, practical applications and inherent drawbacks of current materials the research aimed to define the criteria for an optimal developing agent that balances high sensitivity with minimal background interference to enhance global forensic investigation standards. [32]

Varinder Singh et al. (2025) This study addressed the primary limitation of the iodine fuming method and the rapid sublimation and fading of developed prints by introducing a stabilization technique using tetra-n-butylammonium iodide (TBAI). The researchers demonstrated that pretreating surfaces with TBAI allows for the formation of tetra-n-butylammonium triiodide (TBATI) which is a stable complex that ensures prolonged fixation of the visualized ridge details. Confirmed through UV-Visible, Raman and the FTIR spectroscopy this non-destructive approach proved effective for both porous and non-porous surfaces even for fingerprints aged up to four weeks. [33]

Hanan Ahmar et al. (2025) This critical review evaluated the transformative role of nanotechnology in forensic science specifically focusing on the shift from traditional and potentially toxic powders to advanced organic and inorganic and hybrid nano compositions. The authors discussed how nanoparticles including gold, silver and carbon-based materials provide superior sensitivity and resolution for the latent fingerprint visualization compared to conventional reagents. The study also highlighted the emergence of ecofriendly alternatives such as the dextran based and herbal powders to address sustainability and safety concerns. [34]

Rakshitha K. Jain et al. (2025) This upto date review detailed the utilization of small-molecule organic fluorophores for the high-resolution imaging of latent fingerprints on a broad range of surfaces. The authors examined the evolution of these inexpensive luminophores across various application methods including the powder, solution and the fuming techniques. The study emphasized that organic fluorophores offer superior sensitivity and selectivity by providing wide emission profiles that span the visible spectrum hence effectively eliminating background interference. [35]

Arul G and Akash Kumar Singh (2025) This study investigated the forensic utility of the drumstick (*Moringa oleifera*) skin powder as a sustainable and cost-effective alternative to toxic commercial fingerprint reagents. The researchers also demonstrated that this natural and finely ground powder is highly effective for visualizing latent fingerprints on a variety of surfaces including the porous, non-porous and semi-porous surfaces. The findings highlighted that the powder provides superior ridge enhancement and clarity while also being entirely safe for forensic practitioners to handle. By repurposing this organic waste into a reliable identification tool the study offers an ecofriendly solution for crime scene investigations particularly in settings where conventional chemical powders may be hazardous or inaccessible. [36]

Vaishnavi Thakre et al. (2026) This study evaluated the efficacy of the common construction materials such as the specific Grey Cement and the White Plaster of Paris (POP) as economical and non-hazardous alternatives for the latent fingerprint development. The researchers applied these powders to the twenty distinct porous and non-porous surfaces ranging from glass and aluminum foil to cardboard and fabric using the standard powder dusting technique. The results demonstrated that both the materials were highly effective particularly on the non-porous surfaces yielding clear and well-defined ridge characteristics that were rated highly on a subjective clarity scale. [37]

MATERIALS & METHODS

Indian Barnyard millet (Echinochloa frumentacea) is native to India and is a millet that contains silica and organic compounds and has important properties to utilize its grains as a natural fingerprint powder since it is a fine dry powder it adheres well and is environmentally safe.

The work in the research analysis was carried out by having the following steps:

1. **Preparation of the Barnyard Millet Powder**

The main ingredient in this study was the raw Indian Barnyard Millet grains. The grains were first milled with a mechanical mill to produce a powder. The mill was preferred since the grinders used at home might not be that powerful to provide a fine powder like consistency. The powder obtained was then passed through the fine-mesh sieves to obtain a fine texture of powder sensitive enough for the forensic purposes.

2. **Selection of the Test Surfaces**

In order to test the diverse functionality of the millet powder on various surfaces, several different samples of everyday household items were chosen.

These surfaces were then classified into two types:

Non-Porous Surfaces: These were smooth objects such as clean transparent glass, stainless steel bottles, Mobile screen, sunglasses, plastic boxes, etc.

Porous Surfaces (absorbent): Mainly consisted of absorbent surfaces like the notebook paper, tissue, etc.

3. **Deposition of the Fingerprint Samples**

On these various types of surfaces the latent fingerprint samples were developed using the powder and obtained. In this case the study focused on the sweaty (sebaceous) prints in order to get clearer results. One of the team members rubbed the finger against their nose or forehead as the skin there is oily and then pressed the finger to the surface that needs to be tested.

4. **Development Procedures**

The powder dusting technique was then used for developing the latent prints. A soft bristle brush was lightly dipped into the prepared barn yard millet powder. The brush was then lightly tapped to knock off any excess powder which would otherwise have resulted in a "clumped" or overly dusted fingerprint.

The powder was then dusted onto the surface using light, circular and sweeping motions. The strokes were then continued until the complete ridge pattern became visible. The upward strokes were stopped when the print was fully developed and then the excess background powder was also gently brushed away to enhance the contrast.

5. **Documentation of Results**

The prints were taken post the development as soon as possible. Using a mobile phone camera, the prints were noted with high resolution images (normal and geo tagged images) that were taken under the optimal light conditions. The barnyard millet powder was then assessed for its suitability by the clarity of the print developed, visibility and the ridge detail that appeared for each print. The observations were then noted in a notebook.

RESULT

The latent fingerprint visualizing agent used that is the Indian barnyard millet (Echinochloa frumentacea) powder's efficiency was evaluated in a total of 48 different everyday surfaces. The evaluation was then further divided into two major categories based on the type of surface porosity, i.e. non-porous surfaces (n=24) and porous surfaces (n=24).

Non-Porous Surfaces

The finely ground barnyard millet powder produced very good and uniform latent print visual results on the various 24 different non-porous surfaces. Since the non-porous materials do not allow liquid components of the sweat or any moist substance to penetrate hence these residues stayed on the surface where the powder got bound most effectively.

As shown in the table of images provided below the natural powder is very effective at sticking firmly only to the various raised fingerprint ridges on the different surfaces and at the same time giving almost little to no background staining on the smooth and the glossy objects. Items like the clear glass, stainless steel bottles and the screens of the phones resulted in very clear fingerprint images which also showed the ridge pattern continuously and also displayed where the minutiae points could be recognized without much difficulty. The scores for print visibility and ridge detail obtained by visually examining all 24 non-porous items are given in **Table 1.**

Table 1: Images of Latent Fingerprints developed on Non-Porous Surfaces using Barnyard Millet Powder

1. Clear Glass	2. Metal Can	3. TV Remote
		
4. Stainless Steel Bottle	5. Metal Plate	6. Metal Spoon
		
7. TV Screen	8. Sunglasses	9. Plastic Container
		
10. Plastic File	11. Laptop Screen	12.Door Frame

13. Glass Bottle

14. Plastic Bottle

15. Mirror

16. Door (Glossy)

17. Mobile Screen

18. Keyboard

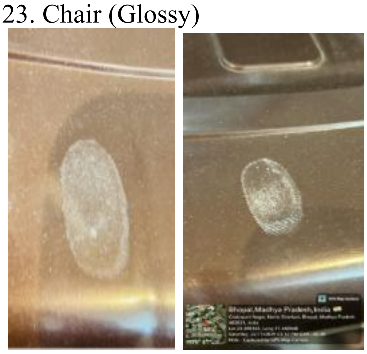
19. Zip Lock Bag

20. Clock

21. Teflon Wrap

22. Charger

23. Chair (Glossy)



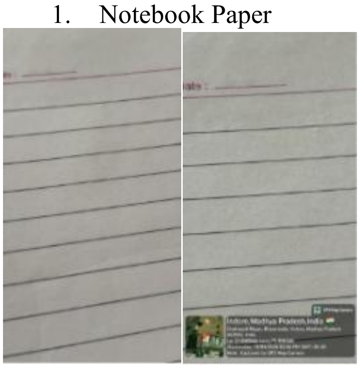
24. Pen

Porous Surfaces

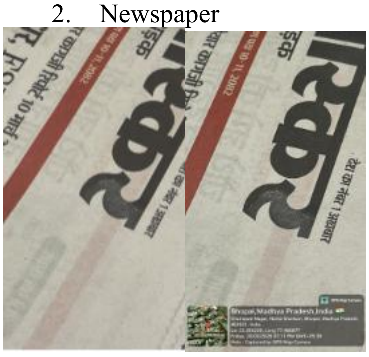
Testing the Barnyard Millet powder on 24 different porous surfaces demonstrated that it works well as a natural fingerprint visualizing agent even though the performance is largely influenced by the nature of the surface due to porosity. Fingerprints were successfully developed but the light-coloured surface and the light-coloured powder could not help in properly visualizing the fingerprints developed. On the other hand the highly fibrous materials like the cotton cloth and curtains showed background interference because the tiny millet particles got physically trapped inside the absorbent fibers resulting in partially covering the finer details. Nonetheless, the organic powder was able to regularly reveal identifiable latent prints on a wide range of paper evidence despite the textural issues as shown in **Table 2**.

Table 2: Development of Fingerprints on Porous Surfaces using Barnyard Millet Powder

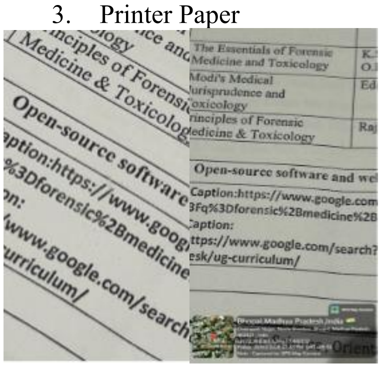
1. Notebook Paper



2. Newspaper



3. Printer Paper



4. Cardboard Paper

5. Envelope

6. Napkin

7. Paper Bag

8. Magazine Page

9. Sticky Notes

10. Egg Carton

11. Match Box

12. Plywood

13. Unpolished Wood

14. Cotton Cloth

15. Denim Cloth

16. Linen Cloth

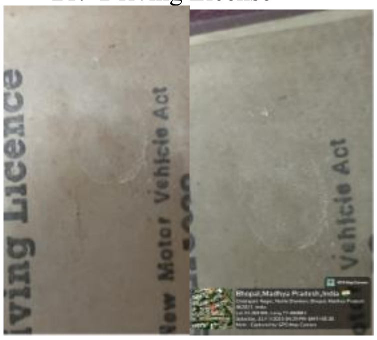
17. Wooden Table

18. Currency Note

19. Passbook

20. Craft Paper

21. Driving License



22. Curtain

23. Greeting Card

24. Receipt

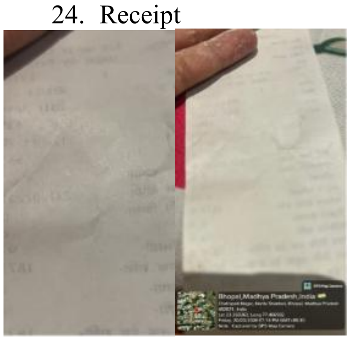


Table 3: Observation of Fingerprints developed on Non-Porous Surfaces

S. No.	Test Surface	Grading of Print Quality (0–4)	Contrast Efficiency	Ridge Continuity & Morphological Observations
1	Clear Glass	Grade 4	Outstanding	Good and sharp ridge definition and no background disturbance.
2	Metal Can	Grade 3	High	Clear ridge details and good quality image produced.

3	TV Remote	Grade 4	Excellent	High contrast development against the dark plastic and clear minutiae was observed.
4	Stainless Steel Bottle	Grade 4	High	Good flow of ridge lines and excellent powder adherence was observed on the glossy coat.
5	Metal Plate	Grade 3	Moderate	Good structural visibility of the fingerprint pattern and little reflection observed on the metallic surface of the plate.
6	Metal Spoon	Grade 3	Moderate	Clear patterns and some minor distortions were observed.
7	TV Screen	Grade 4	Outstanding	Sharp and high-contrast development of fingerprints.
8	Sunglasses	Grade 4	Excellent	Good quality of fingerprints observed on the surface.
9	Plastic Container	Grade 3	High	Clear and well-defined ridge pattern observed over the synthetic surface.
10	Plastic File	Grade 4	Excellent	Good fingerprint pattern with clear ridges observed.
11	Laptop Screen	Grade 4	Outstanding	Good ridge details observed with minimal background dusting.
12	Door Frame	Grade 3	High	Clear fingerprint pattern observed.
13	Glass Bottle	Grade 4	High	Uniform development of fingerprint observed across the cylindrical surface of the bottle.
14	Plastic Bottle	Grade 3	High	Consistent ridge patterns observed with clear visibility.
15	Mirror	Grade 4	Excellent	Sharp separation was observed between the ridges and furrows.
16	Door (Glossy)	Grade 3	Moderate	Visible ridge patterns were observed and light background reflection across the varnish.
17	Mobile Screen	Grade 4	Outstanding	The ridge flow and the core details were highly defined.
18	Keyboard	Grade 3	High	Minor edge scattering observed near characters.
19	Zip Lock Bag	Grade 3	Moderate	Clear prints were developed.
20	Clock	Grade 4	Excellent	Sharp contrast against the dark framework.

21	Teflon Wrap	Grade 3	Moderate	Clear fingerprint patterns were observed.
22	Charger	Grade 4	High	Exceptional visibility on matte black plastic.
23	Chair (Glossy)	Grade 3	High	Pattern type easily categorized.
24	Pen	Grade 3	Moderate	Identifiable ridges.

Table 4: Observation of Fingerprints developed on Porous Surfaces

S. No.	Test Surface	Grading of Print Quality (0–4)	Contrast Efficiency	Ridge Continuity & Morphological Observations
1	Notebook Paper	Grade 3	Moderate	Clear ridge flow.
2	Newspaper	Grade 2	Fair	Print developed, but the background newsprint text creates minor visual issues.
3	Printer Paper	Grade 2	Low	Ridges are visible on closer view but difficult due to the white-on-white contrast.
4	Cardboard Paper	Grade 3	High	Good visibility on the brown surface.
5	Envelope	Grade 3	Moderate	Light coloured surface causing less visibility.
6	Napkin	Grade 1	Poor	Heavy background staining due to rapid moisture absorption and fiber trapping.
7	Paper Bag	Grade 3	High	Good contrast against the raw paper fibers.
8	Magazine Page	Grade 4	Excellent	Good visibility on the colored gloss ink
9	Sticky Notes	Grade 3	Moderate	Clear ridge outlines observed.
10	Egg Carton	Grade 1	Poor	Significant powder clumping observed.
11	Match Box	Grade 3	High	Clear, well-defined print observed.
12	Plywood	Grade 3	Moderate	Ridge patterns follow the wood grain and prints are able to be identified.
13	Unpolished Wood	Grade 2	Fair	Partial ridge development observed.
14	Cotton Cloth	Grade 1	Poor	Particles of the powder seem to scatter within the loose fibers.

15	Denim Cloth	Grade 2	Fair	Heavy interference due to texture of surface.
16	Linen Cloth	Grade 1	Poor	Minimal ridge continuity observed.
17	Wooden Table	Grade 4	Excellent	Exceptional contrast on dark wood observed.
18	Currency Note	Grade 2	Fair	Complex background of the security printing observed to create high visual interference.
19	Passbook	Grade 4	Outstanding	Striking contrast against the dark colored cover observed.
20	Craft Paper	Grade 3	High	Strong physical adherence observed.
21	Driving License	Grade 2	Moderate	Faint but traceable prints observed.
22	Curtain	Grade 1	Poor	Highly disrupted ridge lines observed.
23	Greeting Card	Grade 3	High	Good clarity on the smooth surface.
24	Receipt	Grade 2	Moderate	Identifiable ridge groupings observed.

DISCUSSION

The evaluation of the Indian barnyard millet (Mordhan) powder across all the 48 different surfaces revealed that its fingerprint developing efficiency is also fundamentally dictated by surface porosity and texture. On the 24 non-porous items such as the glass and the mobile screens, the powder delivered exceptional and high contrast ridge details because the latent prints of the sweat and oil remain trapped on the surface hence allowing for precise and mechanical adhesion of the fine particulates without any type of background staining. Conversely, its performance also on the 24 porous and semi porous surfaces were also very highly variable. While the treated materials like the glossy magazine pages and the polished wood had yielded sharp and recognizable prints and highly fibrous and absorbent surfaces such as the cotton cloth and the napkins that had caused the latent moisture to wick away rapidly. The rough macro texture of these untreated materials had also mechanically trapped the powder hence resulting in the severe background smudging that had caused the obscured details of the fingerprint which were not clear. Additionally, the naturally light hue of the organic powder proved highly advantageous for dark or transparent objects, but it inherently struggled with visual contrast when applied to pale or highly patterned backgrounds, such as white printer paper and currency notes.

CONCLUSION

This study establishes that the powdered form of the Indian barnyard millet (Mordhan) is a highly viable, ecofriendly and cost-effective alternative to the usual conventional and chemically synthesized fingerprint powders.

Key findings include:

High Efficacy on Smooth Surfaces: The mordhan powder exhibits an outstanding adherence and almost high contrast visualization on non-porous items like the glass, metal, and plastic hence consistently yielding identifiable ridge details and sufficient enough minutiae suitable for forensic comparison.

Selective Porous Utility: Even though it performs beautifully on the semi porous surfaces that had coated or glossy finishes (such as magazine covers and treated wood) still its utility is significantly limited on the highly absorbent or the loosely woven materials (like cotton, linen, and raw paper pulp) due to the rapid moisture and mechanical trapping of the powder.

Contrast Dynamics: The natural light colour of the powder makes it an excellent choice for the dark and transparent surfaces and as compared to the dark surface the powder requires alternative lighting or lifting techniques when applied to light coloured backgrounds to overcome the poor photographic contrast.
Ultimately it comes to the conclusion that the organic nature of Mordhan powder mitigates the health risks associated with the inhalation of traditional heavy metal or any kind of carbon-based forensic powders. It serves as an excellent nontoxic addition to a crime scene investigator's toolkit especially for processing smooth and dark evidentiary items.

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