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CIÊNCIA e NATURA

ISSN 2179-460X
OPEN ACCESS

Ci. e Nat., Santa Maria, v. 47, e85634, 2025 • https://doi.org/10.5902/2179460X85634
Submitted: 11/06/2023 • Approved: 10/15/2025 • Published: 12/12/2025

Chemistry

Development of revealing powder for the powdering technique using *Hibiscus rosa-sinensis* L.

Desenvolvimento de pó revelador para a técnica de empoamento a partir do *Hibiscus rosa-sinensis* L.

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ABSTRACT

Due to the low rate of crimes solved in Brazil, there is a need to develop and/or enhance techniques that make it possible to solve crimes, identifying and holding the culprit accountable. Within this context, criminal fingerprinting is the most widely used technique for revealing latent fingerprints present at crime scenes. However, the technique uses toxic substances, which are expensive and limited to certain surfaces. Therefore, the main objective of this work is to develop a natural revealing powder using *Hibiscus rosa-sinensis* L. that can be used in forensic examinations, correcting the problems of current powder developers. The revealing powder was produced by grinding the species used until it reached a suitable particle size. It was then applied to glass, plastic and metal surfaces to analyze its effectiveness in identifying natural and sebaceous latent fingerprints in the short and long term. The revealing powder was totally efficient on the metal surface, identifying all the fingerprints and their characteristic points, but for the glass surface, it only showed satisfactory results for the sebaceous prints. On the other hand, the revealing powder was not as effective on plastic surfaces. As a result, it can be concluded that the revealing powder produced was totally effective on metal surfaces, partially effective on glass surfaces and not effective on plastic surfaces.

Keywords: Forensics; Criminal fingerprinting; Fingerprints; Sebaceous prints

RESUMO

Em virtude do baixo índice de crimes solucionados no Brasil, surge a necessidade de desenvolver e/ou potencializar técnicas que possibilitem a resolução do crime, identificação e responsabilização do culpado. Dentro desse contexto, na datiloscopia criminal, se enquadra a técnica de empoamento – técnica mais utilizada para a revelação de impressões digitais latentes presentes em cenas de crime. No entanto, a técnica trabalha com substâncias tóxicas, preços elevados e limitações em determinadas superfícies. Dessa forma, o objetivo principal do trabalho é desenvolver um pó revelador de origem natural a partir do *Hibiscus rosa-sinensis* L. que possa ser utilizado nos exames periciais corrigindo os problemas dos pós reveladores atuais. O pó revelador foi produzido a partir da trituração da espécie utilizada até que apresentasse um tamanho adequado de partículas. Em seguida, foi aplicado em superfícies de vidro, plástico e metal para analisar a sua eficácia em identificar impressões digitais latentes naturais e sebáceas em curto e a longo prazo. O pó revelador foi totalmente eficiente na superfície de metal, identificando todas as impressões digitais e seus pontos característicos, porém, para a superfície de vidro, apresentou resultados satisfatórios apenas para as impressões sebáceas. Já para a superfície de plástico, o pó revelador não foi tão eficaz. Com isso, pode-se concluir que o pó revelador produzido foi totalmente eficaz em superfícies de metal, parcialmente eficaz em superfícies de vidro e não foi eficaz em superfícies de plástico.

Palavras-chave: Perícia; Datiloscopia criminal; Impressões digitais; Impressões sebáceas

1 INTRODUCTION

It is common to hear the phrase “Brazil is the country of impunity” in discussions about public safety. This perception is largely due to the country’s low crime-solving rate—only 44%—which is below the global average (63%) and far lower than that of European countries (92%). These figures become even more concerning when analyzed alongside Brazil’s national homicide rate, which, although it has declined in recent years, remains alarmingly high. The country averaged 110 homicide victims a day in the last year, 2022, which shows that it is far from being considered a safe place. In other words, while Brazil has a large number of homicides, it also has a low crime-solving rate, which results in the lack of punishment and, in many cases, the failure to solve these cases (Batista, 2021; Velasco, 2022).

In this context, there is a need to use and/or develop reliable methods that can help to solve these crimes, or in other words, to identify a suspect who can be held accountable with the necessary evidence within the scope of the Judiciary. This scenario includes criminal investigation, an important means of proof, the purpose of which is to help the court in its decision, facilitating and enabling the resolution of crimes (Batista, 2021; Vargas & Krieger, 2014; ISP-RJ, 2018; Ribeiro & Lima, 2020).

Criminal forensics is a means of proof based on technical-scientific examinations conducted by a professional with specific training and expertise, aimed at clarifying facts for the justice system by identifying the dynamics and authorship of a crime and assisting the judge in forming a reasoned decision through the technical documentation of evidence (Capez, 2020). Based on its legal nature, forensics is highly valued as a means of proof, which is in an intermediate position between evidence and judgment, since it has great validity because it uses proven technical-scientific methods (Silva, 2013; Vargas & Krieger, 2014; Silva, 2020).

These methods of identification, as well as obtaining evidence, include papilloscopy, a branch of Forensic Biology and Chemistry that deals with human identification based on the study of the dermopapillary reliefs present on the palms of the hands, soles of the feet and, as the focus of our work, the study of fingerprints, known as criminal/forensic typoscopy (Pereira, 2010; Oliveira, 2016; Leitão et al., 2019; Mariotti, 2020; Leitzke et al., 2022).

In the criminal field, fingerprints are defined as residue found on surfaces that have come into contact with an individual's unprotected hands. Since these prints are unique to each individual, they can be used as primary human identification tools in forensic investigations. They are divided into three classes: patent (residue in which the material present on the fingertips, upon contact, is deposited on a surface leaving the shape of the subject's fingerprint), plastic (when the fingertips come into contact with a surface that can take the shape of the print, such as bloodstains) and latent fingerprints (invisible to the naked eye), the most commonly found at crime scenes (Pereira, 2010; Leitzke et al., 2022).

Because they are invisible to the naked eye, latent fingerprints require special techniques to reveal them. As a result, various studies have sought methods capable of making this identification over the years and, currently, the most widely used are the powdering method, ninhydrin spray, and immersion in silver nitrate. However, these methods present some problems such as high cost, toxicity and limited effectiveness on some surfaces (Pereira, 2010; Leitzke et al., 2022).

As a way of solving these problems, several substitutes of natural origin have emerged within the Chemistry of Natural Products that can be applied in the powdering technique for revealing fingerprints. These substitutes have great potential when used in criminal investigations due to the constituents present in their composition, which enable good adhesion and pigmentation to powders originating from natural products (Garg et al., 2011; Nicolodi et al., 2019).

Therefore, the aim of this work was to develop and evaluate the effectiveness of a revealing powder produced from the petals of *Hibiscus rosa-sinensis* L. for use in fingerprint powdering techniques, to facilitate and enable fingerprint identification — and consequently the determination of criminal authorship—while addressing issues such as the high cost and toxic effects of the materials currently in use.

2 METHODOLOGY

2.1 Selection of the species under study and creation of a database

As a result of a bibliographical survey, *Hibiscus rosa-sinensis L.* was the species selected for this study, as it was observed that the plant met some of the criteria established for acting as a revealing powder, such as good binding capacity or adhesion (the powder's characteristic of adhering to fingerprint residues) and good pigmentation (the powder produced from the species had a coloration that made it possible to visualize the papillary lines in contrast to the surface clearly). In addition, the species under study can be easily found in the region, has low toxicity and can be obtained commercially for use in the form of teas at a low cost.

After choosing the species, another bibliographic survey was carried out through the Science Direct and PubMed databases, using the specific terms "*Hibiscus rosa-sinensis* and isolation" or "*Hibiscus rosa-sinensis* and isolated" to establish a database of secondary metabolites that had already been identified and/or isolated from the species under study, so that its chemical composition, as well as factors that contributed to the use of this material as a revealing powder could be identified.

2.2 Preparation of revealing powder from the petals of *Hibiscus rosa-sinensis* L.

The material used as the revealing powder in this study was produced from the petals of the *Hibiscus rosa-sinensis* flower, which was purchased commercially (brand: Kisabor, year of production: 2023) in the city of Triunfo in Pernambuco.

The petals (200g) were crushed using a blender, then sieved in order to reduce the particle size of the powder, and finally ground in a mortar in order to further reduce the particle size. It is important to note that the process was repeated until it reached an appropriate size. Approximately 170g of crushed material was obtained.

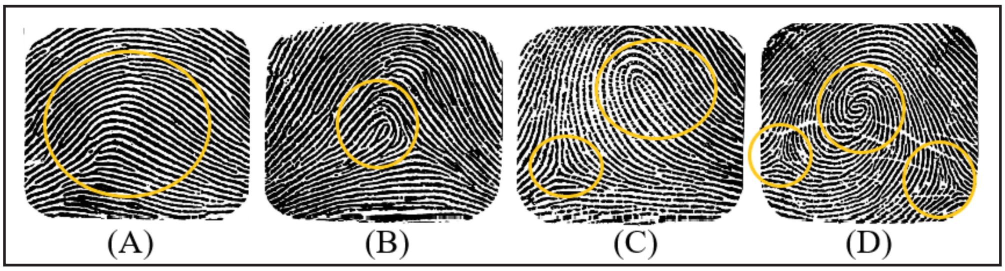
As there is no suitable size for revealing powder particles in the literature, the parameter used was the size that would allow clear and adequate visualization of the papillary lines, as well as having a good binding capacity.

2.3 Selection of volunteers for fingerprinting

To collect fingerprints, 12 volunteers were selected from a group containing 20 students from the Chemistry Degree and Biological Sciences Degree courses at the Federal Rural University of Pernambuco – Serra Talhada Academic Unit (UFRPE-UAST). The sample size chosen, 12 volunteers, was limited due to the time available for the analysis, allowing for greater efficiency in the collection and analysis of the results.

The following criteria were used to select the 12 out of the 20 volunteers: variety of fingerprints, in which the fingerprints of all volunteers were collected and classified according to the Vucetich classification presented in Silva (2018) (Figure 1), seeking to enable the analysis of different types of fingerprints. Furthermore, other parameters were considered in the selection process, namely gender and skin phototype, which aimed to ensure diversity and inclusion of most genders and skin colors. It should be noted that the skin phototypes were classified into 6 categories: extremely fair, fair, light brown, medium, dark brown and black.

Figure 1– Fingerprints types: (A) arch, (B) inner claw, (C) outer claw and (D) whorl



Source: Adapted from http://www.esie.eb.mil.br/images/material-didatico/Datilescola.pdf (2009)

Moreover, an exclusion criterion was also established, referred to as “difficult to identify,” in which individuals whose fingerprints could not be properly classified were not included in the study.

2.4 Collection and analysis of fingerprints

The method used to collect and analyze the fingerprints was adapted from Leitzke and collaborators (2022). Nine of the 12 volunteers were selected for the “instant analysis”, which consists of applying the revealing powder immediately after the fingerprint has been deposited on a given surface. In this analysis, once applied, the excess of revealing powder was removed using a brush and the results were recorded in photographed images. The aim of this stage is to analyze the efficiency of the revealing powder on latent fingerprints deposited in a short period of time. For this stage, three different surfaces were selected and applied (metal, plastic and glass). Later, the fingerprint deposited by three volunteers were analyzed.

The other three volunteers took part in “long-term analysis”, a method in which a single volunteer was assigned to a single type of surface (metal, plastic or glass). In this stage, the volunteers placed their fingerprints on three different objects, but with the same type of surface, then these objects were analyzed after different periods. After 24 hours, the developed powder was applied to object 1, while for object 2 and 3, it was applied after 15 days and 30 days, respectively. After applying the powder, the excess was removed and the results recorded in photographs. This method was used as a way of assessing the efficiency of the revealing powder on older fingerprints, since the chemical and biological composition changes over time CADD et al. (2015); Carvalho (2022).

Furthermore, it is worth noting that the study analyzed two types of fingerprints for each type of analysis (instantaneous or long-term): sebaceous and natural, in order to assess the efficiency of the revealing powder under different conditions, since these prints have different chemical compositions. For natural latent fingerprints (originating from natural secretions), the volunteers first washed their hands with neutral detergent and after drying, closed their hands to cause perspiration on the fingers. After sweating, they deposited their fingerprint on the chosen surface. Next, the revealing powder was applied, the excess removed with the help of a brush and the result recorded in a photograph.

To analyze sebaceous fingerprints, the procedure consisted of the volunteer rubbing their finger on oily areas of the body (forehead, nose, arms, etc.) and then pressing their finger on the surface. After applying and removing the excess revealing powder from the fingerprint residue, the result was recorded in a photograph.

2.5 Data analysis

The effectiveness of the revealing powder was analyzed according to the methods described in Garg et al. (2011); Kumari et al. (2011); Adhithya & Suneetha (2015) and Arshad et al. (2015), which were based on analysis by observation. The results were analyzed based on observation of the following aspects: adhesion (ability of the powder to adhere to the residues of the latent fingerprint), pigmentation (contrast between the color of the powder and that of the surface) and visualization (ability to visualize characteristic points on the latent fingerprints).

3 RESULTS AND DISCUSSION

3.1 Compounds present in *Hibiscus rosa-sinensis* L. according to the Literature

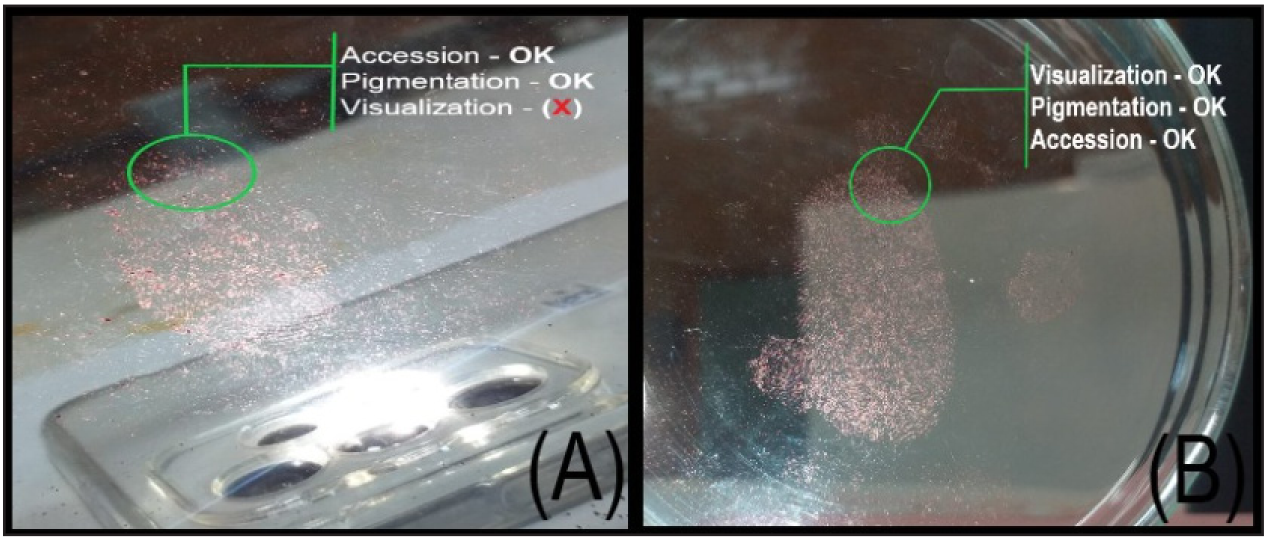
Due to the constant search for this species, several studies have been carried out on its use and phytochemical composition, with the aim of identifying the components responsible for its various activities. In this context, the main compounds present in its composition will be presented, especially those that have been directly involved in this work.

The species contains a majority of flavonoids (rutin, quercetin, kaempferol, myricetin, catechin, among others); flavones and flavonols (naringenin, quercetin-hexuronide-hexoside, taxifolin-dihexoside, kaempferol-hexuronide-hexoside, quercetin-trihexoside, epicatechin, quercetin-dihexoside, kaempferol-3-glucoside and others), anthocyanins (cyanidin sambubioside, cyanidin-3-glucoside, cyanidin-sophoroside) and vitamins (thiamine, riboflavin, niacin, ascorbic acid). In particular, the class of flavonoids, quercetin and the flavylium cation are used to justify and demonstrate the intermolecular interactions that explain the adhesion and pigmentation of the revealed powder (Al-Snafi, 2018; Rengarajan et al., 2020; Mejía et al., 2023).

3.2 Instant fingerprint analysis

For the instant analysis on the glass surface, the revealing powder did not make it possible to visualize the papillary lines, but it did have a good binding capacity and good pigmentation in relation to the surface for the analysis of natural fingerprints. However, for the analysis of sebaceous fingerprints, the revealing powder worked very efficiently, making it possible to see the papillary lines, good pigmentation in relation to the substrate and adequate binding capacity (Figure 2).

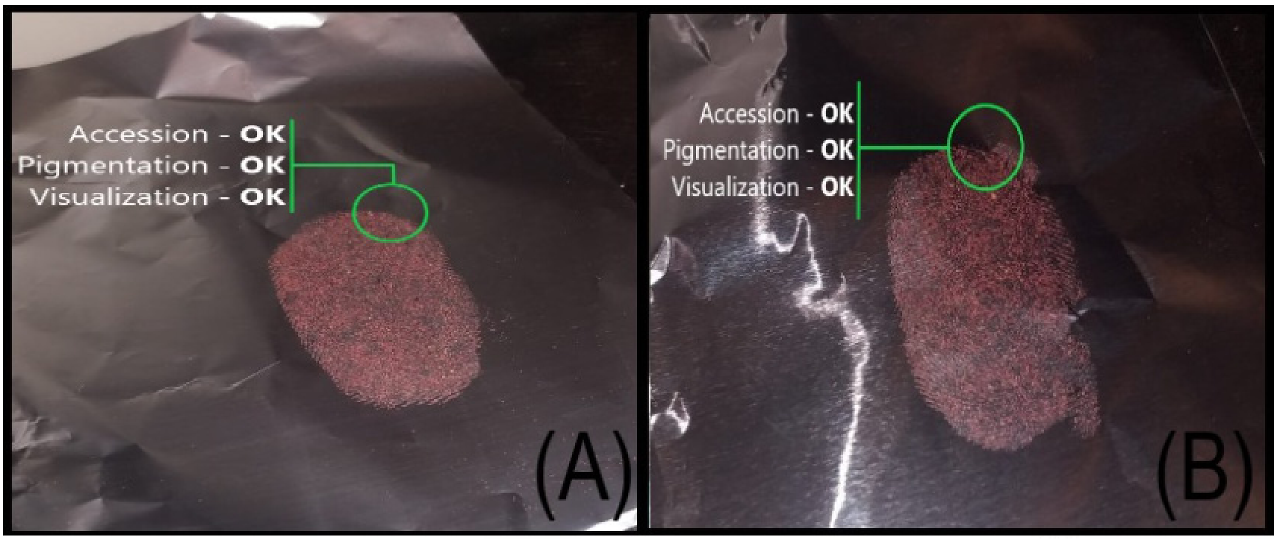
Figure 2 – Instant analyzes on the glass surface: (A) Natural fingerprint and (B) Sebaceous fingerprint



Source: Authors (2023)

The instant analysis on the metal surface showed satisfactory results for identifying natural and sebaceous fingerprints, making it possible to visualize the papillary lines, providing a good binding capacity and pigmentation in relation to the surface (Figure 3).

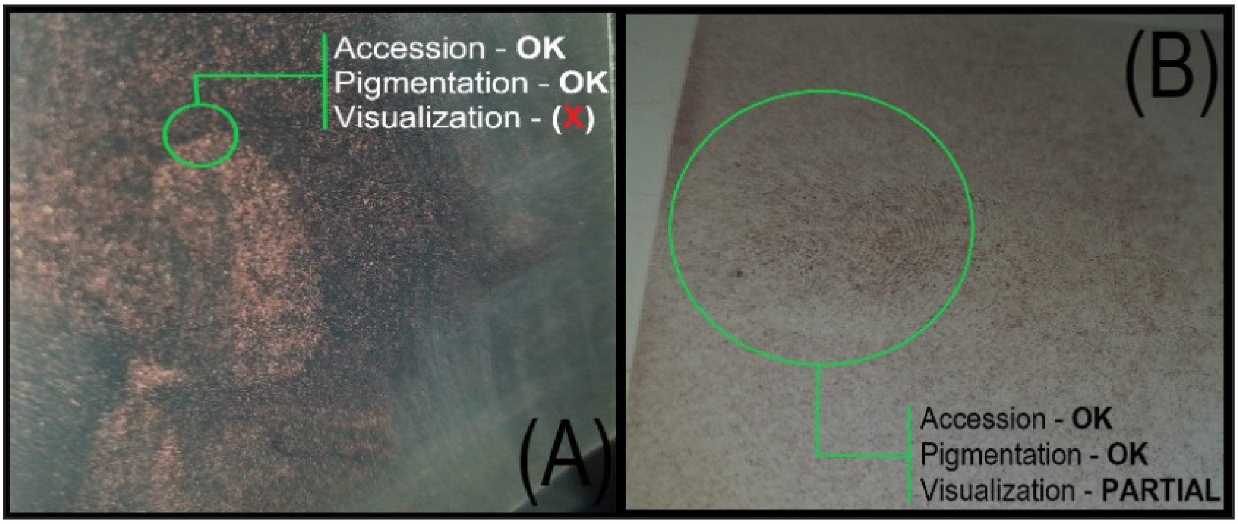
Figure 3 – Instant analysis on the metal surface. (A) Natural fingerprint and (B) Sebaceous fingerprint



Source: Authors (2023)

The efficiency of the revealing powder on the plastic surface was not considered satisfactory, so it was not possible to identify the papillary lines of natural fingerprints. It did, however, have good pigmentation and binding capacity. For the sebaceous fingerprints, the revealing powder made it possible to visualize the papillary lines only slightly. It also showed good pigmentation and adhesion to the substrate (Figure 4).

Figure 4 – Instant analyzes on the plastic surface. (A) Natural fingerprint and (B) Sebaceous fingerprint



Source: Authors (2023)

The binding capacity is closely linked to the interactions that occur between the revealing powder and the residues of the latent fingerprint. After analyzing the factors that could have interfered with the identification efficiency of natural fingerprints, it can be understood that the method used was decisive in causing this interference. The method used to take natural fingerprints consisted of causing perspiration through human heat after closing the fist for the required period. This technique, nonetheless, was shown to be ineffective, since the residue secreted to form the fingerprint was not sufficient to create a strong interaction between the residue and the developing powder, making it difficult to adhere to the natural residue, and thus, unable to reveal the papillary lines.

For the adhesion process to be efficient, the affinity between the revealing powder and the fingerprint residue must be greater than the interaction between the powder and the substrate (Carvalho et al., 2021). The results show that the revealing powder had a strong interaction with the plastic surface, making it difficult to clearly see the papillary lines on this type of surface.

During the first few moments after the fingerprints are deposited on the surface, their composition is dominated by water, which means the interaction that takes place during this phase is caused by the affinity of the revealing powder with the moisture present in the compounds of these prints. This interaction can be explained by the phenomenon of adsorption, which corresponds to the process in which the powder molecules (adsorbate) attach to the surface containing the latent fingerprint residues (adsorbent). Therefore, for fingerprints recently deposited on surfaces, the interaction that occurs with the revealing powder is explained by adsorption, given that in the first moments there is a large presence of humidity (water) in the composition of these prints. Therefore, the more recent the fingerprint, the greater the amount of moisture and, consequently, the greater the adhesion of the revealing powder to the water particles present in these residues (Sebastiany et al., 2013; Carvalho et al., 2021; Leitzke et al., 2022; Poletti, 2021).

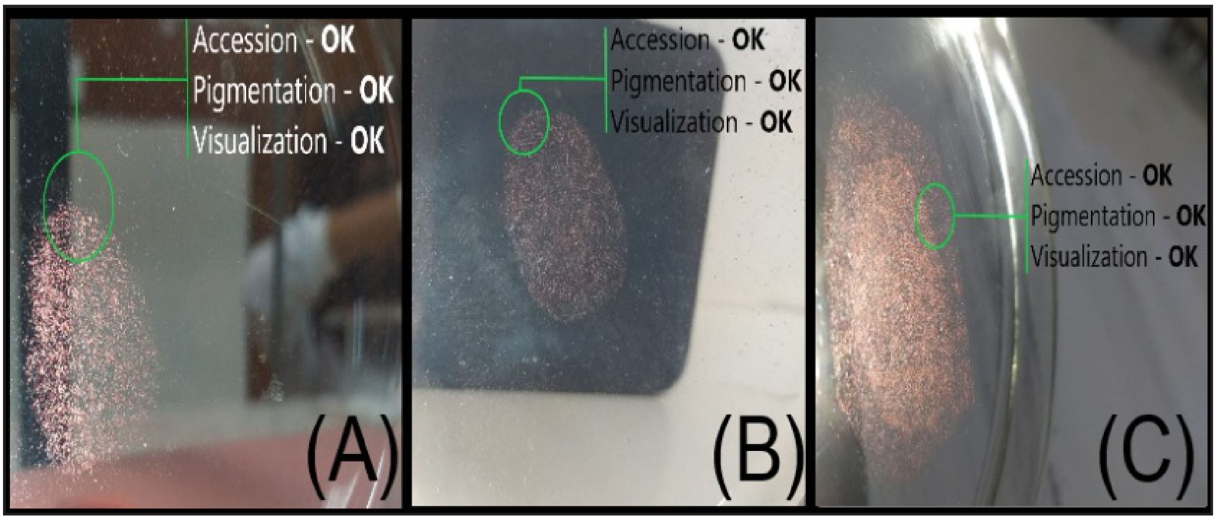
Furthermore, the revealing powder showed excellent pigmentation on all the surfaces analyzed. As pointed out in Poletti (2021), the different pigments applied in the powdering technique can result in efficient visualization, presenting optimum contrast in relation to the substrate applied. The color of the revealing powder produced from *Hibiscus rosa-sinensis* L. can be explained by the presence of natural pigments in its composition, such as flavonoids (water-soluble pigments) like anthocyanins, flavanones and flavonols (Lima et al., 2000). From the literature review, it was possible to identify these constituents in the composition of the flower petals, which results in the characteristic color of the revealing powder produced from this material, enhancing and enabling its use as a fingerprint revealer due to the factors mentioned, including its color.

From the results obtained for the instant analysis, it can be said that, for the most part, the revealing powder was effective in identifying natural and sebaceous fingerprints on the metal surface, while for the other surfaces (plastic and glass), only the sebaceous type was identified with greater clarity due to the aspects mentioned above.

3.3 Long-term analysis of fingerprints

For the long-term analysis on the glass surface, the revealing powder was not effective in identifying and visualizing natural fingerprints, because as discussed above, the method for collecting them was not as effective. However, the revealing powder was very effective in identifying and visualizing sebaceous fingerprints after 24 hours, 15 days and 30 days, showing good binding capacity, adequate pigmentation and visualization of the papillary lines, as can be seen in Figure 5.

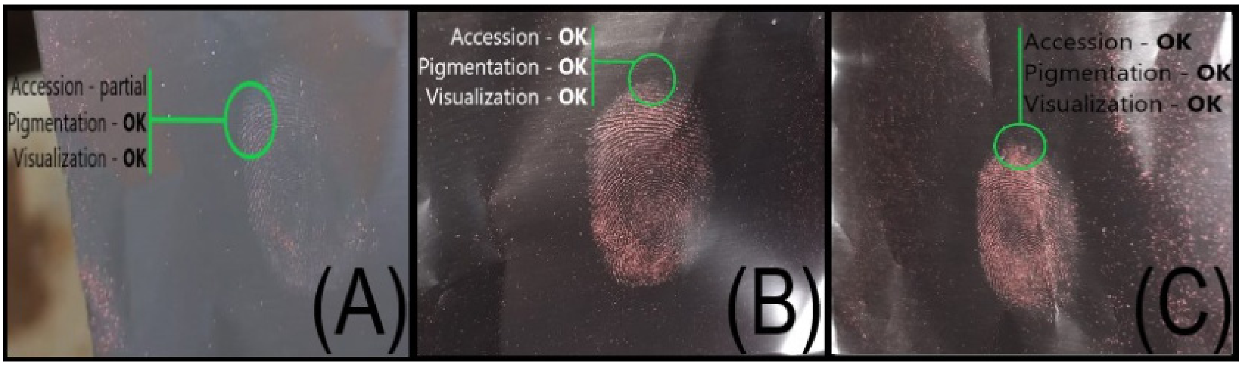
Figure 5 – Long-term analysis on the glass surface for sebaceous fingerprints. (A) 24-hour analysis, (B) 15-day analysis, and (C) 30-day analysis



Source: Authors (2023)

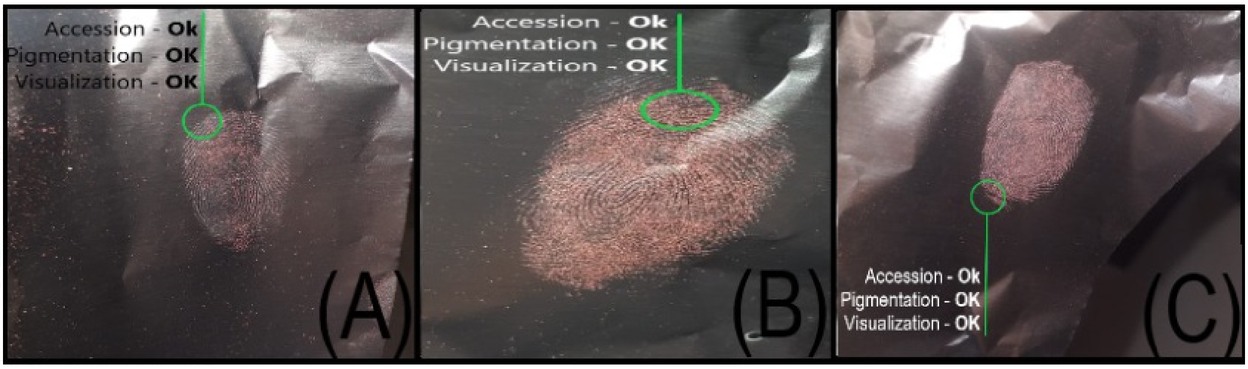
On the metal surface, the revealing powder was very efficient for identifying and visualizing natural and sebaceous fingerprints in both periods (24h, 15d and 30d), showing good binding capacity, pigmentation with excellent contrast with the surface, and visualization of the papillary lines (Figures 6 and 7).

Figure 6 – Long-term analysis on the metal surface for natural fingerprints: (A) 24-hour analysis, (B) 15-day analysis, and (C) 30-day analysis



Source: Authors (2023)

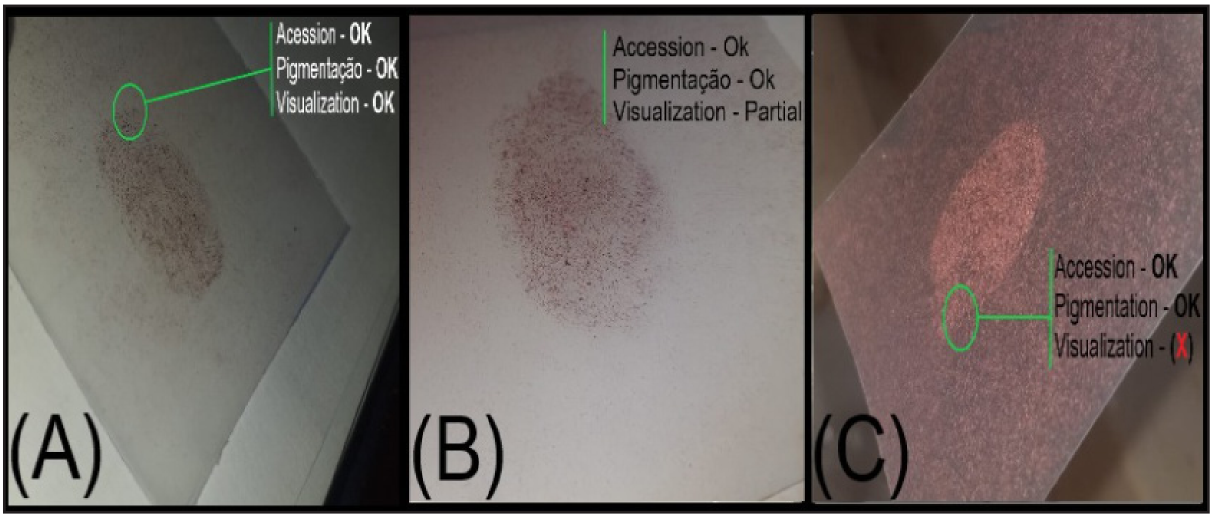
Figure 7 – Long-term analysis on the metal surface for sebaceous fingerprints: (A) 24-hour analysis, (B) 15-day analysis, and (C) 30-day analysis



Source: Authors (2023)

The results obtained on the plastic surface over the long term did not show results for the identification of natural fingerprints, but they show positive results for the identification and visualization of sebaceous fingerprints over the periods analyzed. The powder was efficient in showing good pigmentation and agglutination, and through these characteristics, it made it possible to visualize the papillary lines, which lost their quality as time went by, as seen in Figure 8.

Figure 8 – Long-term analysis on the plastic surface for sebaceous fingerprints: (A) 24-hour analysis, (B) 15-day analysis, and (C) 30-day analysis



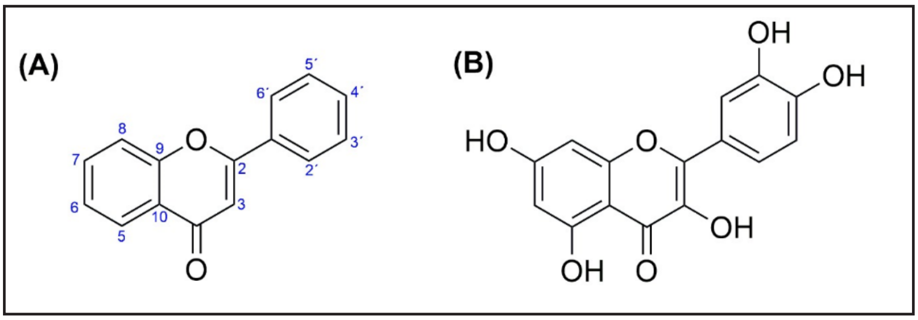
Source: Authors (2023)

Over time, the water present in the latent fingerprint residue evaporates, so the compounds that remain in this residue are sebaceous (alcohols, hydrocarbons and lipids), especially free fatty acids. As a result, the interaction between these compounds occurs through intermolecular interactions, such as Van der Waals forces and hydrogen bonds with the compounds present in the revealing powder (Sebastiany et al., 2013; Poletti, 2021; Leitzke et al., 2022).

Therefore, the binding capacity will be explained by the interactions between the sebaceous compounds, taking as an example the fatty acids present in fingerprint residues, and the compounds present in the revealing powder. It is worth noting that after the literature review, the revealing powder produced from *Hibiscus rosa-sinensis L.* showed a predominance of flavonoids in its composition, and this class will therefore be used to demonstrate the existing interaction that enables adhesion.

The basic structure of flavonoids is formed from a fundamental nucleus with 15 carbon atoms, organized into 3 rings, two of which (A and B) are substituted phenolics (Dornas et al., 2007). The flavonoid quercetin present in the composition of the revealing powder will be used to analyze the interactions, as shown in Figure 9.

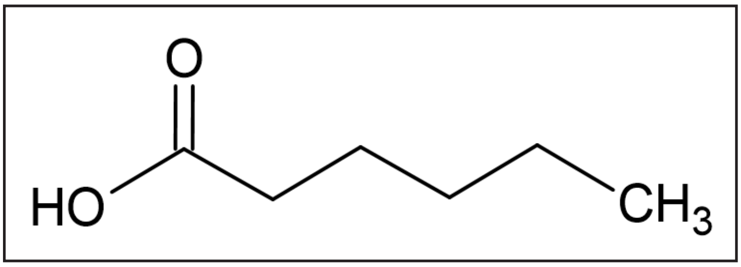
Figure 9 – (A) Basic structure of flavonoids and (B) Chemical structure of quercetin



Source: Authors (2023)

An example of fatty acids is hexanoic acid (Figure 10), which, according to the study carried out by Carvalho (2022), was one of the fatty acids most present in aged fingerprints.

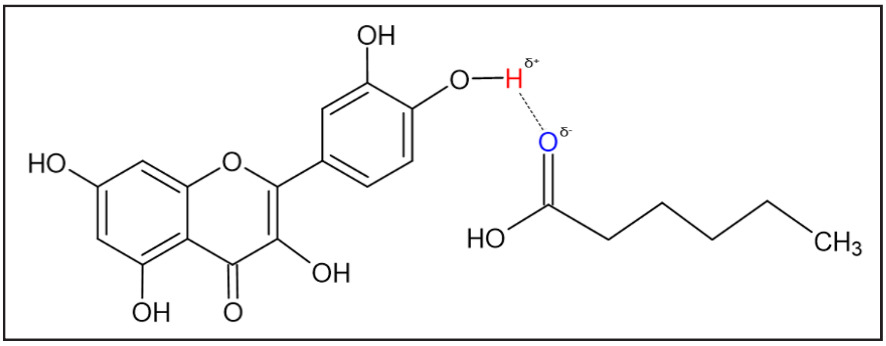
Figure 10 – Chemical structure of hexanoic acid



Source: Authors (2023)

One way of explaining the interactions that occur between residues and the revealing powder can be represented by hydrogen bonds, an attractive interaction between a hydrogen atom and a more electronegative atom. Therefore, it is possible to say that this interaction can be formed through the interaction between the oxygens present in latent fingerprint compounds, such as fatty acids, with the hydrogens present in flavonoids (Figure 11) (Aruan, 2011; Carvalho et al., 2021). In addition, this same type of interaction can also occur with the structures of flavonoids, which interact with the hydrogens present in sebaceous compounds.

Figure 11 – Hydrogen bond formed between quercetin and fatty acids



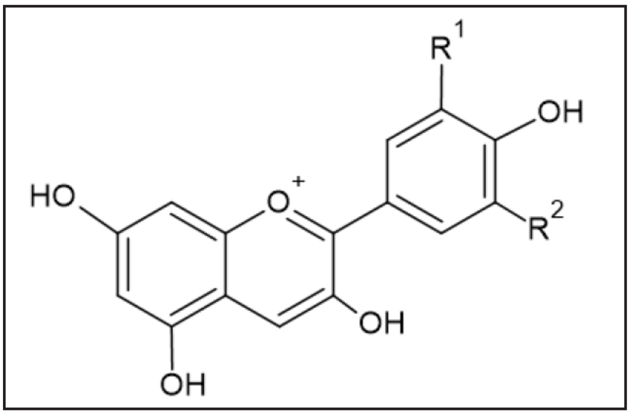
Source: Authors (2023)

It is important to note that this interaction is particularly strong, since the hydrogen bonds formed are electrostatic interactions involving attraction between positive and negative species, as is the case with the bond between hydrogen and oxygen. In this way, this interaction facilitates and guarantees the fixation of the revealing powder on the residues present in the latent fingerprints (Brown et al., 2005; Barreiro & Manssour, 2015; Carvalho et al., 2022).

From another perspective, adhesion capacity can be related to other electrostatic interactions, which are defined as the interaction between oppositely charged dipoles and/or ions. To illustrate this additional interaction, and again considering that the revealing powder produced contains a high concentration of flavonoids, this class of compounds was used to represent the interaction. Anthocyanins, which belong to the flavonoid class, are one of the most important groups of pigments of plant origin and are most frequently found in nature, in the form of a 2-phenyl benzopyrylium cation, known as flavylium cation, as shown in Figure 12 (Lopes et al., 2007).

An example of these compounds is cyanidin (anthocyanin with a structure similar to that in Figure 12, but with the following substituents: R1=OH and R2=H) which has been identified in the composition of *Hibiscus rosa-sinensis* L. (Março & Poppi, 2008; Maganha et al., 2010).

Figure 12 – Flavylium cation, fundamental nucleus of anthocyanins



Source: Authors (2023)

Based on the structure seen in Figure 12, the positive charge present in anthocyanins in the aromatic ring C means that interaction can occur through the attraction of the cation (positive charge present in anthocyanins) with an anion. The negative charge that will be part of the interactions may come from fatty acids, which have a polar part in their structures due to the carboxyl group present (Fahy et al., 2005). In this sense, anthocyanins can have an electrostatic interaction with fatty acids when they are in contact, since anthocyanins have positive electrical charges while fatty acids have a polar region that allows this interaction between the molecules to occur. Thus, when the interaction occurs, these molecules can result in the formation of molecular complexes and thus, help to identify latent fingerprints.

As a result, when applied to the instant analysis, the revealing powder also showed good pigmentation on older fingerprints, which can be explained by the presence of natural pigments in its composition, such as anthocyanins, making it possible to see the papillary lines well on both surfaces tested, with the glass and metal surfaces standing out.

Finally, in order to categorize the results obtained, they will be classified according to the following parameters established by Castelló and collaborators (2013): 0- No visible impression; 1- Poor quality, few ridges visible; 2- Poor quality, some ridge detail visible or partial mark with limited characteristics; 3- Reasonable quality, ridge detail and some characteristics visible. Possible identification; 4- Good quality impression, details and characteristics of the ridges visible, probable identification and 5- Excellent quality, very clear complete mark. Identification guaranteed. Thus, the results obtained for the instantaneous and long-term analyses can be represented according to Table 1.

Table 1 – Results for the instantaneous and long-term analyses for natural fingerprints (NFI) and sebaceous fingerprints (SDI)

Surfaces	NFI	SDI	NFI (24h)	SDI (24h)	NFI (15d)	SDI (15d)	NFI (30d)	SDI (30d)
GLASS	1	4	0	4	0	4	0	3
METAL	4	4	4	4	4	4	4	4
PLASTIC	0	1	0	3	0	2	0	0

Source: Authors (2023)

4 CONCLUSIONS

The need for criminal investigation to develop new techniques or enhance those already in use as a way of contributing to crime-solving is evident. In this context, this study demonstrates the great potential of natural revealing powders for identifying latent fingerprints as an excellent alternative to the revealing powders currently used.

Based on the results obtained, it is possible to say that, for the identification of latent fingerprints, especially those with sebaceous compounds, the revealing powder was efficient in identifying and visualizing these prints, especially on glass and metal surfaces. However, more studies are needed to prove its efficiency on plastic surfaces.

Finally, natural powders, particularly *Hibiscus rosa-sinensis* L., are an excellent alternative to the powdering technique, solving the problems of toxicity, high cost and inefficiency on some surfaces. Therefore, this material can be effectively applied in criminal investigations, contributing to the pursuit of justice. However, further studies should be conducted to evaluate the powder produced from *Hibiscus rosa-sinensis* L.

in conditions similar to those found at crime scenes, in order to validate the results obtained in this work.

ACKNOWLEDGEMENTS

The authors are thankful to the Federal Rural University of Pernambuco (UFRPE) for their support in carrying out the project.

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How to quote this article

Silva, D. F., & Pinheiro, E. B. F. (2025). Development of revealing powder for the powdering technique using *Hibiscus rosa-sinensis* L. *Ciencia e Natura*, 47, e85634. DOI: 10.5902/2179460X85634. Available in: https://doi.org/10.5902/2179460X85634