

**RECOVERY AND PERSISTENCE OF LATENT
FINGERMARKS ON FOOD**

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RECOVERY AND PERSISTENCE OF LATENT FINGERMARKS ON FOOD

by

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**Thesis submitted in fulfilment of the requirements
for the degree of
Bachelor of Science in Forensic Science**

February 2025

CERTIFICATE

This is to certify that the dissertation entitled Recovery and Persistence of Latent Fingermarks on Food submitted is the bona fide record of research work done by Koh Pei Yee during the period from October 2024 to February 2025 under my supervision. I have read this dissertation, and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation to be submitted in partial fulfilment for the degree of Bachelor of Science in Forensic Science.

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DECLARATION

I hereby declare that this dissertation entitled Recovery and Persistence of Latent Fingermarks on Food is my own original work and has not been submitted previously, in whole or in part, to any other institution for any academic award or qualification.

A handwritten signature in black ink, consisting of a stylized 'K' followed by 'P' and 'Y' with a horizontal line extending to the right.

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LIST OF SYMBOLS AND ABBREVIATIONS

AFIS	Automated Fingerprint Identification Systems
BIOFIS	Biometric Fingerprint Identification Systems
CV	Crystal violet
CA	Cyanoacrylate
DFO	1,8-Diazafluoren-9-one
FT-IR	Fourier Transform Infrared Spectroscopy
HDPE	High-density polyethylene
JPN	Jabatan Pendaftaran Negara
LDPE	Low-density polyethylene
ORO	Oil Red O
PET	Polyethylene terephthalate
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl chloride
SWGFAST	Scientific Working Group on Friction Ridge Analysis, Study and Technology
SPR	Small particle reagent

ABSTRAK

Cap jari merupakan bukti forensik yang penting dan sering ditemui di tempat kejadian jenayah. Dalam beberapa kes, penjenayah meninggalkan makanan yang separuh dimakan di tempat kejadian dan meninggalkan kesan cap jari yang tersembunyi di permukaan makanan tersebut. Walau bagaimanapun, pemulihan cap jari daripada makanan masih kurang diterokai. Kajian ini bertujuan untuk menyiasat keberkesanan pelbagai teknik pembangunan cap jari pada pelbagai substrat makanan dan mengkaji ketahanan cap jari dari masa ke masa. Sebanyak sepuluh jenis makanan dengan ciri permukaan berbeza telah dipilih, termasuk kuih lapis, wrap, mantou, telur rebus, ketam, kerang, roti, popiah, bola ikan, dan sosej. Kajian dijalankan dalam dua fasa: eksperimen utama untuk menentukan kaedah pembangunan cap jari yang paling berkesan pada permukaan makanan serta kajian ketahanan bagi menilai kelangsungan cap jari pada tempoh 1, 6, dan 24 jam selepas pemendapan pada mantou dan ketam. Lapan teknik pembangunan cap jari yang digunakan ialah serbuk cap-cap jari magnetik dan bukan magnetik, *small particle reagent (SPR)*, *sudan black*, *amido black*, *crystal violet (CV)*, *oil red-O (ORO)* dan *ninhydrin*. Hasil kajian menunjukkan bahawa ciri permukaan makanan memainkan peranan penting dalam keberkesanan pemulihan cap jari. Permukaan licin dan tidak berliang seperti mantou dan ketam memberikan hasil pemulihan semula yang lebih baik. Sebaliknya, permukaan yang terlalu licin seperti kulit telur dan cangkerang kerang, serta substrat yang melekit atau berminyak seperti kuih lapis dan popiah goreng, memberikan cabaran dalam pemulihan cap jari. *Sudan black* dan *ninhydrin* dikenalpasti sebagai teknik yang paling berkesan. Kajian ketahanan mendapati cap jari masih boleh dikesan sehingga 24 jam, walaupun mengalami degradasi. Kajian ini membuktikan bahawa pemulihan cap jari daripada

makanan adalah mungkin dan berterusan, menjadikannya faktor yang tidak boleh diabaikan dalam kes forensik sebenar.

ABSTRACT

Fingermarks are important forensic evidence often found at crime scenes. In some cases, criminals leave half-consumed food at the crime scene, leaving behind latent fingermarks on the food's surface that provide critical information for forensic investigations. However, recovery of latent fingermark from food items remains an underexplored area. This study aimed to investigate the effectiveness of various fingermark development techniques on different food substrates and examined the persistence of latent fingermarks over time. Ten food items with varying surface properties were selected, including kuih lapis, wrap, mantou, boiled egg, crab, clam, bread, popiah, fish ball, and hotdog. The study was conducted in two phases: a main experiment to determine the most effective development method and a persistence study evaluating fingermark survivability at 1, 6, and 24 hours of post-deposition on mantou and crab. Eight different development methods were used, namely non-magnetic powder, magnetic powder, small particle reagent (SPR), sudan black, amido black, crystal violet (CV), oil red-O (ORO) and ninhydrin. The findings indicated that the surface characteristics of food significantly influenced fingermark recovery. Smooth, non-porous surfaces such as mantou and crab shells yielded better results. In contrast, overly smooth surfaces such as eggshells and clam shells, along with sticky or oily substrates like kuih lapis and fried popiah presented challenges. Sudan black and ninhydrin were identified as the most effective development techniques. The persistence study revealed that fingermarks remained detectable for up to 24 hours, with notable degradation over time. The study highlighted that developing fingermark from food item is both possible and persistent, making it a factor that should not be overlooked in real forensic cases.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Fingerprints are the unique patterns of friction ridges found on an individual's fingers (Champod *et al.*, 2004; Daluz, 2018). These patterns are permanent, unchanging, and unique to each person, making them a reliable tool for personal identification. Fingerprints play a vital role in forensic science, serving as critical evidence for linking suspects to crime scenes or objects.

Whereas, fingermarks refer to the impression or residue left behind by a finger when it comes into contact with a surface (Bumbrah *et al.*, 2016; Champod *et al.*, 2004). These marks may be latent (invisible to the naked eye), patent (visible due to contamination by substances like blood or ink), or plastic (three-dimensional impressions). Fingermarks are not always as distinct as fingerprints due to environmental factors and the nature of the substrate they are left on, which can degrade their quality or clarity.

Fingerprints have long been considered a fundamental tool in forensic investigations due to their distinct and immutable features, making them invaluable for personal identification. Over time, fingerprint analysis has advanced significantly, focusing on refining methods to recover fingermark from a variety of surfaces, enhancing its utility in criminal investigations.

While much of the research has focused on conventional surfaces such as glass, metal, and paper, food items on the other hands have received limited attention as a surface for fingermark recovery. The distinct textures, compositions, and environmental factors associated with food surfaces, including porosity, moisture, oil, and surface irregularities, present significant challenges for effective fingermark

recovery. This study aimed to address these challenges by exploring the methods for recovering latent fingerprints from food items, investigating their persistence over time, and contributing to the broader field of forensic science by enhancing techniques for evidence collection from unconventional surfaces.

1.2 Problem Statement

Every contact leaves a trace, and fingerprints are important forensic evidence that commonly encountered at crime scenes. Since the late 19th century, fingerprints have been utilized in forensic investigations for personal identification due to their unique and immutability characteristics (Gomes *et al.*, 2023). Every individual has unique and distinct fingerprint, with no two people, not even twins, having the same patterns. Additionally, a person's fingerprint ridge will remain consistent throughout their lifetime.

Generally, there are three types of fingerprints, which are patent prints, plastic prints, and latent prints. Patent prints are visible impressions left by substances like blood or ink. Plastic prints are three-dimensional impressions created when a fingerprint is pressed into a soft surface, capturing the ridge details. In contrast, latent prints are hidden and cannot be seen without specialized techniques. These latent prints are revealed through physical or chemical processes designed to enhance the residues left behind by the friction ridges (Yamashita *et al.*, 2014).

However, it is challenging when dealing with fingerprints at crime scenes, particularly because many of these marks are latent and often found on unconventional surfaces. Currently, forensic practices are heavily focused on recovering fingerprints from conventional surfaces such as glass, metal, paper and etc, leaving a significant

knowledge gap when it comes to food items. Food items have diverse textures, porosity, colours, and compositions that complicate the fingerprint recovery and development. Factors such as moisture, oil, and surface irregularities in food further hinder the adherence and visibility of fingerprint residues.

While some studies have investigated fingerprint recovery from fruits and vegetables using powders, chemical reagents, and cyanoacrylate fuming, these studies have highlighted both the potential and the limitations of these methods in retrieving fingerprints from food items (Amit and Chattopadhyay, 2014; Ferguson *et al.*, 2013a; Hiroi, 2021; Hong *et al.*, 2019; Trapecar and Vinkovic, 2008). The limited understanding of optimal recovery techniques for food surfaces has limit forensic practitioners from fully utilising potential evidence.

This research aims to addresses these gaps by identifying the most effective methods for recovering latent fingerprints on various types of food surfaces and studying the persistence of these fingerprints over certain period of time (Daluz, 2018). The goal is to provide new insights that could expand current forensic practices to include latent fingerprint recovery from unconventional surfaces, enhancing the comprehensiveness of evidence collection in forensic investigations.

1.3 Objectives

1.3.1 General Objective

The general objective of this study was to investigate the recovery and persistence of latent fingerprints that deposited on various food items.

1.3.2 Specific Objectives

- I. To determine the most effective fingerprint development technique on food surfaces.

- II. To examine the persistence of latent fingerprint on food items.

1.4 Scope of the Study

This study focused on food items with varying surface properties for the deposition of latent fingerprint. The food items included kuih lapis, wrap, mantou, boiled egg, crab, clam, bread, popiah, fish ball and hotdog, which were purchased freshly on the day of experiment. The experiment was conducted in two main parts. The first part was main experiment to determine the most effective development technique for latent fingerprint on food. While, the second part investigated the persistence study on the latent fingerprint that deposited on food over intervals of 1 hour, 6 hours and 24 hours of post-deposition.

1.5 Significance of the Study

The findings of this research have the potential to expand the utility of latent fingerprints as forensic evidence by identifying effective techniques to recover them on non-conventional surfaces such as food. This study provides law enforcement agencies with insights into the possibility of retrieving valuable evidence from food items present at crime scenes, allowing for a more comprehensive examination of overlooked evidence. Furthermore, by examining the persistence of fingerprints, this study offers forensic practitioners a timeframe within which latent fingerprints may still be recoverable, thus aiding in determining the relevance and reliability of fingerprint evidence on perishable items.

CHAPTER 2

LITERATURE REVIEW

2.1 Fingerprint

Fingerprint are unique pattern that made up of friction ridge. According to Scientific Working Group on Friction Ridge Analysis, Study and Technology (SWGFAST), friction ridges is a raised portion of the epidermis on the palmar (hands) or plantar (feet and toes) skin, that composed of interconnected ridge units (Daluz, 2018). These ridges are essential for gripping and tactile sensitivity, but their uniqueness and permanence also make fingerprints a powerful tool for personal identification and forensic investigations.

The unique and permanent nature of fingerprints makes them a cornerstone of biometric identification systems, such as those used for device access and physical security controls. Additionally, fingerprints are integral to forensic science. Many countries, including Malaysia, store citizens' fingerprints in centralized databases like the Jabatan Pendaftaran Negara (JPN) for identification purposes. The existence and availability of large fingerprint database make fingermarks¹ become the most commonly used as evidence that provide investigative leads in investigations, which can use to establish a link between a crime scene or an object and an individual, to identify the perpetrator or elimination of a suspect (Ferreira *et al.*, 2021).

However, confusion often arises between fingerprints and fingermarks. A fingerprint is defined as a reference impression taken under controlled conditions with the cooperation of the individual, using either an inking process or an optical device. Because of these pristine acquisition conditions, fingerprints are near-perfect

¹ Fingermark: Impression that left by unknown individual in uncontrolled conditions.

representations of the friction ridge skin(Champod *et al.*, 2004; J. Fraser and Williams, 2013). In contrast, a fingermark refers to an impression composed primarily of sweat residues, left unintentionally when someone touches an object without gloves or footwear (Becue *et al.*, 2012). Due to the uncontrolled nature of their deposition, fingermarks often vary in quality compared to fingerprints.

Skin consists of three main layers, which are epidermis, dermis and hypodermis. The epidermis, the outermost layer, is further stratified into five sublayers, which are stratum corneum, stratum lucidum, stratum granulosum, stratum spinosum, and stratum basale (**Figure 2.1**). Strata corneum is the top layer of skin while the stratum basale, the deepest layer of the epidermis, plays a pivotal role in fingerprint formation. It generates cells during fetal development as the volar pads recede, forming the friction ridges that create the fingerprint pattern (Daluz, 2018).

Fingerprint uniqueness stems from the biological process of friction ridge skin morphogenesis. The formation of ridge patterns begins around the 6th week of gestation and is significantly influenced by physical stresses exerted by volar pads—localized subcutaneous tissue on the hands and feet. By the 10th to 14th week of gestation, primary ridges form as these volar pads compress and shape the overlying skin. By the 24th week, secondary ridges develop, and the dermis matures to anchor the ridge structure. This anchoring ensures the permanence and stability of fingerprints, which remain unchanged throughout an individual's life unless the dermis is destroyed (Meuwly, 2009).

Several factors contribute to the individuality of friction ridges, including genetic and epigenetic influences, fetal positioning, nutrition, environmental factors, and growth stresses. Additionally, the morphology of volar pads, such as their height, thickness, and contour, plays a critical role. The timing and rate of ridge formation,

bone structure, and the presence of vessel–nerve pairs in the dermal papillae also contribute to the unique arrangement of ridges and minutiae. The basal layer serves as the blueprint for ridge patterns, ensuring their permanence throughout an individual’s life (Daluz, 2018).

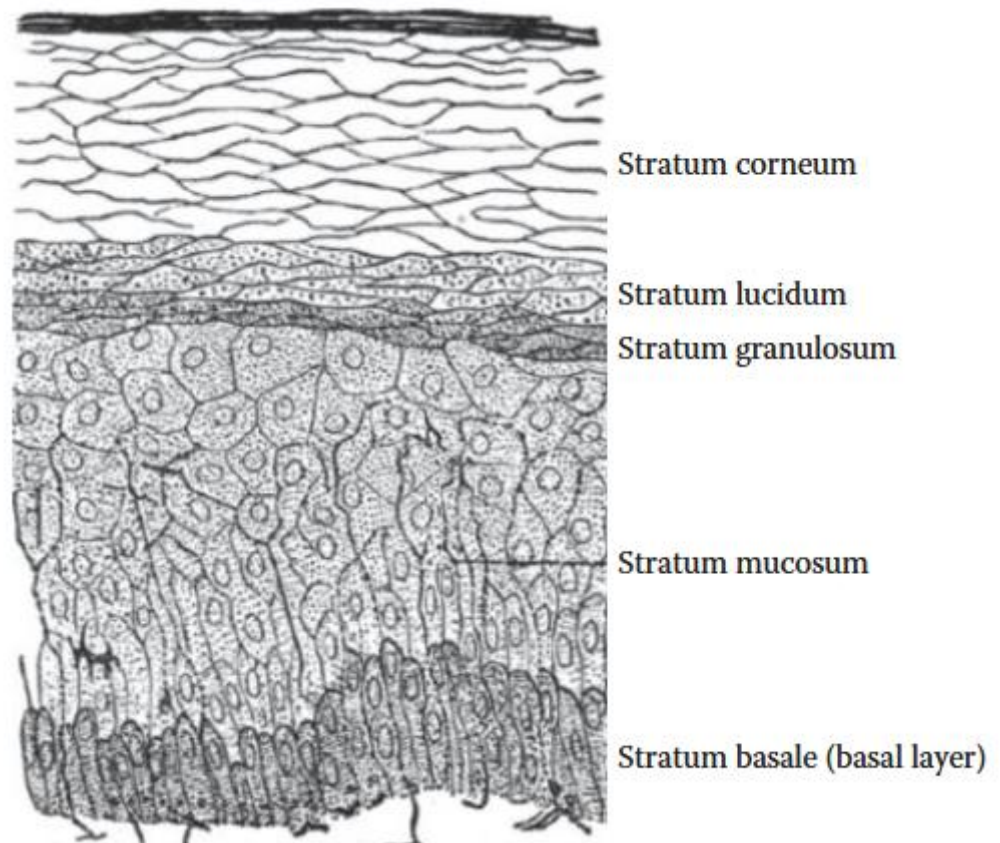


Figure 2.1: Five layers of the epidermis (Daluz, 2018)

2.2 Fingerprint Identification and Classification

Fingermarks are highly valuable in forensic investigations due to their unique and permanent nature. No two individuals, not even identical twins who share the same genetic makeup, possess identical fingerprints. This individuality categorizes fingerprints as an individual characteristic rather than a class characteristic. Their permanence, persisting unchanged throughout an individual’s life until death unless

the dermis is damaged, ensures their reliability for identification purposes. Fingermarks are often inadvertently left on surfaces by individuals, particularly when fingers are perspiring, making them an important source of evidence in forensic science

The inherent discriminative characteristics of fingerprints ensure their acceptance as a robust method for individualization. The reliability of fingerprint comparison stems from the distinctive features carried by friction ridges, which are categorized into three dimensions: Level 1, Level 2, and Level 3 features as shown in **Figure 2.2** (Chen *et al.*, 2022)..

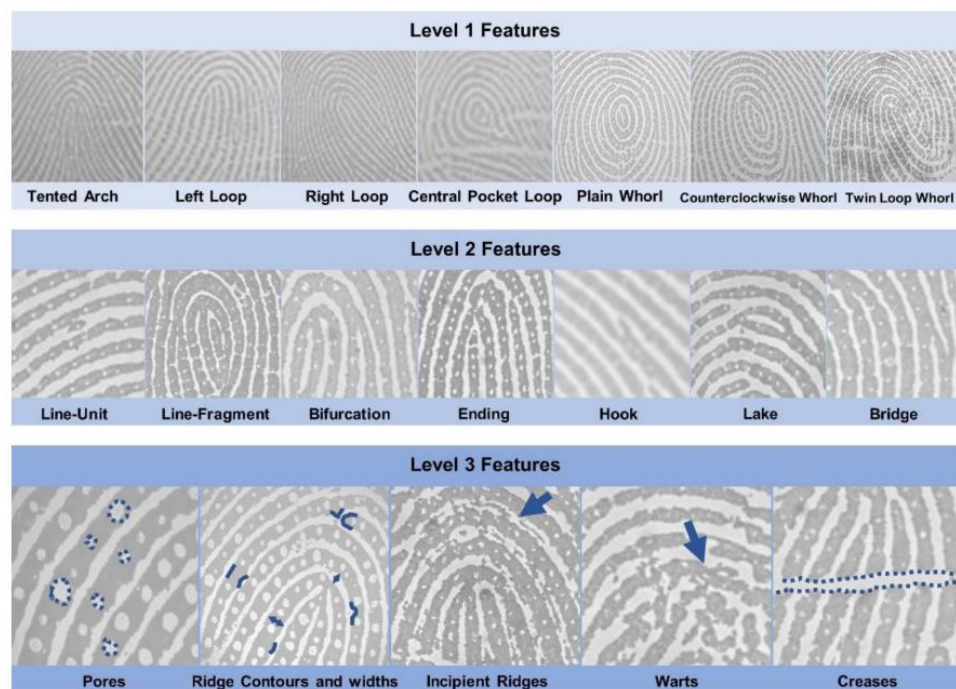


Figure 2.2:Fingerprint features at levels 1, 2 and 3 (Chen *et al.*, 2022)

2.2.1 Level 1 Fingerprint Features

Level 1 features include the general ridge flow and macro patterns of the fingerprint. These features classify fingerprints into three basic fingerprint pattern types which are loops, whorls, arches. These patterns provide an initial classification and are useful for narrowing down potential matches in fingerprint databases. Although Level 1 features alone are insufficient for individualization, they serve as a foundation for further analysis.

Before exploring the general patterns of fingerprints, it is essential to introduce two key features frequently observed in fingerprint analysis: core and delta points. The core is located at the approximate centre of a fingerprint pattern, serving as a focal point for ridge flow. The delta, on the other hand, is a point where two ridge lines diverge, typically located at or near the divergence point of two type lines.

Loops are the most common fingerprint pattern, found in approximately 60%–70% of the population (Daluz, 2018). In this pattern, ridges enter from one side of the finger, curve back, and exit on the same side. Loops are sub-divided into two main groups: ulnar and radial loops. Ulnar loop is when the loops open toward ulnar bone or the little finger, while radial loops when the loop opens toward radial bone or the thumb.

Whorls are the second most common fingerprint pattern, found in approximately 30%–35% of the population. They exhibit a circular pattern and must have at least two deltas with a sufficient recurving ridge in front of each delta. There are four subcategories of whorls: plain whorls, double-loop whorls, central pocket loop whorls, and accidentals. Plain whorls, which consist of concentric circles or spirals; double-loop whorls, featuring two interwoven loop formations; central pocket loop whorls, which include a loop with a circular or spiral ridge near the core; and

accidentals, which combine multiple pattern types, such as loops and arches, into a more complex structure.

Arches are the least common fingerprint pattern, appearing in approximately 5% of the population. They are characterized by the ridges enter from one side of the print and flow out the other side with a rise in the centre. It has two types: plain and tented arches. Plain arch has a relatively smooth and uniform ridge flow, while tented arch has a sharper, more pronounced rise at the centre, resembling a tent-like structure.

2.2.2 Level 2 Fingerprint Features

Level 2 features focus on the ridge characteristic of fingerprint or also known as minutiae. These ridge characteristics includes ridge endings, where a ridge abruptly terminates; bifurcations, where a single ridge splits into two; enclosure, which form closed loops or ovals; dot, appearing as tiny, isolated ridges; short ridge, which is significantly shorter than typical ridge lines; spur, small protrusions extending from a ridge; and crossover, small ridges joining two longer adjacent ridges (**Figure 2.3**) (Champod *et al.*, 2004; Ho and Eswaran, 2011; K. and Aithal, 2017; Kumar *et al.*, 2018). Additionally, occasional features such as warts, scars, creases, and wrinkles also fall under Level 2 features, further contributing to the unique nature of individual fingerprints (Champod *et al.*, 2004).

The presence of the ridge characteristic and its relative location in which the ridge characteristic on the fingerprint provide sufficient discriminative power to establish individualization. The identification process involves analysing and comparing these points of interest across fingerprint samples. While Level 1 features provide general patterns such as loops, whorls, and arches, they are insufficient on their own to uniquely identify individuals. However, when combined with Level 2

features, which offer a finer level of detail, the accuracy and reliability of fingerprint identification systems are significantly enhanced (K. and Aithal, 2017).

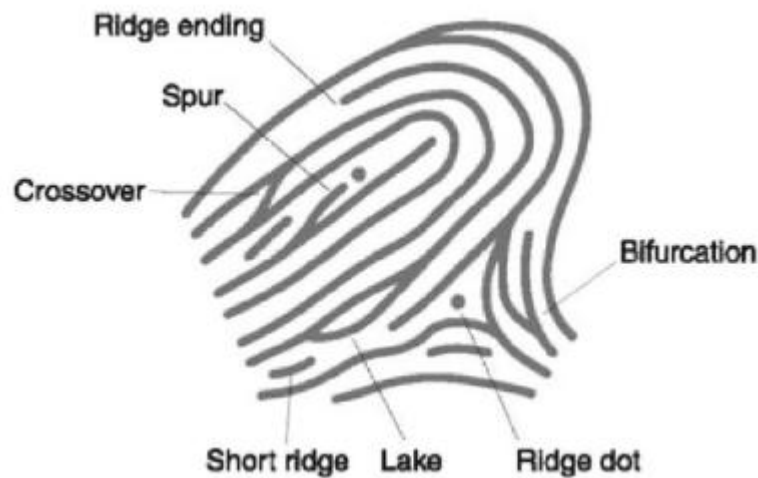


Figure 2.3: Ridge characteristic (Alsawwaf and Chaczko, 2020)

2.2.3 Level 3 Fingerprint Features

Level 3 features include the most intricate and microscopic details of friction ridges, including location, shape, size, frequency, and spacing of pores (referred to as poroscopy) as well as the contour, width, and texture of individual ridges (referred to as ridgeoscopy) Chen *et al.*, 2022. These minute characteristics, often imperceptible without advanced imaging technologies, form the foundation of highly refined fingerprint analysis.

Recent research has demonstrated that Level 3 features provide more than just individualization capabilities. They can reveal additional insights into the donor, such as gender, age, ethnicity, and even health status (Chen *et al.*, 2022). This expanded utility positions Level 3 details as a powerful tool in forensic science, particularly for solving complex cases. In forensic investigations, Level 3 features are invaluable when dealing with challenging samples, such as partial or degraded fingermarks.

Modern fingerprint technologies, such as Automated Fingerprint Identification Systems (AFIS) and Biometric Fingerprint Identification Systems (BIOFIS), are predominantly designed to analyse and compare Level 1 and Level 2 features of fingerprints. On an average fingerprint, there are up to 150 individual ridge characteristics, offering a wealth of data for analysis. However, the reality of forensic investigations often presents a challenge: only partial prints are recovered from crime scenes, which limits the number of ridge characteristics available for comparison. There is no universal agreement on the minimum number of ridge characteristics required for positive fingerprint identification. Generally, it is suggested that 12 to 16 matching ridge characteristics are sufficient to establish the uniqueness of a fingerprint, although this standard varies between countries. In Malaysia, the minimum threshold is set at 12 matching characteristics (Said *et al.*, 2021).

2.3 Latent Fingermarks and Their Composition

A fingerprint is composed of sweat secretions transferred onto a substrate, resulting in an impression of the ridge pattern or fingerprint left behind. Fingerprint residue originates from the epidermis and secretory glands in the dermis, specifically eccrine, sebaceous, and apocrine glands (Champod *et al.*, 2004). The eccrine glands, distributed across the body and predominant on the hands and feet, produce secretions primarily composed of 98% water, along with inorganic salts, amino acids, proteins, and peptides (Cadd *et al.*, 2015). These components contribute to the water-soluble deposits found in fingerprints.

Sebaceous glands, absent on the hands and feet, secrete lipid-rich sebum containing fatty acids, glycerides, and cholesterol (Girod *et al.*, 2012). These substances are transferred to fingerprints through contact with sebaceous-rich areas of

the body, such as the face or scalp (Champod *et al.*, 2004). The resulting non-water-soluble deposits include waxes and long-chain alcohols, which serve protective and hydrating functions.

Apocrine glands, localized to regions such as the armpits and groin, secrete compounds of potential forensic significance, especially in crimes of a sexual nature (Champod *et al.*, 2004). Their contribution to fingerprint residue is minimal but noteworthy due to their specific localization and composition.

There are also extrinsic components of fingerprint residue, which originate from external sources that come into contact with the skin. These include environmental contaminants such as dust, dirt, and chemicals, as well as residues from everyday items like cosmetics, lotions, and cleaning agents. Such extrinsic elements can alter the chemical composition of the residue, potentially impacting the visibility and development of fingerprints during forensic analysis. Recognizing the interplay between intrinsic and extrinsic components is essential for advancing detection techniques and ensuring precise fingerprint analysis.

2.4 Factors Affecting Latent Fingermarks

Once deposited on a surface, fingermarks begin to undergo a series of alterations and degradations over time. These changes result from complex chemical, biological, and physical processes that act upon the initial composition of the residue. The relationship between fingermark composition, the substrate and the environment is demonstrated in the triangle of interaction as shown in **Figure 2.4**. A thorough understanding of these three factors and their interactions, allows forensic scientists to make more informed decisions regarding the most effective enhancement techniques to apply in specific scenarios (Sears *et al.*, 2012).

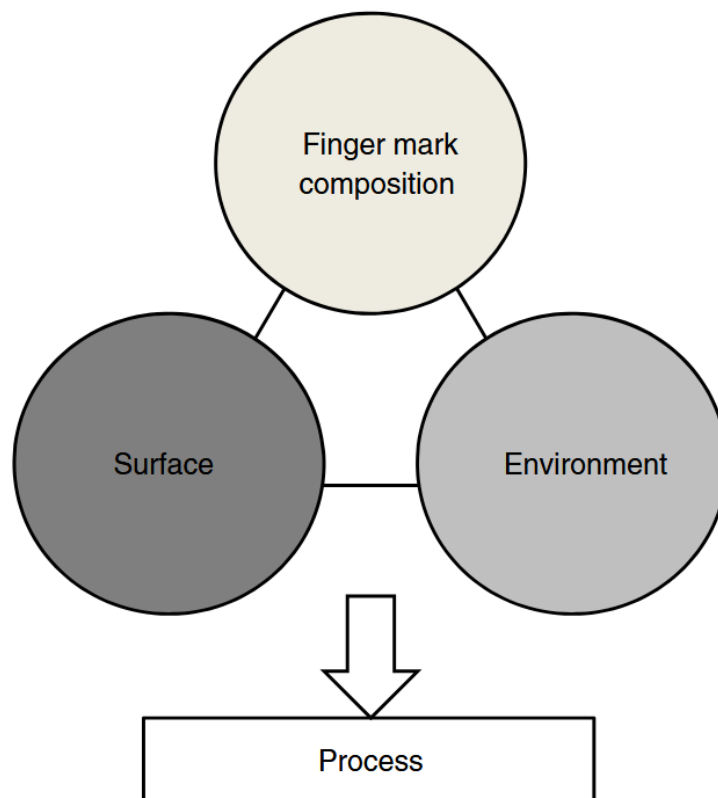


Figure 2.4: Triangle of interaction (Sears *et al.*, 2012)

The factors that affected the fingerprint initial composition can be classified into two stages which is deposition stage and aging stage as shown in **Figure 2.5** (Girod *et al.*, 2012). The influence factors in deposition stage are donor characteristics, including age, gender, race and diet; the deposition conditions, including deposition action, contact time, angle and pressure; and the nature of the substrate, including porosity, curvature and surface texture (Cadd *et al.*, 2015). While factors that influenced during the aging stage are the substrate, environmental conditions, such as temperature, humidity and light levels; the enhancement techniques, such as physical, physico-chemical or chemical methods; and the time elapsed since deposition, with longer aging periods leading to greater degradation of its components (Cadd *et al.*, 2015).

The final aged composition of a fingerprint is a combination of all the factors from both the deposition and aging stages. By thoroughly understanding these influences and applying the triangle of interaction framework, forensic scientists can tailor their approaches to optimize recovery and enhance the visualization of fingerprints, ensuring that critical evidence is preserved and effectively utilized.

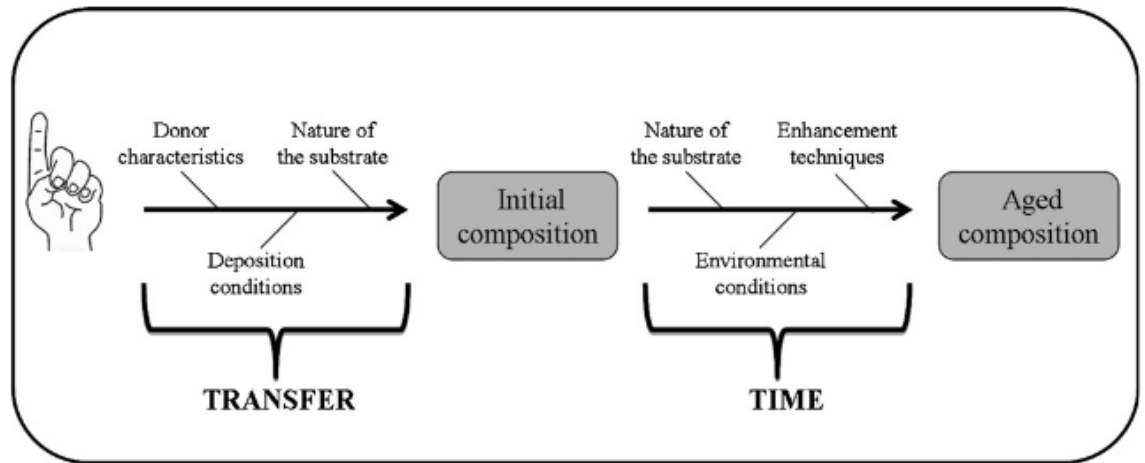


Figure 2.5: The variables that affect fingerprint composition prior to and after deposition (Girod *et al.*, 2012)

2.5 Substrate Nature

During an investigation, identifying the type of surface on which a fingerprint is deposited is crucial because the surface characteristics directly influence the choice of enhancement techniques. Generally, substrates are classified based on their porosity into three categories: porous, nonporous, and semiporous (Champod *et al.*, 2004).

For porous surfaces such as cardboard, paper and etc, the fingerprint residues especially the water-soluble components will be quickly absorbed, while the non-water-soluble components tend to remain on the surface (**Figure 2.6**) (Champod *et al.*, 2004; De Alcaraz-Fossoul, 2021). The level of absorption depends on the substrate's porosity; higher porosity leads to greater absorption. However, the absorption process

also means that residues penetrate below the surface, making initial detection challenging. Forensic experts often rely on chemical enhancement methods such as ninhydrin, DFO (1,8-diazafluoren-9-one), and physical developer to visualize latent fingerprints on porous substrates. This is due to these techniques react with amino acids and the amino acids tend to remain stationary when absorbed and do not migrate (Yamashita *et al.*, 2014).

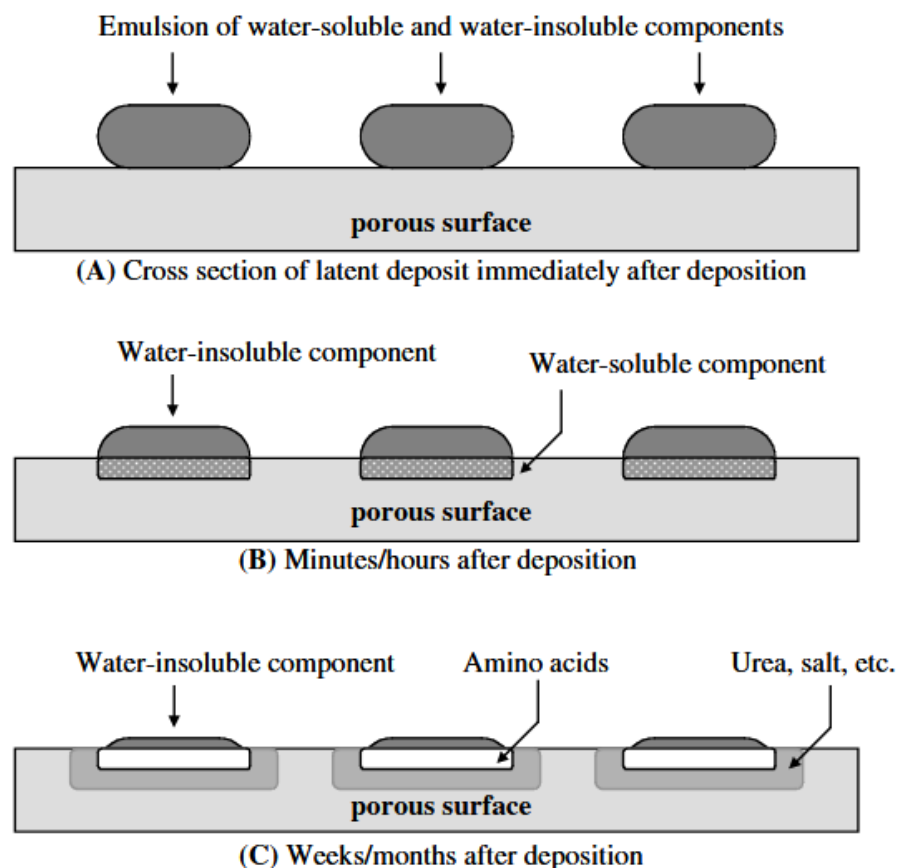


Figure 2.6: Aging of latent fingerprint on porous substrate (Champod *et al.*, 2004)

Nonporous substrates, such as glass, metal, and plastic, do not absorb any component of the fingerprint residue. Instead, the residue forms an emulsion of water-soluble and non-water-soluble components that remains on the surface for an extended period unless removed through physical contact or degraded by environmental factors such as heat, humidity, or ultraviolet light (**Figure 2.7**) (Champod *et al.*, 2004).

Because the residue resides on the outermost layer, fingerprints on nonporous surfaces are more vulnerable to damage. To enhance latent marks on nonporous materials, techniques such as cyanoacrylate (CA) fuming, dye staining, powder application, and vacuum metal deposition are widely used (Yamashita *et al.*, 2014). These methods work by adhering to the oily or watery residues left behind, making ridge details visible.

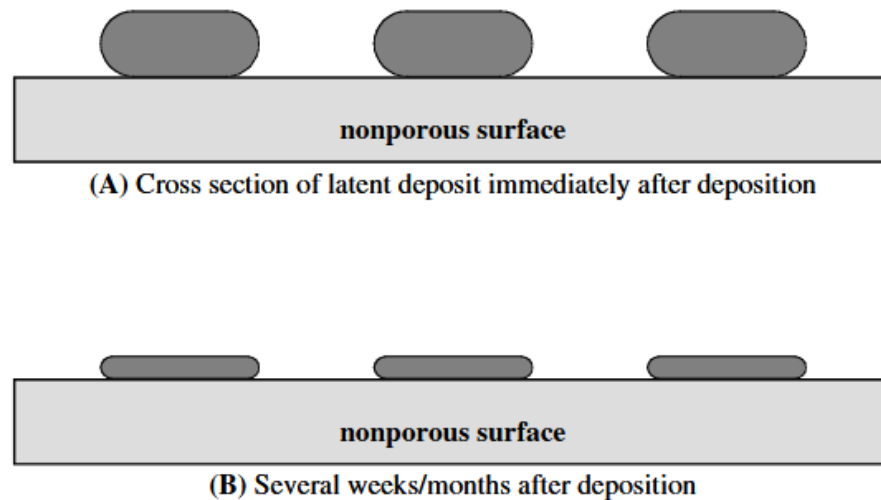


Figure 2.7: Aging of latent fingerprint on nonporous substrate (Champod *et al.*, 2004)

Semiporous substrates exhibit properties of both porous and nonporous materials. They partially absorb fingerprint residues while retaining some on the surface. Examples of semiporous surfaces include polymer banknotes, waxed wrapping paper, and some painted surfaces.

2.6 Latent Fingerprints Development and Enhancement Methods

Latent fingerprints commonly found at crime scenes are invisible and require specialised techniques for development and enhancement. The selection of the appropriate method depends on factors such as the type of surface, environmental

conditions, and etc. Generally, fingerprint development method is categorised into two, which are physical method and chemical method.

Physical methods rely on the physical interaction with sweat deposition of latent fingerprints (Bumrah *et al.*, 2019). One of the most commonly used physical method is the application of fingerprint powders. This method remains one of the most widely practised techniques due to its speed, effectiveness, and cost-efficiency, making it ideal for crime scenes where large areas or fixed objects like furniture and windows need to be processed quickly and thoroughly (Daluz, 2018). This technique is based on the adsorption of powder particles onto moisture and oily fingerprint components, making it most effective on dry, nonporous, and smooth surfaces (Ferreira *et al.*, 2021).

According to Ferreira *et al.* (2021), various types of fingerprint powders are available today, categorized based on their composition and specific applications. Regular powders, such as traditional black and white powders, are commonly used for contrasting purposes, with black powder being ideal for light-coloured surfaces and white powder for dark surfaces. Metallic powders, such as aluminium powder and magnetic black powder, are especially effective on glossy or nonporous surfaces, with magnetic powders being applied using a magnetic wand to minimize surface abrasion, making them suitable for fragile surfaces. Fluorescent powders, including products like GREENescent and PINKescent powders, are designed to fluoresce under specific light sources and are particularly useful for multicoloured or patterned surfaces where achieving contrast can be challenging. The choice of powder depends on the condition, texture and colour of substrate for the optimization of ridge detail visibility.

On wet and nonporous surfaces, powder techniques that require dry conditions are unsuitable. To address this limitation, the small particle reagent (SPR) method, which also known as the wet powdering technique, is used. This method relies on the

adherence of fine particles from a treating solution to the oily or fatty components of latent fingerprint residues, interacting specifically with the water-insoluble sebaceous elements (Bumbrah, 2016). SPR involves a suspension of fine molybdenum disulfide particles in an aqueous medium containing a detergent solution, which acts as a surfactant. These particles bind to the fatty components of the latent residues, forming a distinct grey deposit that enhances the visibility of the fingerprint. (Bumbrah, 2016).

Chemical methods for latent fingerprint development involve chemical reactions between the fingerprint residue and a chosen reagent, transforming specific constituents of sweat into visible, coloured derivatives (Bumbrah *et al.*, 2019; Ferreira *et al.*, 2021). These methods are particularly effective for enhancing latent fingerprints on various surfaces, even under challenging environmental conditions. Among the chemical techniques, Sudan Black and Oil Red O (ORO) are two of the most widely used lipid stains. They specifically target the fatty or lipid components of fingerprint residues.

Sudan black (**Figure 2.8**) is a lipophilic dye highly effective for developing latent fingerprint on non-porous surfaces contaminated with substantial amounts of fatty or greasy substances (Kent, 2013). This includes surfaces exposed to food residues or found in industrial environments such as mechanic workshops. When the sudan black solution is applied, its dye molecules preferentially bind to the oily residues of the fingerprint, transferring from the solution and forming a visible black fingerprint pattern (Ferreira *et al.*, 2021).

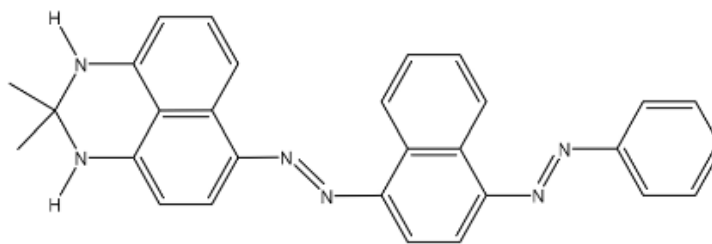


Figure 2.8: Chemical structure of sudan black

While Oil red O (ORO) (**Figure 2.9**) is a lipophilic dye that will dissolve in lipids and developed visible red marks. ORO reacts with the labile fraction of latent fingerprint residues, which includes fats and other non-water-soluble components (Salama *et al.*, 2008). The ORO solution is prepared by mixing two components: one containing ORO dye and methanol as the solvent, and the other containing sodium hydroxide to create a basic environment and water to enhance ORO's affinity for lipids. A buffer solution with sodium carbonate, nitric acid, and water is required to neutralize and stabilize the medium, allowing the development of fingerprints (Ferreira *et al.*, 2021). Unlike Sudan Black, ORO is often employed when porous surfaces are involved, particularly those that have been exposed to wet or high level of humidity (Beaudoin, 2004). It is also beneficial in cases where the amino acid content of the latent fingerprint is low, making it less suitable for enhancement using protein-reactive methods like ninhydrin.

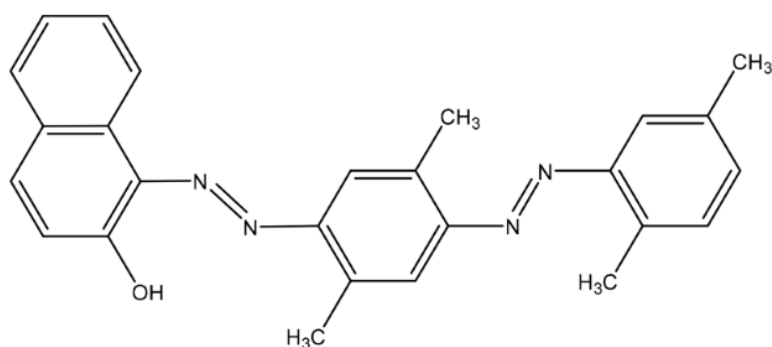


Figure 2.9: Chemical structure of Oil red O (ORO)

Crystal violet (CV) (**Figure 2.10**) or also known as gentian violet is particularly useful for developing latent fingermarks on adhesive surfaces such as cellophane tape and masking tape. These materials are often encountered in cases involving kidnappings, improvised explosive device or drug-related crimes. Adhesive surfaces pose challenges due to their sticky nature, which can obscure fingermark residues. CV addresses this issue by staining the sebaceous components of the fingermark deposit, producing a distinct dark purple coloration that enhances ridge visibility (Champod *et al.*, 2004).

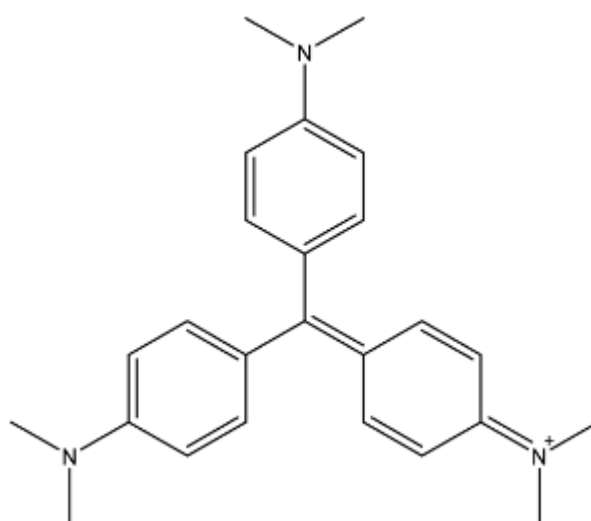


Figure 2.10: Chemical structure of crystal violet

Amido black is a protein stain that recommended for developing latent fingermarks that contain blood, applicable to both porous and non-porous surfaces. The anionic sulfonate groups of amido black will bind with the cationic group of blood proteins under moderately acidic condition and give a blue-black stain, as shown in **Figure 2.11** (Bossers *et al.*, 2011; Ferreira *et al.*, 2021). However, amido black does not react with the eccrine or sebaceous components of natural fingermarks, limiting its use to blood-contaminated marks (Kent, 2013). After staining, a destaining process is often required to reduce the background colouration especially on porous surface that will absorb and ‘hinder the contrast (Bossers *et al.*, 2011; Ferreira *et al.*, 2021).

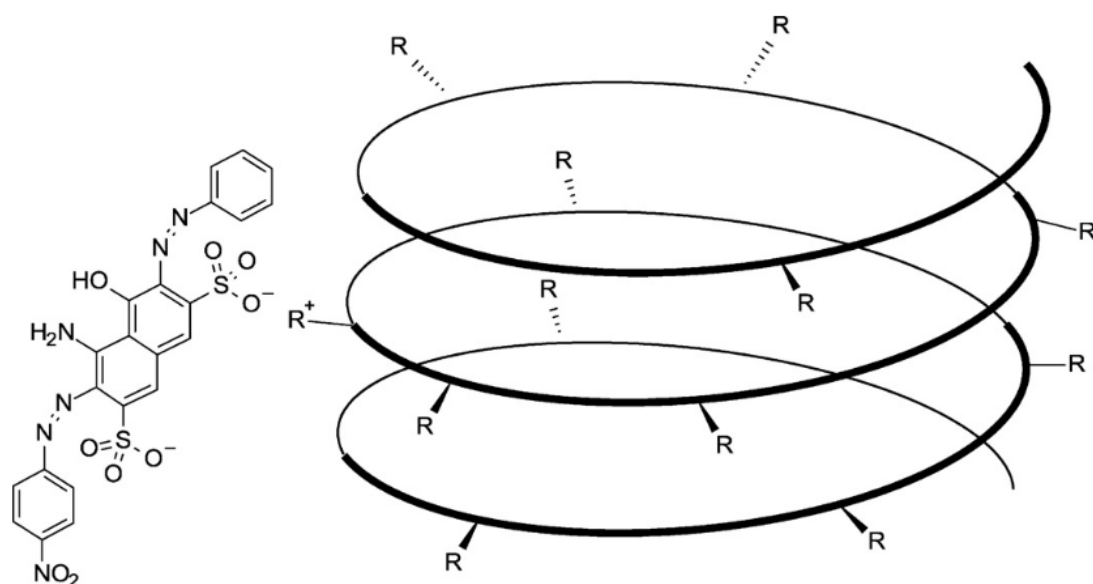


Figure 2.11: Interaction between amido black and protein

Ninhydrin is one of the most widely used reagents for developing latent fingermarks on paper and other porous substrates. It is a pale-yellow substance and react with amino acid amino acids secreted by eccrine glands, producing a purple product known as Ruhemann’s Purple (Ferreira *et al.*, 2021). The chemical reaction between ninhydrin and the amino acid is shown in **Figure 2.12**. Ninhydrin is a non-

specific amino acid reagent, reacting uniformly with various amino acids (Champod *et al.*, 2004). Due to the high affinity of amino acids for cellulose, the residues remain near their original deposition sites, ensuring the clarity and reliability of the developed fingerprints (Champod *et al.*, 2004; Yamashita *et al.*, 2014).

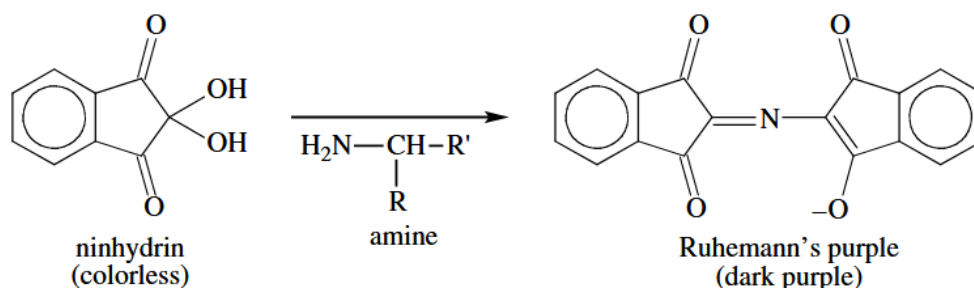


Figure 2.12: Chemical reaction between ninhydrin and amino acid

Each of these methods demonstrates unique strengths and specific applications, allowing forensic experts to select the most appropriate technique based on surface type, environmental conditions, and the composition of the latent fingerprint residue.

2.7 Recovery of Latent Fingerprints on Conventional Surfaces

The recovery of latent fingerprints has long been a critical area of forensic science, especially for evidence collection and criminal investigations. Conventional surfaces, such as glass, metal, plastic, and paper, have been extensively studied due to their frequent presence at crime scenes. This section reviews previous research conducted on the recovery methods, efficiency, and challenges associated with latent fingerprints on such surfaces.

2.7.1 Metal surface

Metal surfaces are frequently encountered in forensic investigations, especially as components of weapons involved in violent crimes and vehicles implicated in theft cases. Sometimes, it can be challenging, as the surface condition and properties can affect the effectiveness of development techniques. A study by Kirk *et al.* (2025) examined on the efficacy of development methods on clean metal types, including brass, bronze, and stainless steel. The result highlighted cyanoacrylate fuming was most effective on brass and bronze, while carbon-based black powder suspensions excelled on stainless steel.

The superior performance of carbon-based black powder suspensions on stainless steel likely results from the electrical interactions between the fingerprint residues and the particles in the suspension. Specific filler particles in the suspension act as deposition sites for carbon particles through these interactions. In contrast, for metals like bronze and brass, which are excellent electrical conductors, these interactions are disrupted or overshadowed by the metal's inherent conductivity, reducing the technique's efficacy. Stainless steel, with its non-conductive oxide surface layer, allows sufficient separation between the conductive metal beneath and the fingerprint residues, facilitating effective particle deposition and fingerprint development (Bacon *et al.*, 2013).

However, various other techniques such as sudan black, small particle reagent and others have been shown to be effective in recovering fingerprints from metal surfaces, even under challenging conditions like burial or submersion in water.

In a study by Yong *et al.* (2020) on fingerprint recovery from metal plates in a burial environment, sudan black demonstrated remarkable performance, producing clear ridge details even after eight weeks of burial. This is because its ability to stain