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Research Paper

Touch DNA Recovery from Edible Surfaces: Forensic Implications for Crime Scene Evidence Collection

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Abstract

Touch DNA analysis has become an essential tool in forensic science, enabling the recovery of trace genetic material from handled objects. However, the viability of edible items such as fruits as substrates for Touch DNA recovery remains underexplored, despite their frequent presence at crime scenes.

This study investigates the recovery and persistence of Touch DNA from six commonly encountered fruits—apples, grapes, strawberries, raspberries, oranges, and lemons—selected to represent a spectrum of surface textures and biochemical compositions.

Three individuals with varying DNA shedding profiles handled each fruit type, and DNA was collected at five post-deposition time intervals (0 hours to 7 days). DNA was extracted and quantified using standard forensic protocols, followed by STR profiling. Statistical analysis (ANOVA) was used to assess the effects of fruit type, surface texture, and time on DNA yield and profile completeness.

Smooth-surfaced fruits (apples and grapes) yielded the highest DNA concentrations and retained the most alleles over time, with apples maintaining near-complete profiles after 7 days. In contrast, rough or porous fruits (strawberries and raspberries) exhibited significantly lower recovery rates and substantial allelic dropout. Moisture-rich, acidic fruits (oranges and lemons) showed moderate DNA persistence, with degradation accelerating after 3 days. Statistically significant differences were observed in both DNA concentration ($p = 0.024$) and allele counts ($p = 1.09 \times 10^{-5}$) across fruit types.

Surface morphology, internal composition, and time since deposition critically influence Touch DNA recovery from fruits. These findings highlight the potential forensic value of edible evidence and support its inclusion in trace DNA protocols. As fruits and other food items are frequently encountered at crime scenes, expanding forensic attention to such substrates may enhance investigative outcomes. Further research under variable environmental conditions is recommended to validate these findings in practical casework settings.

Keywords: Forensic Genetics, Forensic science, DNA Profiling, STR profiling, Touch DNA, Trace DNA, Forensic Trace Analysis, Edible Evidence, DNA degradation.

1. Introduction

Touch DNA—often referred to as trace DNA—has emerged as a powerful and increasingly indispensable form of forensic evidence. Its utility lies in its ability to link individuals to objects, environments, or crime scenes even in the absence of visible biological fluids such as blood, saliva, or semen, which have traditionally dominated forensic DNA analysis [1–6]. Unlike bodily fluids, Touch DNA is deposited through incidental or sustained contact with objects, making it particularly relevant in property crimes, sexual assaults, and other investigative scenarios where overt biological traces are not always present. This DNA originates from a combination of biological materials, including shed keratinocytes, epithelial cells derived from sweat or saliva, and cell-free DNA suspended in sebum, reflecting the complex biological makeup of such deposits [7–11].

Despite its proven forensic potential, the successful recovery of Touch DNA remains methodologically challenging and highly variable, which has prompted extensive research into factors affecting its transfer, persistence, and retrievability. A multitude of factors influence Touch DNA yield and quality, notably the physicochemical characteristics of the surface substrate, such as porosity, roughness, and material composition [12–13]. These characteristics can significantly impact how DNA binds to the surface and how easily it can be later recovered. Environmental conditions, including fluctuations in humidity, temperature, and exposure to UV light, further compound this complexity by affecting DNA degradation rates over time [14–16].

The effectiveness of Touch DNA recovery is also strongly influenced by collection techniques. Variability in DNA yield has been attributed to inconsistencies in swabbing pressure, duration of contact, directionality, and surface coverage, as well as the subjective application of protocols by forensic personnel [17–20]. Additionally, the choice and application of wetting agents—which are used to improve cellular transfer during swabbing—and the number of adhesive lifts employed in sampling, play crucial roles in DNA retrieval but lack universal standardization [21–25]. These inconsistencies can undermine reproducibility across laboratories and compromise the evidentiary value of samples in legal contexts.

Beyond the collection stage, variability persists in the downstream processing of Touch DNA, such as in the DNA extraction and quantification phases. The selection of extraction kits, elution volumes, lysis buffers, and the efficacy of purification steps can significantly affect the quantity and quality of DNA recovered from trace samples [26–29]. Contamination remains a persistent concern, especially given the low copy number (LCN) nature of Touch DNA, which is more susceptible to both contamination and stochastic effects during amplification. Another critical but less predictable variable is inter-individual variability in DNA shedding rates, which differs widely across populations. While some individuals are known as "good shedders" who consistently leave behind recoverable DNA, others deposit little to no detectable material despite prolonged contact [30–35]. These biological and procedural variables jointly influence the success of DNA profiling and the reliability of forensic interpretations.

The choice of collection tools also plays a decisive role in recovery efficiency. Comparative studies have shown that cotton, nylon, and flocked swabs, as well as adhesive tapes, differ significantly in their ability to capture DNA depending on the surface type [12]. Smooth, non-porous substrates—such as plastic, glass, or metal—typically allow for more effective DNA recovery through swabbing due to the limited absorption of biological material into the surface [12,36]. In contrast, porous or fibrous surfaces, such as textiles or unfinished wood, often require adhesive lifting methods to access DNA trapped within surface crevices [37–42]. These findings underscore the importance of substrate-matched collection protocols that take into account the physical properties of evidence items.

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In response to these persistent challenges, the forensic field has witnessed the emergence of innovative hybrid sampling approaches and advanced technologies aimed at improving the efficiency and reliability of Touch DNA collection. Examples include the integration of microFLOQ® swabs with traditional cotton swabs for improved direct-to-PCR amplification, and the adoption of wet-vacuum systems that enhance recovery from irregular surfaces and porous materials [43,45]. Additionally, the use of decontamination agents and strict contamination controls have become standard practice to address the heightened risk of sample degradation or cross-contamination in low-template DNA contexts. These advances reflect a growing shift toward flexible, technology-driven workflows that seek to adapt sampling methodologies to diverse and unpredictable crime scene conditions. The wide variability in Touch DNA recovery across materials and settings further reinforces the need for context-dependent, evidence-specific strategies in forensic casework [46–51].

To remain relevant in modern forensic applications, current protocols must not only incorporate technological innovations but also prioritize scientific validation and adaptability. There is a growing consensus that rigid, one-size-fits-all procedures may hinder the ability to recover usable DNA from the wide variety of surfaces encountered in real-world investigations [52–53]. This includes unconventional or overlooked substrates, such as organic or perishable items that may inadvertently serve as repositories of forensic DNA.

One such underexplored substrate is food, particularly fruits, which are commonly present at crime scenes—especially in domestic settings such as homes, restaurants, or cafeterias. In cases such as burglaries, intruders may handle or consume food and beverages, inadvertently leaving behind valuable trace DNA evidence. While such behavior is often considered incidental, it provides an unexploited opportunity for forensic linkage. Notably, a prior experimental study demonstrated that Touch DNA could be successfully collected from the skin of bananas—even when partially decomposed—if stored indoors under moderate temperature and humidity conditions for up to a week after deposition [54]. This finding suggests that perishable organic surfaces, while complex, may offer viable options for DNA recovery if appropriately sampled and processed.

To build upon this preliminary evidence, the current study aims to systematically investigate the feasibility of recovering and analyzing Touch DNA from the surfaces of various fruits under controlled laboratory conditions. By examining how surface texture, biochemical composition, and decomposition time affect DNA concentration and profile completeness, this research seeks to determine whether fruits can serve as viable substrates for forensic evidence collection. These insights may help expand the spectrum of analyzable surfaces considered during crime scene investigations and contribute to the development of evidence-based protocols for handling organic and perishable materials in forensic practice.

2. Materials and methods

2.1 Experimental Design and Setup

2.1.1 Fruit Selection

To investigate the influence of surface morphology and biochemical composition on the recovery of Touch DNA, Six fruit types were carefully selected. Apples and grapes were chosen to represent smooth, non-porous surfaces; strawberries and raspberries were selected for their rough and porous textures; while oranges and lemons were included due to their moisture-rich and acidic characteristics. This strategic selection was intended to reflect a spectrum of surface textures commonly encountered in real-world scenarios. Furthermore, these fruits are frequently present in residential environments, kitchens, and dining spaces, and may be handled or consumed by individuals during the commission of a crime, making them forensically relevant. A visual categorization of the selected fruits and their associated surface characteristics is presented in Figure 1, which serves to

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contextualize the experimental substrates examined in this study. By incorporating fruits with varying physical and chemical properties, the study aimed to assess how these factors impact the success of Touch DNA recovery and profiling, thereby contributing valuable insight to forensic practices involving perishable evidence.

2.1.2 Fruit Preparation

Prior to the DNA deposition phase, all fruit samples underwent a strict sterilization protocol to eliminate potential pre-existing DNA contamination. Initially, each fruit was thoroughly rinsed with sterile distilled water to remove any residual dirt or environmental debris. The cleaned fruits were then treated with a 2% Virkon® solution, an effective DNA-degrading disinfectant, and subsequently exposed to ultraviolet (UV) radiation for 15 minutes. This dual-step sterilization ensured the degradation of nucleic acids that could interfere with the experimental results. Once sterilized, the fruits were stored under controlled laboratory conditions, specifically at ambient room temperature ranging between 20 and 25°C, and maintained at a relative humidity of approximately 50%. These environmental parameters were selected to simulate typical indoor settings and were kept constant throughout the duration of the study to ensure experimental consistency.

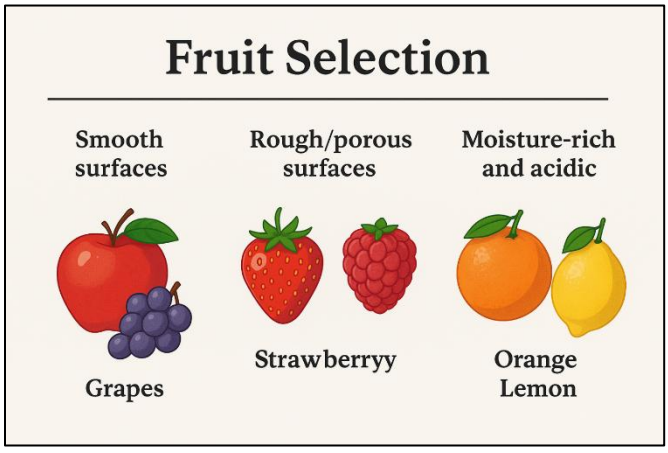

Figure 1. This figure presents the six fruits selected for experimental analysis, grouped into three categories based on surface morphology and biochemical characteristics: smooth-surfaced (apple, grape), rough or porous-surfaced (strawberry, raspberry), and moisture-rich and acidic (orange, lemon). The selection reflects a range of substrate types relevant to forensic investigations involving perishable evidence. Smooth fruits, with homogenous non-porous skins, were included for their potential to facilitate consistent DNA transfer, akin to surfaces like glass or plastic. Rough or porous fruits were chosen to simulate complex substrates that may trap DNA within surface crevices, mimicking fibrous materials. Moisture-rich, acidic fruits were incorporated to assess DNA stability on biologically active surfaces known to accelerate nucleic acid degradation. This categorization enabled controlled comparison of surface-related factors affecting Touch DNA recovery under simulated forensic conditions.

2.2 DNA Deposition Protocol

2.2.1 Participant Preparation

Three individuals were recruited as DNA donors, selected based on prior assessments of their DNA shedding capacity, categorized into high, moderate, and low shedders. This stratified selection was designed to reflect natural biological variability in shedding propensity, a factor known to influence the outcome of trace DNA studies. In preparation for handling the fruits, participants were instructed to wash their hands thoroughly using antibacterial soap to minimize external contamination. They then remained inactive for a period of ten minutes to reduce the impact of transient environmental contact. To facilitate optimal DNA deposition, participants conditioned their hands by briefly touching areas of the body rich in eccrine glands—specifically the forehead and the area behind the ears—as these are known to produce secretions that aid in epithelial cell transfer.

2.2.2 Deposition Process

Each participant handled each fruit specimen with their dominant hand, maintaining moderate pressure and natural contact for a duration of 30 seconds. This simulation was intended to replicate realistic, unconscious interactions that may occur during

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criminal activity. The procedure was repeated three times for each fruit, creating three independent replicates for each individual, across all fruit types and time intervals. The resulting dataset comprised a total of 270 samples, generated from a matrix of three participants, six fruit types, five time intervals, and three replicates per condition. To maintain the integrity of the sampling process, participants wore fresh nitrile gloves for each trial, and new sterile swabs were used in every collection to eliminate the possibility of cross-contamination.

2.3 Time-Point Sampling Intervals

The temporal dynamics of DNA degradation were assessed through five post-deposition sampling intervals: immediately after deposition (0 hours), 6 hours, 24 hours, 3 days, and 7 days. These intervals were selected to emulate the range of delays that may occur in real forensic investigations, where evidence collection does not always happen immediately. Throughout this time period, all fruit specimens were stored under consistent ambient conditions as previously described. This ensured that any observed differences in DNA recovery could be attributed to biological degradation over time rather than to fluctuations in environmental factors.

2.4 DNA Recovery Procedure

2.4.1 Swabbing Technique

Touch DNA was recovered from each fruit using sterile Copan 150C cotton swabs, which were pre-moistened with 100 microliters of sterile distilled water applied via a calibrated spray bottle to ensure uniform hydration. Swabbing procedures were tailored according to the surface characteristics of each fruit while maintaining standardized handling protocols.

For apples and grapes, which possess relatively smooth surfaces, swabs were applied using a firm, rotating motion focused on the area previously handled by the participant. In the case of strawberries and raspberries, which exhibit a more irregular and porous surface, swabbing involved gentle pressing to extract DNA from the surface crevices without rupturing the fruit. For oranges and lemons, characterized by their high moisture content and acidic surface, a combination of circular and linear swabbing strokes was used to ensure maximum contact with the handled area while minimizing juice interference. These methods were designed to replicate practical forensic conditions while maintaining consistency across fruit types.

2.4.2 Negative Controls

To ensure the reliability of the DNA recovery process and to rule out contamination, a series of negative controls were implemented throughout the study. Sterilized fruits were swabbed prior to DNA deposition to verify the absence of residual or background DNA. Additionally, procedural blanks and unused sterile swabs were included during each collection and processing phase. All negative controls were processed using the same extraction and amplification protocols as the experimental samples. No measurable DNA was detected in any of the control samples, thereby confirming the integrity and sterility of the experimental workflow.

2.5 DNA Extraction and Quantification

DNA was extracted from the collected swabs using the PrepFiler® Express DNA Extraction Kit, implemented on the AutoMate Express™ Forensic DNA Extraction System in accordance with the manufacturer's instructions. The full swab head was inserted into the extraction cartridge to maximize DNA recovery, and the final elution volume was standardized at 50 microliters. Quantitative analysis of the DNA was conducted using the Quantifiler® Trio DNA Quantification Kit on the QuantStudio™ 5 Real-Time PCR System. This system was selected for its sensitivity in low-template DNA analysis. All samples were processed in parallel with negative controls, which yielded no detectable DNA, thereby verifying the absence of contamination during the extraction and quantification stages.

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2.6 DNA Profiling and Short Tandem Repeat (STR) Analysis

DNA amplification was carried out using the GlobalFiler™ PCR Amplification Kit, employing a total of 29 cycles as per the recommended thermal cycling conditions provided by the manufacturer. Amplified DNA products were then prepared for capillary electrophoresis by combining them with Hi-Di™ formamide, GeneScan™ 600 LIZ® Size Standard v2.0, and an internal allelic ladder to ensure accurate sizing.

Electrophoretic separation was performed using an ABI 3500 Genetic Analyzer equipped with a 36-cm capillary array and POP-4™ polymer. Standard injection parameters of 1.2 kilovolts for 24 seconds were used. The DNA fragments were denatured at 95°C for five minutes and immediately placed on ice prior to analysis. Profile interpretation was conducted using GeneMapper® ID-X Software Version 1.5. A threshold of 75 Relative Fluorescence Units (RFUs) was applied for allele calling. In homozygous loci, peak heights were recorded as single values, while heterozygous loci were quantified based on the sum of both allele peaks. As with earlier stages, negative controls confirmed the absence of amplification products, reinforcing the procedural integrity.

2.7 Statistical Data Analysis

The dataset was analyzed using RStudio, applying a factorial Analysis of Variance (ANOVA) framework to assess the effects of three independent variables—fruit type, surface texture, and time interval—on two key outcomes: DNA concentration and number of alleles recovered per STR locus. Statistical significance was determined at the 95% confidence level ($p < 0.05$). Where appropriate, post-hoc tests were used to identify significant differences between individual fruit types and time points, facilitating a more granular understanding of the factors influencing DNA recovery success.

3. Results

The recovery and persistence of Touch DNA were evaluated across six fruit types—apples, grapes, strawberries, raspberries, oranges, and lemons—over five post-deposition intervals: immediately (0 hours), 6 hours, 24 hours, 3 days, and 7 days. The analysis focused on two primary outcomes: the concentration of DNA recovered (in ng/µL) and the number of alleles detected per short tandem repeat (STR) profile. Together, these measures allowed for assessment of both DNA quantity and profile completeness, offering insight into the effects of surface texture, chemical composition, and time on forensic DNA recovery from perishable substrates.

3.1 DNA Concentration Over Time

The mean DNA concentrations recovered from each fruit type at all five time points are summarized in Figure 2, with each data point representing the average of 15 replicates (three participants × five time intervals). Fruits with smooth, non-porous surfaces—namely apples and grapes—consistently yielded the highest DNA concentrations across all time points. Apples began with a mean DNA concentration of 0.08 ng/µL immediately after handling, which gradually declined to 0.04 ng/µL by day seven. Grapes exhibited a similar trend, with an initial concentration of 0.07 ng/µL falling to 0.04 ng/µL over the same period.

In contrast, fruits with rough or porous surfaces—strawberries and raspberries—demonstrated significantly lower DNA recovery. Strawberries yielded 0.05 ng/µL at 0 hours, declining to 0.03 ng/µL by the seventh day. Raspberries, which possess a highly irregular surface morphology, showed the steepest drop in DNA concentration, decreasing from 0.045 ng/µL to just 0.025 ng/µL over the course of the study.

Fruits classified as moisture-rich and acidic—specifically oranges and lemons—produced intermediate DNA yields. Both fruit types began at 0.06 ng/µL, with oranges declining to 0.035 ng/µL and

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lemons to 0.03 ng/µL by day seven. While these values were lower than those observed for smooth fruits, they remained consistently higher than the porous fruit group, suggesting moderate DNA preservation despite their challenging surface chemistry.

A one-way analysis of variance (ANOVA) confirmed statistically significant differences in DNA concentration among fruit types ($p = 0.024$), indicating that surface texture and chemical composition are critical factors influencing the efficiency of DNA recovery from organic substrates.

3.2 STR Allele Recovery and Dropout

The average number of STR alleles recovered per fruit type and time interval is presented in Figure 3, based on the same 15 replicates per condition. Smooth fruits again outperformed other categories in preserving STR profile integrity. Apples yielded complete or near-complete STR profiles immediately after deposition, averaging 45 alleles, with only modest allelic dropout observed over time (down to 38 alleles by day seven). Grapes followed a comparable pattern, declining from 43 alleles at 0 hours to 36 alleles at the final time point.

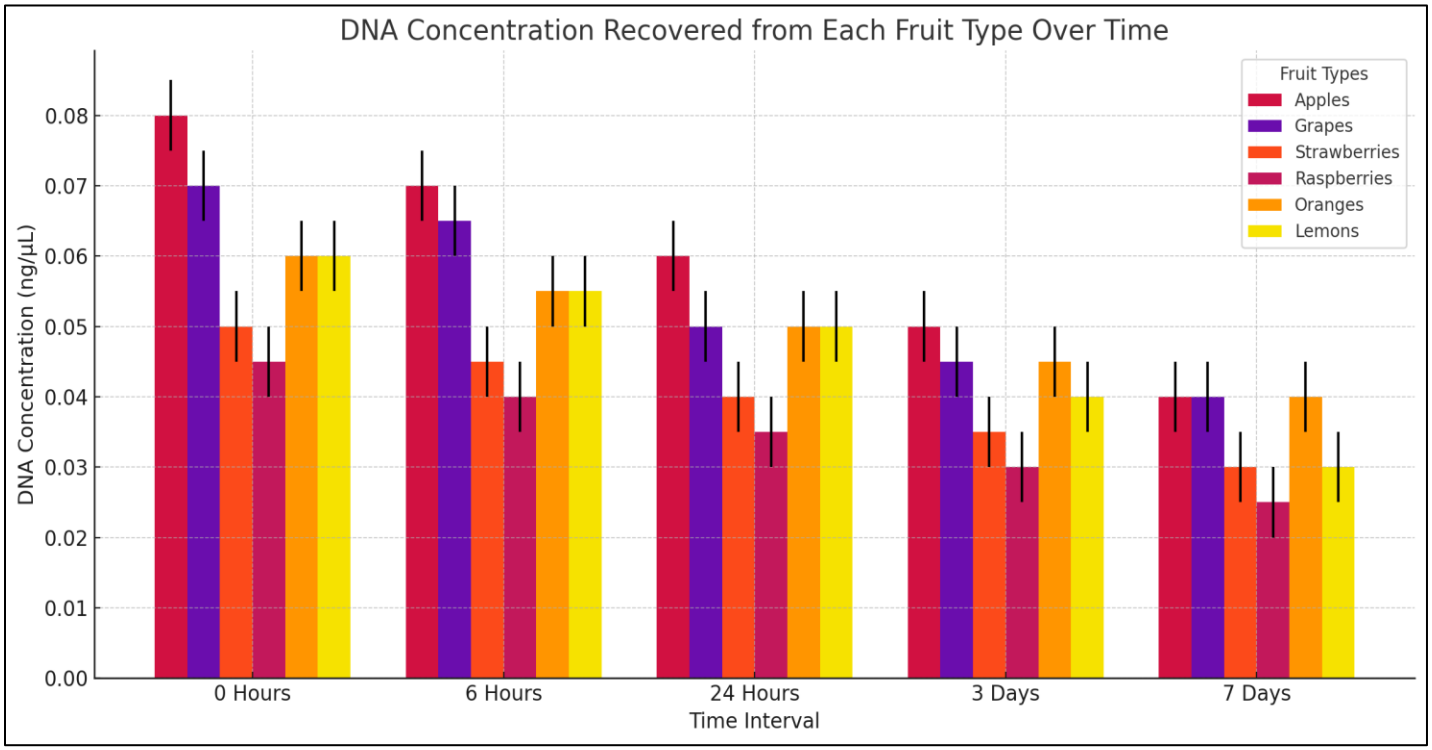

Figure 2. This bar chart shows the average DNA concentrations (ng/µL) recovered from apples, grapes, strawberries, raspberries, oranges, and lemons across five post-deposition intervals (0 hours to 7 days). Each bar represents the mean of 15 replicates per condition ($n = 270$), with error bars indicating standard deviation. Smooth fruits (apples, grapes) yielded the highest DNA concentrations, with apples decreasing from 0.08 ng/µL to 0.04 ng/µL and grapes from 0.07 ng/µL to 0.04 ng/µL. Porous fruits (strawberries, raspberries) exhibited lower recovery, declining from 0.05 to 0.03 ng/µL and 0.045 to 0.025 ng/µL respectively. Oranges and lemons showed intermediate retention, both dropping from ~0.06 ng/µL to ~0.03–0.035 ng/µL. All samples were stored at 20–25°C and 50% relative humidity. One-way ANOVA revealed a statistically significant difference in DNA recovery across fruit types ($p = 0.024$), underscoring the impact of surface characteristics on Touch DNA yield.

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Porous fruits exhibited markedly reduced allele recovery and greater time-dependent degradation. Strawberry samples began with an average of 30 alleles and dropped to 15 by day seven. Raspberries demonstrated the poorest performance, with allele counts falling from 28 to just 12 over the same interval. This level of dropout reflects both limited DNA deposition and accelerated degradation, likely due to the absorptive and uneven surface topography.

Oranges and lemons showed intermediate allelic retention. Both began with average counts of 35 alleles at 0 hours, declining to 20 and 15 alleles respectively by day seven. These findings suggest that while acidic and moisture-rich environments may accelerate DNA breakdown, the relative smoothness of citrus rinds still facilitates initial deposition and short-term retention.

Statistical analysis using one-way ANOVA revealed a highly significant difference in the number of alleles recovered across fruit types ($p = 1.09 \times 10^{-5}$), underscoring the strong influence of surface structure and biochemical environment on STR profiling success.

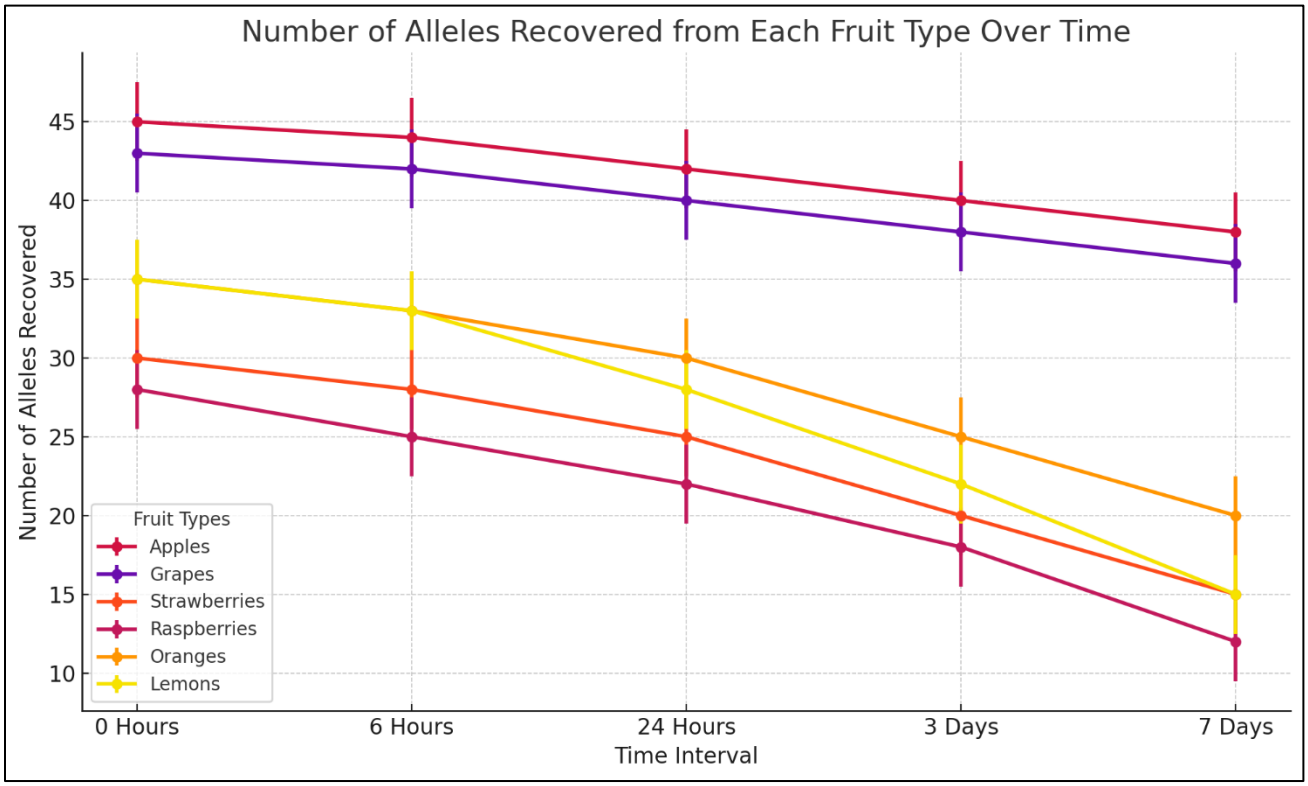

Figure 3. This line graph depicts the average number of STR alleles recovered from six fruit types over five time intervals, with each data point representing the mean from 15 replicates (n = 270). Apples and grapes consistently yielded the most complete profiles, declining modestly from 45 to 38 alleles and 43 to 36 alleles respectively. Strawberries and raspberries showed substantial allelic dropout, falling from 30 to 15 and 28 to 12 alleles respectively. Oranges and lemons exhibited moderate degradation, both starting at 35 alleles and ending at 20 and 15 by day seven. Samples were stored under controlled laboratory conditions (20–25°C, 50% relative humidity). One-way ANOVA confirmed a highly significant effect of fruit type on allele retention ($p = 1.09 \times 10^{-5}$), highlighting the influence of substrate texture and composition on DNA profile completeness. Notably, all profiles generated across all fruit types and time points were single-source, with no indication of DNA mixtures.

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All recovered alleles were attributed to single-source DNA profiles, either full or partial, corresponding to the known handlers. No evidence of mixed DNA profiles was detected in any of the samples across all fruit types and time intervals. This indicates that the deposited Touch DNA originated from a single contributor per sample, and that the collection and handling procedures effectively minimized the risk of cross-contamination.

3.3 Summary of Observed Trends

Taken together, the data clearly demonstrate that both surface texture and composition of fruit substrates significantly influence Touch DNA recovery. Smooth fruits such as apples and grapes supported the highest DNA yields and the most complete STR profiles across all time points, indicating superior retention and resistance to degradation. Rough and porous fruits, particularly raspberries, showed rapid declines in both DNA quantity and profile completeness, reflecting challenges in both deposition and collection. Moisture-rich and acidic fruits like oranges and lemons occupied a middle ground, with better performance than porous fruits but still lower recovery than smooth surfaces.

4. Discussion

4.1 Effect of Surface Texture on DNA Recovery

Smooth-skinned fruits such as apples and grapes consistently demonstrated higher DNA recovery and allelic retention across all time intervals, supporting the hypothesis that surface morphology significantly influences Touch DNA deposition and collection. Uniform, non-porous surfaces promote consistent contact between the skin and substrate, enhancing the transfer of epithelial cells and DNA, which aligns with previous findings on non-food surfaces like glass and plastic [12]. In contrast, rough or porous fruits, such as strawberries and raspberries, exhibited markedly lower DNA yields and higher allelic dropout, likely due to their microtopographies trapping biological material beyond the reach of standard swabbing techniques [55,56]. Surface roughness and wettability are known to influence the deposition and adherence of biological materials [55], reinforcing the importance of substrate characteristics in Touch DNA forensics.

4.2 Impact of Composition and Moisture

Fruits with higher internal moisture and acidity, such as oranges and lemons, showed intermediate recovery levels. While their relatively smoother rinds allow for adequate deposition, their biochemical environments—particularly low pH and enzymatic activity—may accelerate DNA degradation. This is consistent with the literature indicating that acidic or moisture-rich surfaces can facilitate hydrolysis and microbial growth, both of which compromise DNA stability [57]. The observed increase in allelic dropout after 72 hours parallels prior research showing that DNA integrity is progressively lost in humid or enzymatically active environments [58]. As with other perishable biological matrices, controlling post-deposition conditions is essential for maintaining DNA viability.

4.3 Time-Dependent Degradation

The temporal decay observed across all fruit types underscores the importance of timely DNA collection. Smooth fruits retained relatively high STR allele counts over the seven-day period, whereas porous fruits, particularly raspberries, demonstrated significant and rapid allelic loss. These findings corroborate studies on other materials, such as banana skin [54], where Touch DNA persisted for up to a week under room conditions. However, fruit composition, surface absorptiveness, and exposure to endogenous enzymes or moisture still pose a risk to DNA longevity, especially under fluctuating environmental conditions [16]. Additionally, studies have shown that Touch DNA becomes more difficult to recover or interpret when mixed with other sources (e.g., victim-perpetrator mixtures) or subjected to activity like sweating or washing [23].

Notably, DNA persistence has been demonstrated to vary considerably based on storage conditions. For

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example, substrates such as steel and fabric retained usable STR profiles for months when stored indoors, whereas environmental exposure significantly reduced DNA recoverability [59]. This highlights the relevance of collection timing and environmental shielding in the forensic workflow.

4.4 Forensic Implications

Fruits and other food items—frequently handled or consumed during criminal activities—represent an underutilized category of forensic evidence. This study contributes to the limited body of literature exploring the feasibility of DNA recovery from edible substrates. While prior work has focused on cables [60], cigarette butts [61], and fabric [56], little has been published on fresh produce as Touch DNA substrates, despite their frequent presence at crime scenes involving domestic settings, assaults, or burglaries. The successful generation of DNA profiles from fruits underlines the potential of expanding forensic collection protocols to include perishable substrates, provided that surface type, degradation risk, and collection timing are properly accounted for.

This research advocates for the development of standardized collection protocols for food evidence, particularly where rapid environmental degradation is likely. Touch DNA from food items, when sampled under appropriate conditions, may serve as critical links in cases lacking traditional evidence sources such as blood or saliva.

4.5 Limitations and Future Directions

While this study was conducted under controlled conditions (20–25°C, ~50% humidity), real-world environments are far more variable. Future investigations should explore the influence of fluctuating temperatures, UV exposure, and microbial activity on DNA degradation from fruits. Additionally, studies such as those by Sirker et al. have highlighted the importance of co-extracting RNA and DNA to recover both identity and activity-related information [62]. This dual-approach could be tested with food substrates in the future to enhance both biological source attribution and activity-level inference.

Furthermore, advanced DNA repair and amplification techniques such as DOP-PCR with locked nucleic acids may provide opportunities to recover degraded DNA from highly perishable items [58]. The application of such methods to fruit surfaces may improve STR recovery even when degradation is evident.

Other substrates like teeth [63], cigarette butts [61], and even epigenetic markers in trace DNA [64] offer insight into future directions, including source attribution and post-deposition interval estimation. Investigating the effect of sample degradation and environmental inhibitors on rapid field-based identification is also promising [65] and could eventually be adapted to perishable or edible substrates.

4.6 Broader Forensic Context and Emerging Considerations

Touch DNA analysis continues to evolve, but food evidence remains a largely uncharted frontier. While considerable research has been devoted to recovery from materials like metal, fabric, rubber, and biological fluids [12,14,16,59], forensic exploration of food items is limited. This is surprising, considering that fruits are often present at crime scenes and are likely to be handled casually by suspects, making them a potential goldmine for Touch DNA recovery.

Emerging research suggests that DNA persistence varies greatly by surface, environmental condition, and time—factors that are particularly volatile in the context of perishable evidence [55,57]. There is a clear need for expanding forensic sampling protocols to include food and organic substrates, especially in scenarios where conventional evidence is absent. As forensic methods advance, the integration of newer analytical tools, such as next-generation sequencing and epigenetic profiling, could enhance the evidentiary

value of even degraded or mixed DNA sources from such substrates [64,65].

Additionally, recent investigations into Touch DNA dynamics provide further context for why food substrates warrant systematic study. Research on glove-mediated secondary transfer has demonstrated that even indirect contact can leave recoverable DNA profiles on surfaces traditionally considered low-risk [66]. Complementary work examining how material type, cleaning frequency, and swab selection affect DNA yield from door handles further illustrates that surface characteristics and handling patterns critically influence recovery success [67]. These findings collectively support the expanding view that nontraditional substrates—whether metallic, synthetic, or organic—can carry significant evidentiary value when sampled appropriately.

In sum, this study provides foundational insights into an underexplored domain of forensic science and underscores the urgency for further research to standardize and validate DNA recovery from food-based substrates under realistic conditions.

5. Conclusion

This study highlights the feasibility and forensic potential of recovering and profiling Touch DNA from edible substrates, a domain that remains significantly underrepresented in forensic literature. By systematically investigating six common fruit types—categorized by surface texture and biochemical composition—this research provides compelling evidence that smooth, non-porous fruits such as apples and grapes yield the highest DNA concentrations and retain the most complete STR profiles over time. In contrast, rough or porous fruits like strawberries and raspberries demonstrate diminished recovery rates and substantial allelic dropout, while moisture-rich fruits such as oranges and lemons exhibit intermediate DNA retention, often hindered by biochemical degradation.

The results underscore the critical roles of surface morphology, internal composition, and post-deposition interval in determining DNA recovery success. The observed degradation trends emphasize the necessity for timely evidence collection and reinforce the need for standardized protocols when sampling perishable items—particularly in scenarios where delay can compromise evidentiary value.

Importantly, this work contributes to a growing but still sparse body of research on food evidence in forensic investigations. While significant advancements have been made in Touch DNA analysis from traditional substrates like clothing, metal, or plastic, fruits and other food items have largely been overlooked, despite their frequent presence in domestic and violent crime scenes. By demonstrating that viable and forensically useful DNA can be obtained from commonly encountered edible surfaces, this study expands the scope of trace DNA analysis and encourages broader consideration of non-traditional substrates in forensic protocols.

Moving forward, it is imperative that future studies build upon these findings by replicating them under real-world conditions, such as fluctuating temperatures, outdoor environments, and variable handling scenarios. Additionally, incorporating advanced analytical methods, including DNA repair techniques and next-generation sequencing, may further improve recovery rates from degraded or complex food-based substrates.

In conclusion, this study not only validates the potential of fruits as viable sources of forensic DNA but also calls for increased attention to food items as a legitimate category of trace evidence. Incorporating edible evidence into the forensic toolkit has the potential to enhance investigative outcomes, especially in cases where other biological evidence is absent or degraded.

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Conflict of interest

The authors declare no financial or personal conflicts that could have influenced the study. All work was conducted independently to maintain objectivity and integrity.

Ethics Statement

This study was approved by the General Department of Forensic Science and Criminology, Dubai Police. All participants gave informed consent, and procedures followed international ethical standards for human research and biological sample handling.

Author Contributions

Salem K. Alketbi contributed to the conceptualization, methodology, investigation, supervision, formal analysis, validation, and project administration, and led the original drafting as well as the review and editing of the manuscript. Hafiz M. Salleh contributed to the methodology, data curation, laboratory investigation, validation, and provision of resources, and participated in the review and editing of the manuscript. Both authors reviewed and approved the final version and accept full responsibility for the integrity, accuracy, and completeness of the work.

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