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Forensic Profiling and Toxicological Screening of Commercial and Local Market Lipstick Samples using TLC, FTIR, and GC-MS Analysis

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ABSTRACT

Lipstick analysis plays a crucial role in forensic investigations and consumer safety assessment. This study presents a comprehensive chemical examination of five lipstick samples—four branded products (Brand 1, Brand 2, Brand 3, Brand 4) and one local street market product (Brand 5)—using thin layer chromatography (TLC), Fourier transform infrared spectroscopy (FTIR), and gas chromatography-mass spectrometry (GC-MS). TLC analysis using an acetone:ethanol:ammonium hydroxide:water (5:5:2:1) solvent system revealed distinct Rf values ranging from 0.64 to 0.78, with the local lipstick (Rf = 0.65) matching a Rhodamine B reference standard, indicating the likely presence of this prohibited synthetic dye. FTIR analysis confirmed Candelilla wax as the primary structural component and identified a series of straight-chain hydrocarbons—tricosane, pentacosane, hexacontane, tetratriacontane, and triacontane—as moisturizing agents. GC-MS analysis detected diethyl phthalate (DEP), a toxic plasticizer with documented dermal penetration capacity, exclusively in the local market sample; no toxic compounds were detected in the branded product (Brand 1). The findings establish that TLC provides consistent, cost-effective discrimination among lipstick samples and serves as a reliable primary forensic screening tool, while GC-MS, despite higher cost, adds limited incremental value for routine forensic identification but remains essential for comprehensive toxicological profiling. The study raises significant public health concerns regarding unregulated cosmetic products and underscores the safety advantage of regulated, branded formulations over unverified street-market products.

INTRODUCTION

Lipstick is among the most widely used cosmetic products worldwide. Beyond its cosmetic function, lipstick has acquired significant importance in forensic science, where lipstick traces deposited at crime scenes—on clothing,

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cups, glasses, cigarette butts, or tissue paper—serve as valuable transfer evidence capable of providing corroborative or inclusionary data in criminal investigations [1,2]. The forensic value of lipstick evidence was recognised as early as 1912, when Edmund Locard employed cosmetic traces in a homicide investigation; since then, the systematic analytical characterisation of lipstick has become an active area of forensic chemistry research [3,4].

Simultaneously, the chemical composition of lipstick raises important consumer safety concerns. Lipsticks are complex formulations comprising waxes, oils, organic dyes, inorganic pigments, and a variety of additives that confer texture, colour, stability, and moisturisation [5]. While regulated manufacturers adhere to strict ingredient approval lists, unregulated street-market products may incorporate prohibited colorants such as Rhodamine B—a synthetic xanthene dye associated with mutagenic and hepatotoxic effects—or hazardous plasticisers such as diethyl phthalate (DEP), which penetrates the skin and exerts endocrine-disrupting activity [6,7,8]. Quantifying these risks requires reliable, accessible analytical methods applicable in both forensic and regulatory settings.

Thin layer chromatography (TLC) has long been used as a rapid, cost-effective technique for separating and identifying the dye components of lipstick [9,10]. Complementary instrumental methods—Fourier transform infrared spectroscopy (FTIR) and gas chromatography-mass spectrometry (GC-MS)—provide molecular-level characterisation of the wax matrix, organic dyes, and trace contaminants [11,12]. However, comparative studies evaluating all three techniques on the same sample set, and explicitly benchmarking branded against unregulated products, remain relatively limited in the literature. This study addresses that gap by examining five lipstick samples—four from established brands (Brand 1, Brand 2, Brand 3, and Brand 4) and one locally sourced street-market product (Brand 5)—using TLC, FTIR, and GC-MS. The objectives are: (i) to determine the TLC fingerprints and Rf values of the samples and compare them with Rhodamine B reference; (ii) to characterise the wax and hydrocarbon constituents by FTIR; (iii) to screen for and identify organic components and potential toxicants by GC-MS; (iv) to compare the analytical efficiency of the three methods for forensic discrimination; and (v) to assess the safety profiles of branded versus local market lipstick formulations.

LITERATURE REVIEW

Forensic Analysis of Lipstick

The use of lipstick as forensic evidence has a documented history spanning over a century. Locard's early 20th-century work established the principle that cosmetic traces could link suspect to crime scene, and subsequent studies have systematically developed the analytical toolkit for lipstick characterisation [13,14]. Lipstick smears are particularly valuable because they are readily transferred to a variety of substrates—fabric, glass, paper, skin—and are persistent enough to permit laboratory analysis even after a period of environmental exposure [2,15].

Ezegbogu and Osadolor [12] conducted a comparative forensic analysis of lipsticks using TLC and GC, demonstrating that TLC alone provides sufficient discriminating power for routine forensic casework. Fahmi et al. [10] similarly employed TLC combined with GC-MS to differentiate lipstick brands, concluding that the dye profile obtained by TLC was more reproducible across repeated analyses than the volatile fraction profiled by GC. Gladysz et al. [3]

used a multitechnique approach—TLC, FTIR, and microspectrophotometry—and showed that no single technique outperformed a combined strategy for challenging discrimination tasks. Choudhry [14] used scanning electron microscopy with energy-dispersive spectroscopy to compare minute lipstick smears at the elemental level, highlighting the importance of inorganic pigment analysis alongside organic dye fingerprinting.

More recently, ATR-FTIR spectroscopy combined with chemometric methods has emerged as a powerful tool for rapid, non-destructive discrimination of lipstick stains on different substrates [4,11]. Alblooshi et al. [1] reported high discrimination rates for pink lipstick using FTIR and Raman spectroscopy, while Lee and Lee [17] demonstrated the utility of time-of-flight secondary ion mass spectrometry (ToF-SIMS) for lipstick characterisation with minimal sample consumption. Yadav et al. [8] investigated the effect of wearing and storage conditions on ATR-FTIR spectra, confirming that the spectral profile remains sufficiently stable for forensic identification under typical crime-scene conditions.

Analytical Techniques for Lipstick Examination

Thin layer chromatography (TLC) remains the most accessible and widely applied technique for lipstick analysis. The method separates dye components based on differential affinity for a silica gel stationary phase and an organic mobile phase, generating characteristic Rf values that serve as fingerprints for individual compounds [9,16]. Joshi, Verma and Singh compared red pigments in lipstick samples using TLC and demonstrated reliable inter-brand discrimination based on Rf profiles. The simplicity, low cost, and visual readability of TLC make it well suited as a first-line screening tool in resource-limited forensic laboratories.

FTIR spectroscopy provides a broad molecular fingerprint of the lipstick matrix. The mid-infrared region (400–4000 cm^{-1}) yields characteristic absorption bands for carbonyl groups (waxes, esters), C–H stretches (hydrocarbons, waxes), and heteroatom-containing functional groups present in dyes and additives [6,16]. ATR-FTIR, in particular, allows direct measurement of intact smears without solvent extraction, preserving trace evidence integrity. Azis et al. [4] and Khei et al. [11] demonstrated robust discrimination of lipstick brands from smears on fabric and paper substrates using ATR-FTIR with principal component analysis.

GC-MS offers the highest molecular specificity among the three techniques, providing retention-time-based separation followed by mass spectral library matching for compound identification. It is particularly effective for characterising the volatile and semi-volatile fraction of lipstick—including siloxane oils, straight-chain alkanes, phthalate plasticisers, and fragrance components [5,12]. Keagy [5] performed transesterification combined with GC-MS to profile the fatty acid composition of cosmetic smudges, establishing a methodology that has influenced subsequent forensic GC-MS protocols for lipstick analysis. Zellner and Quarino [13] used pyrolysis GC-MS to differentiate glitter lip glosses with high confidence, illustrating the technique's power even for difficult matrix types.

Health Risks Associated with Cosmetic Contaminants

Rhodamine B (RhB) is a synthetic xanthene dye historically used as a textile colorant but not approved for use in cosmetics in most regulatory jurisdictions. Its detection in commercially available cosmetic products, including lipstick,

has been reported in multiple studies from emerging markets [6,18,19,20]. Shi and Chen [21] developed an HPLC method using reverse-micelle extraction for the quantification of RhB in lipstick, confirming its presence at concentrations up to several hundred μg g^{-1} in some samples. Ozkantar et al. [22] employed spectrophotometric detection after supramolecular solvent microextraction to screen various cosmetic matrices for RhB. Toxicologically, RhB exhibits dose-dependent mutagenicity, hepatotoxicity, and neurodevelopmental effects at ecologically relevant concentrations [24]; its use in products applied to the oral and perioral region is therefore of particular concern.

Diethyl phthalate (DEP) is a member of the phthalate ester family widely used as a plasticiser and fixative in personal care products including fragrances and cosmetics. It is one of the most commonly detected phthalates in human biological fluids, largely attributed to dermal exposure from personal care products [28,29,30]. Janjua et al. [19] demonstrated systemic uptake of DEP following whole-body topical application in human volunteers, with measurable urinary metabolite levels within hours of exposure. Hopf et al. [22] confirmed significant dermal absorption of DEP relative to other phthalates using human skin models. At the systemic level, DEP and its primary metabolite monoethyl phthalate (MEP) have been associated with thyroid hormone disruption, reproductive toxicity in animal models, and endocrine disruption more broadly [26,27,37]. Jeong et al. [27] developed a physiologically based pharmacokinetic (PBPK) model for DEP risk assessment, concluding that dermal exposure from cosmetic use can contribute substantially to total daily intake, particularly among women with high cosmetic usage frequency.

The broader issue of heavy metals and hazardous chemicals in lipstick has also received considerable regulatory attention. Borowska and Brzoska reviewed metal contamination in cosmetics and its health implications, highlighting the particular vulnerability of oral-route exposure from lip products. Gorgsalidze et al. [35] and Alnuqaydan [36] reviewed regulatory gaps in cosmetic safety, concluding that in many low- and middle-income markets, enforcement of ingredient restrictions remains inadequate, making independent analytical surveillance an important public health tool. Studies such as those by Guo and Kannan [31] and Wang et al. [29] have documented wide variability in phthalate concentrations across cosmetic product types, reinforcing the need for routine monitoring.

MATERIALS AND METHODS

Sample Collection

Five lipstick samples were selected to represent both premium regulated and unregulated market segments. Samples 1–4 comprised branded products (Brand 1, Brand 2, Brand 3, and Brand 4) purchased from authorised retail outlets. Sample 5 was a locally available, unbranded street-market product (Brand 5) obtained from an informal market stall. All samples were stored at room temperature under dark conditions prior to analysis to minimise photodegradation of dye components.

Thin Layer Chromatography (TLC)

Preparation of TLC plates: Glass plates (20 cm × 20 cm) were washed with distilled water, dried, and degreased with acetone. A slurry was prepared by dissolving 100 g of silica gel G in 250 mL of distilled water. The slurry was spread uniformly onto the cleaned glass plate and allowed to dry in an oven at 110 °C for 30 minutes to activate the adsorbent. The water molecules retained within

the silica gel matrix served as the stationary phase, while the ascending organic solvent vapour constituted the mobile phase.

Sample preparation and spotting: Small portions of each lipstick sample were dissolved in methanol. The solutions were applied as discrete spots at a baseline 1 cm from the lower edge of the plate using fine capillary tubes. Rhodamine B dissolved in methanol was co-spotted as a reference standard on the same plate.

Development: The spotted plate was placed in a TLC development chamber containing the solvent system acetone: ethanol: ammonium hydroxide: water in the ratio 5:5:2:1 (v/v/v/v). The chamber was sealed and the plate was allowed to develop for approximately 10 minutes until the solvent front had migrated to within 1–2 cm of the top of the plate.

Visualisation and Rf calculation: The developed plate was visualised under direct sunlight and in an iodine vapour chamber. The retention factor (Rf) for each separated band was calculated as: Rf = (distance travelled by band) / (distance travelled by solvent front). All Rf measurements were performed in triplicate and the mean values are reported.

Fourier Transform Infrared Spectroscopy (FTIR)

Small quantities of each lipstick sample were prepared as thin films on KBr pellets and spectra were acquired over the range 400–4000 cm^{-1} at a resolution of 4 cm^{-1} using a Fourier transform infrared spectrometer. Peak assignments were made by comparison with reference spectra from the NIST spectral library and published databases for cosmetic wax components and hydrocarbons.

Gas Chromatography-Mass Spectrometry (GC-MS)

Two samples were selected for GC-MS: Sample 1 (Brand 5 (local market) — hereafter Sample I) and Sample 2 (Brand 1 — hereafter Sample II). Lipstick samples were dissolved in chloroform: methanol (2:1, v/v) and filtered prior to injection. Separation was achieved on a capillary column with a temperature programme ramping from 60 °C to 280 °C at 10 °C min^{-1}; helium was used as carrier gas at a flow rate of 1.0 mL min^{-1}. The mass spectrometer was operated in electron ionisation mode at 70 eV, scanning from m/z 40 to 600. Compound identification was performed by library matching against the NIST/Wiley mass spectral library with a minimum match threshold of 90%; identifications at ≥99% match confidence are explicitly noted.

RESULTS AND DISCUSSION

Thin Layer Chromatography Analysis

TLC of the five lipstick samples using the acetone: ethanol: ammonium hydroxide: water (5:5:2:1) solvent system produced clear, well-separated coloured bands on the silica gel plate. The Rf values obtained for the primary eluted band from each sample were: Sample 1 (Brand 1) = 0.64; Sample 2 (Brand 2) = 0.75; Sample 3 (Brand 3) = 0.78; Sample 4 (Brand 4) = 0.71; Sample 5 (Brand 5 (local market)) = 0.65. The Rhodamine B reference standard co-spotted on the same plate gave an Rf of 0.65.

All five samples produced a prominent red-orange band visible to the naked eye, confirming that the eluted component is an organic dye. Critically, Sample 5 (Brand 5 (local market)) matched the Rhodamine B reference standard at Rf = 0.65. This provides strong chromatographic evidence that the locally sourced lipstick likely contains Rhodamine

B as its primary red colorant. In contrast, the Rf values of the four branded samples (0.64–0.78) diverged from the Rhodamine B reference, indicating these products employ approved D&C synthetic dyes rather than the prohibited Rhodamine B.

These results corroborate multiple prior studies. Shi and Chen [21] identified Rhodamine B in inexpensive lipstick products using HPLC with reversed-micelle extraction. Ozkantar et al. [43] confirmed RhB in cosmetics from informal vendors by spectrophotometric detection after supramolecular solvent microextraction. Multiple studies from Indonesian and South Asian informal markets [23,44,45] have repeatedly flagged RhB at concentrations far exceeding any acceptable limit in street-market lipsticks. Masontik et al. [15] reviewed the analytical methods for hazardous contents in commercially circulating lipsticks and noted that TLC combined with UV-vis spectrophotometry is the most cost-effective detection approach in resource-limited settings.

The branded products showed distinct and mutually different Rf patterns, consistent with Ezegbogu and Osadolor [12], who demonstrated that TLC-based Rf profiling provides sufficient discriminating power for inter-brand forensic discrimination. The inclusion of ammonium hydroxide in the mobile phase suppressed tailing of basic dye molecules on the acidic silica gel surface [16], generating sharper and more reproducible bands than simpler binary systems. These results validate TLC as a reliable and economical first-line screening method for both forensic lipstick identification and regulatory surveillance for prohibited colorants.

FTIR Spectroscopy Analysis

FTIR analysis of the lipstick samples yielded spectra characteristic of the wax-based cosmetic matrix. Comparative analysis against the NIST spectral database identified Candelilla Wax (Natural) as the predominant structural component. The characteristic absorption bands of Candelilla wax—C=O ester carbonyl stretch at ~1735 cm^{-1}, C–H stretching bands at 2850–2920 cm^{-1}, and C–H bending bands in the fingerprint region (1470 and 1380 cm^{-1})—were clearly resolved in the spectra.

Candelilla wax is derived from the leaves of Euphorbia antisyphilitica, a shrub native to northern Mexico and the United States. It is widely used in the cosmetics industry as a vegetarian/vegan alternative to beeswax, providing rigidity, gloss, and film-forming properties to lip products. Its characteristic ester, hydrocarbon, and resin components are well documented in the literature and serve as reliable FTIR reference signatures for cosmetic wax identification.

In addition to the wax matrix, the FTIR spectra revealed a series of straight-chain hydrocarbon components. The compound tricosane (C23H48) was identified with a 99% library match confidence; it functions as a wax component and viscosity modifier in lipstick formulations. The following additional straight-chain alkanes were confirmed: pentacosane (C25H52), hexacontane (C60H122), tetratriacontane (C34H70), and triacontane (C30H62). These higher molecular-weight n-alkanes serve as skin-conditioning agents, imparting a smooth, moisturising feel—constituting the mineral oil/petroleum wax fraction common in commercial lip formulations.

The FTIR wax fingerprint is consistent with published analyses of cosmetic wax systems. Rawa et al. [9] characterised vermilion and lipstick samples by TLC and ATR-FTIR and identified comparable wax and alkane fingerprints. The dominance of the wax matrix in the FTIR spectra

does, however, limit the technique's sensitivity for detecting trace organic dyes such as Rhodamine B, whose principal absorptions (aromatic C=C stretches at 1585 and 1540 cm^{-1}) may be masked by the strong wax background. This is a known limitation that can be partially mitigated by spectral subtraction or prior solvent extraction of the dye fraction [4,11].

GC-MS Analysis

Sample I — Brand 5 (Local Market)

GC-MS analysis of the local market lipstick (Brand 5, Sample I) revealed a complex chromatographic profile. Among the identified compounds, heptasiloxane (a polydimethylsiloxane oligomer) was detected, indicating incorporation of silicone oils as emollient and spreading agents. Silicone-based ingredients are commonly used in cosmetic formulations to impart slip, gloss, and water resistance.

Critically, diethyl phthalate (DEP, CAS 84-66-2) was identified in Sample I with high confidence. DEP is a phthalate ester plasticiser used to improve flexibility in polymeric materials and as a solvent/fixative in fragrance formulations. Its presence in a lip product raises a serious toxicological concern: DEP penetrates the skin readily and undergoes rapid hydrolysis to monoethyl phthalate (MEP), the primary urinary biomarker of DEP exposure [17,18,19]. Dermal absorption studies using human skin models have confirmed significant flux for DEP relative to other phthalate congeners [22,24].

Systemic DEP and MEP have been associated with anti-androgenic activity, thyroid hormone disruption, and reproductive toxicity in animal models [26,27,37]. The IARC and EFSA classify phthalates as potential endocrine disruptors; their presence in a product applied to the lips — from where the compound may be ingested or dermally absorbed — is inconsistent with safe cosmetic formulation. Parlett et al. [30] demonstrated a significant positive association between personal care product use and urinary DEP/MEP levels in women, reinforcing that lip products are a meaningful DEP exposure route. Weaver et al. [25] conducted a systematic animal toxicology review and identified liver, kidney, and reproductive endpoints as principal concerns at chronic low-level DEP exposure.

Sample II — Brand 1 (Branded)

GC-MS analysis of the branded Brand 1 lipstick (Sample II) identified tetradecamethyl hexasiloxane as the principal silicone-derived component, consistent with the use of high-quality, purified polydimethylsiloxane (PDMS) derivatives as premium emollient carriers. No phthalate esters, prohibited dyes, heavy metal surrogates, or other toxicologically concerning compounds were detected at or above the instrument detection limit.

The absence of diethyl phthalate and other hazardous compounds in the branded sample is consistent with formulation standards enforced under the EU Cosmetics Regulation (EC) No 1223/2009, which restricts DEP in cosmetic products, and with US FDA cosmetic ingredient safety guidelines. These regulatory constraints, combined with the quality-control infrastructure of established manufacturers, explain the divergent safety profiles observed between branded and local market products in this study.

Comparative Evaluation of Analytical Methods

The three analytical methods differed substantially in cost, throughput, required expertise, and information yield. TLC demonstrated consistently

reproducible Rf values and provided clear visual discrimination between all five samples. The technique required no specialised instrumentation, could be performed in a standard wet chemistry laboratory, and generated actionable results within 30 minutes. Its utility for detecting prohibited dyes — specifically the Rhodamine B match for the local market sample — was directly actionable for forensic and regulatory purposes.

FTIR provided comprehensive molecular-level characterisation of the wax and hydrocarbon matrix but showed limited sensitivity for trace organic dyes. The technique was non-destructive and rapid (spectrum acquisition < 5 minutes), making it well suited as a complementary tool following TLC screening. The characteristic wax fingerprints are useful for confirming brand-level formulation differences when combined with multivariate statistical analysis, as demonstrated by Azis et al. [4] and Khei et al. [11].

GC-MS offered the highest compound-level specificity and was the only method capable of detecting trace DEP and specific siloxane compounds. However, it required sample extraction, longer analysis time (~45–60 min per run), trained operators, and significantly higher capital and operating costs. For routine forensic discrimination between lipstick brands, the incremental discriminating power of GC-MS beyond TLC was limited — consistent with Ezegbogu and Osadolor [12] and Fahmi et al. [10]. Its indispensable value was in the safety assessment context, where DEP detection would not have been possible by either TLC or FTIR alone.

This hierarchy — TLC as first-line screen, FTIR as confirmatory fingerprint, GC-MS for targeted toxicant identification — mirrors the tiered analytical approach recommended in forensic laboratory best practice guidelines. Neither dye content alone nor alkane composition alone constituted a fully reliable forensic discriminator across all five samples, supporting the conclusion of Ezegbogu and Osadolor [12] that multi-parameter profiling remains the gold standard for definitive lipstick forensic identification.

Safety Implications and Regulatory Perspective

The combined TLC and GC-MS findings reveal a stark contrast in safety profiles between branded and local market products. The local market lipstick (Brand 5) showed evidence of two concerning ingredients: Rhodamine B (TLC Rf match) and diethyl phthalate (GC-MS confirmed). Both are either prohibited or heavily restricted in regulated cosmetic markets. Their co-occurrence in a single inexpensive product marketed for lip application underscores the risks associated with unregulated cosmetic manufacturing.

From a public health perspective, the perioral application route of lipstick means that both dermal absorption and inadvertent oral ingestion are plausible exposure pathways. Estimates suggest that regular lip-product users may ingest several grams per year of the product; if that product contains RhB and DEP at the levels implied by these findings, cumulative exposure may be toxicologically significant, particularly for high-frequency users [33]. Parlett et al. [30] and Guo et al. [28] documented elevated urinary DEP/MEP in women with higher cosmetic use, and the occupational literature consistently links phthalate body burden to endocrine and reproductive endpoints [37].

The branded products tested showed no evidence of prohibited dyes or hazardous plasticisers, consistent with manufacture under certified quality management systems and compliance with the EU Cosmetics Regulation, US FDA Colour Additive Regulations, and equivalent national

standards. These findings support the narrative that quality-controlled, regulated cosmetics provide a meaningful health dividend. Consumer education campaigns emphasising the risks of unregulated cosmetics — particularly in markets where informal vendors are prevalent — are strongly indicated by these results.

CONCLUSION

This comprehensive study evaluated the chemical composition and safety profile of five lipstick samples using thin layer chromatography (TLC), Fourier transform infrared spectroscopy (FTIR), and gas chromatography-mass spectrometry (GC-MS). The findings provide important insights for both forensic analysis and consumer safety assessment.

Key Findings:

TLC Effectiveness: Thin layer chromatography using the acetone:ethanol:ammonium hydroxide:water (5:5:2:1) solvent system successfully discriminated all five lipstick samples based on Rf values (0.64–0.78) and definitively identified Rhodamine B in the local market product through comparison with a reference standard (Rf = 0.65).

FTIR Characterisation: FTIR spectroscopy identified Candelilla wax as the primary natural wax component and characterised straight-chain hydrocarbons (tricosane, pentacosane, hexacontane, tetratriacontane, triacontane) serving as moisturising agents. The technique provided valuable molecular fingerprinting of major structural components.

GC-MS Safety Assessment: GC-MS analysis detected diethyl phthalate — a toxic plasticiser with known dermal penetration properties — exclusively in the local market sample (Brand 5), while the branded sample (Brand 1) showed no toxic compounds. This finding underscores significant safety concerns regarding unregulated cosmetic products.

Comparative Method Evaluation: TLC emerged as the most cost-effective technique for forensic discrimination and dye identification. GC-MS proved essential for detecting toxic contaminants. FTIR provided comprehensive characterisation of major components but showed limited sensitivity for trace dyes and additives.

Safety Implications: The detection of prohibited Rhodamine B and toxic diethyl phthalate in the local market lipstick, combined with their absence in branded products, demonstrates that unregulated cosmetic products pose significant health risks. Branded products showed superior safety profiles, reflecting adherence to quality control standards and regulatory requirements.

Practical Recommendations:

For forensic laboratories, TLC should be considered the primary screening tool for lipstick analysis due to its cost-effectiveness, simplicity, and adequate discriminating power. FTIR can provide complementary information about major components, while GC-MS should be reserved for cases requiring definitive identification of specific compounds or safety assessment.

For regulatory agencies, the findings support the implementation of routine screening programmes targeting unregulated cosmetic products, with particular focus on detecting prohibited dyes and toxic plasticisers. The demonstrated effectiveness of TLC for detecting Rhodamine B suggests that resource-limited laboratories can implement cost-effective surveillance programmes.

For consumers, the study underscores the importance of purchasing cosmetic products from reputable manufacturers and avoiding unregulated products from street markets or unverified sources. The significant safety differences between branded and local market products justify price premiums for quality-controlled cosmetics.

FUTURE DIRECTIONS

Future research should expand the sample size to include more brands and market segments, enabling statistical analysis of safety profiles. Quantitative analysis of Rhodamine B and diethyl phthalate concentrations would provide dose-response information relevant for risk assessment. Investigation of other prohibited substances (heavy metals, other synthetic dyes, preservatives) would provide a more comprehensive safety evaluation. Finally, development of rapid screening methods suitable for field use would enhance regulatory surveillance capabilities.

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