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*Article*

# Olfactory Signatures of Bladed Weapons: Characterization and Implications for Canine Detection

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**Abstract**

Knife crime has increased globally, yet the effectiveness of current detection methods used by law enforcement is often limited in operational settings. This challenge highlights the need for innovative detection approaches. The use of canines as highly mobile and sensitive biosensors for the detection of bladed objects may provide an effective and novel solution. A critical step toward implementing canine-based detection is the characterization of the odor signatures associated with bladed objects. Therefore, it is hypothesized that box cutter blades possess a distinct volatile organic compound (VOC) profile that can be differentiated from those of other common metal substrates. To test this hypothesis, headspace extraction and chemical analysis were conducted on box cutter blades of varying sizes, and their VOC profiles were compared with those of metal keys. Five compounds were consistently identified across blade samples and may be considered characteristic odorants of box cutter blades: decanal, eicosane, nonadecane, nonanal, and octadecane. The results suggest that box cutter blades possess detectable and distinguishable VOC profiles that are consistent across different blade sizes. These findings provide foundational data for future odor characterization studies and support the development of canine training aids and detection programs targeting bladed objects.

**Keywords:** canines; knife crime; metal substrates; volatile organic compounds (VOCs); odor profile

## 1. Introduction

The use of firearms in violent crime is driven by multiple factors, including their effectiveness, perceived intimidation value, and the psychological distance they create between the perpetrator and the victim [1]. The impersonal nature of firearms stems from their ability to discharge projectiles that can inflict lethal injury from a distance, unlike hand-held weapons such as knives, which require the offender to be in close physical proximity to the victim [2]. Recognizing the significant threat posed by firearm-related violence, many countries have implemented strict regulations governing the purchase, possession, and use of firearms. While such measures can contribute to reducing gun-related crime, individuals intent on committing violent offenses may seek alternative weapons. Bladed objects, including knives and box cutters, are widely available, relatively inexpensive, and often more difficult to regulate and track than firearms. Although the use of bladed weapons requires close physical proximity to a victim, their accessibility and ease of acquisition have contributed to their continued use in violent offenses. Consequently,

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knife crime has emerged as a growing public safety concern in many regions worldwide, highlighting the need for effective methods to detect and deter the possession of bladed weapons [3].

A comparison of knife crime trends in the United States and the United Kingdom, two countries with markedly different approaches to firearm regulation, highlight the need for effective knife detection strategies regardless of the strictness of gun control policies. Although the right to bear arms is constitutionally protected in the United States, knife-related violence remains a significant public safety concern. According to FBI crime statistics, 597,187 aggravated assaults involving knives or cutting instruments were reported between 2019 and 2024 [4]. Furthermore, knives had been the second most used weapons in homicides, accounting for roughly 10% of all homicides between 2013 and 2017 consistently [5]. In that same 5-year time frame the UK recorded around 250,000 knife offenses, which in comparison seems considerably less at first sight, but considering that the UK's population is roughly just a fifth of the USA's, this number is alarming [6]. Furthermore, sharp objects are the most commonly used weapons in the UK, accounting for almost half of homicides [6]. These figures demonstrate that, despite differences in firearm accessibility and regulation, bladed weapons continue to play a substantial role in violent crime and underscore the need for improved methods of detection and prevention.

Although recent increases in knife-related violence have heightened public concern, knife crime itself is not a new phenomenon. Consequently, law enforcement agencies have developed several established methods for detecting bladed weapons, including pat-down searches [7], metal detectors [8], and X-ray screening systems [9]. While these approaches are widely accepted and effective in many settings, each possesses inherent limitations. Some drawbacks are method-specific, such as the potential legal and ethical concerns associated with pat-down searches [10], whereas others are more universal. Most notably, these methods are often labor-intensive, time-consuming, and restricted by limited mobility, making them less suitable for rapidly screening large areas or dynamic operational environments. Mobility and rapid screening capabilities are particularly important in large public venues, social gatherings, and special events, where the potential for opportunistic acts of close-range violence is greatest. These limitations highlight the need for alternative detection approaches that are both efficient and adaptable to a variety of real-world scenarios.

Canines offer rugged and highly mobile detection capabilities well suited to the operational scenarios described above. Dogs have been recognized for their exceptional olfactory abilities for centuries and have long served as a cornerstone of law enforcement operations [11,12]. They are currently deployed for a range of detection tasks, including narcotics and explosive detection, human scent tracking/trailing, search and rescue, as well as suspect apprehension [13]. More recently, there has been growing interest in extending canine detection capabilities to include bladed objects, reflecting the continued evolution of operational canine applications. A critical step toward this expansion is the establishment of a robust scientific proof of concept that defines and validates the odor signatures associated with such targets. Applied efforts in this area have already demonstrated promising operational potential. For example, private-sector initiatives have trained detection dogs to alert to bladed substrates [14]. These developments highlight the feasibility of canine-based knife detection and underscore its potential operational value in real-world security contexts. However, broader scientific validation remains essential to fully characterize the chemical basis of these detections and to translate applied training outcomes into standardized, reproducible methodologies. Such validation is particularly important for informing evidence-based training protocols, ensuring operational reliability

across agencies, and supporting the admissibility and defensibility of canine alerts in judicial settings.

Within the forensic odor science literature, substantial work has focused on explosives [15–17], illicit drugs [18–20], and firearm-associated odor signatures, for example, Nettles et al. 2022 [21] demonstrated the presence of volatile organic compounds (VOCs) associated with firearms and related components, contributing to the growing body of evidence supporting instrument-based characterization of contraband odor profiles. In contrast, comparatively scientific research has seldom examined odor signatures associated with inert metal substrates themselves, despite their relevance as common contact materials in bladed objects and related items, as well as potential odor contributions arising from metal–skin interactions as described in prior work by Glindemann et al. 2006 [22]. Metals are generally considered low-emission substrates under ambient conditions; however, emerging evidence in surface chemistry and occupational exposure literature indicates that metallic materials can exhibit trace volatile signatures derived from manufacturing processes, protective coatings, and adsorbed environmental organics [23,24]. These may include residual machining oils, polymeric additives from coatings, and oxidation-driven secondary products that collectively contribute to measurable surface-associated VOC profiles. Additionally, frequent handling of metallic objects facilitates the adsorption and transfer of exogenous compounds such as skin lipids, sweat-derived volatiles, and environmental contaminants, which can dominate surface chemical signature [22]. The limited available studies in this space suggest that any detectable odor may be influenced more by surface contamination, manufacturing residues, or environmental exposure than by the bulk metal itself, underscoring the need for controlled investigations.

The objective of this study is to characterize the chemical odor profile of small metal blades, and to establish a foundational understanding of volatile odor signatures associated with sharp edged metal objects. This work directly addresses a critical gap in forensic odor science by systematically evaluating whether commonly encountered blades exhibit reproducible and discriminable VOC profiles relative to inert metal substrates. It is hypothesized that there are detectable chemical odor compounds characteristic of box cutter blades that are distinct when compared to metal substrates used as controls. Establishing these chemical distinctions has important implications for improving instrumental odor characterization and supporting the development of more reliable odor-based detection strategies in forensic applications.

## 2. Materials and Methods

### *2.1. Box Cutter Blades and Metal Keys*

Two metal box cutter blades and a control metal substrate were selected for instrumental analysis: a 5-inch Tajima blade and a 1-inch Excel blade. The newly purchased knives were not removed from original packaging (as depicted in Figure 1) until headspace sampling began. Metal keys, a commonly carried metal item, served as the control. Items were chosen based on their ubiquity and relevance to everyday handling and contact scenarios. Used keys were donated from various members of the laboratory and were stored in cloth bags until sampling began. Each experimental group consisted of 25 replicates, and all samples were handled with nitrile gloves (Fisher Scientific, Hampton, NH, USA) and were weighed prior to analysis to ensure consistency.

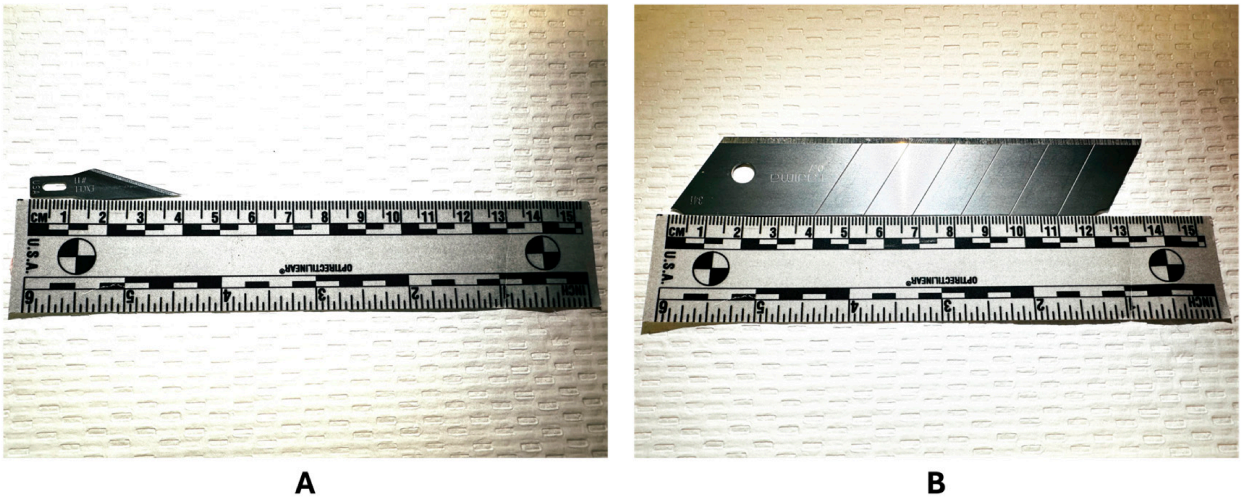



**Figure 1.** Bladed substrates: image (**A**) is the 1-inch Excel blade and image (**B**) is the 5-inch Tajima.

For sample containment and headspace extraction, 40 mL clear glass vials with PTFE/silicone septa screw caps (Supelco, Bellafonte, PA, USA) were used for blade samples, while 8 oz glass mason jars fitted with rubber septa were used for control samples, as depicted in Figure 2. Containers were sampled as negative control and were washed in between runs with Liquinox odorless soap (Alconox, White Plains, NY, USA), then rinsed with methanol (Fisher Scientific, Hampton, NH, USA) and heat purged at 105 °C for 2 h.

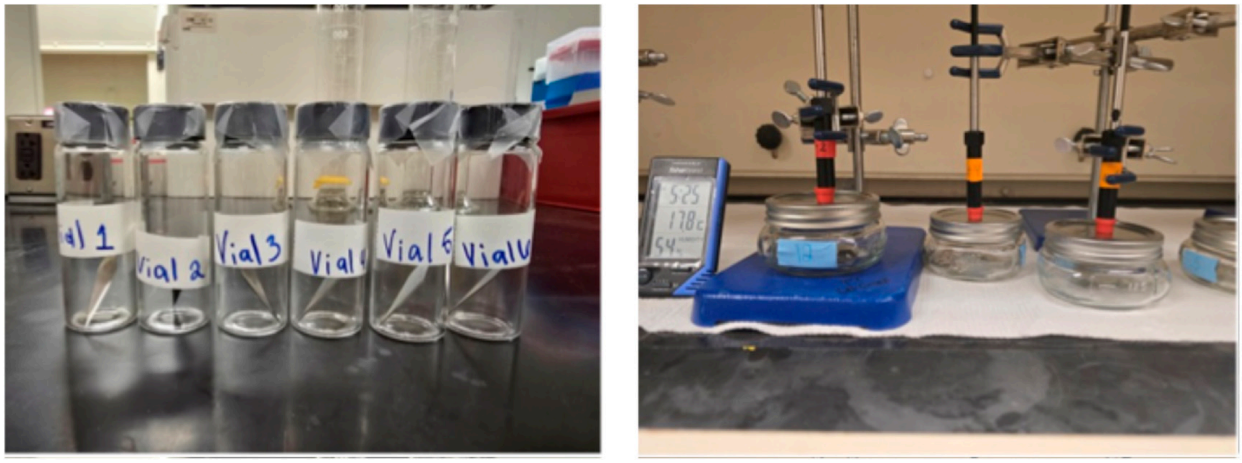


**Figure 2.** Sample containment setup for headspace analysis: box cutter blades were placed in glass vials (**left**), while metal keys were placed in glass mason jars (**right**).

### *2.2. Sample Equilibration and Headspace Extraction*

Headspace sampling was performed using Supelco PDMS/DVB/CAR solid-phase microextraction (SPME) fibers (gray coating) (Supelco, Bellafonte, PA, USA), which were applied consistently across all groups. As a quality control measure, the GC-MS method used for the blade samples was performed between SPME fiber analyses to monitor for cross-contamination and ensure complete desorption. Blade samples were equilibrated in their respective containers for 24 h prior to extraction, based on previous study where metal substrates were analyzed [25]. Headspace collection was then conducted for 15 h based on optimization results that are later discussed.

### *2.3. Gas Chromatography–Mass Spectrometry (GC-MS) Analysis*

The laboratory facility used for analysis was the Texas Tech University Forensic Analytical Chemistry and Odor Profiling Laboratory, and the instrument used for GC/MS analysis was an Agilent 7890A 5975C MSD system (Agilent Technologies, Santa Clara, CA, USA) equipped with an Rtx-5 capillary 30 mm × 250 µm × 0.25 µm column (Restek Corporation, Bellefonte, PA, USA). The 28.71 min method of analysis selected for the experiment is based on Smith et al. 2024 [25]. The carrier gas used for analysis was Helium with a flow rate of 1.0 mL/min. The temperature program started 50 °C and was held there for 5 min. The rate of the first ramp was 7 °C/min, until oven temperature reached 160 °C, and it was held for 2 min. The rate of second, and final ramp was 20 °C/min until the oven temperature reached 260 °C, where it was held for 1 min. To maximize analyte concentration, samples vaporized at 250 °C inlet temperature were injected without splitting onto the column. The mass spectrometer scanned over a mass range of 45 to 550 $m/z$. Instrumental control runs were conducted throughout the experiment to verify the absence of compound carryover between SPME fiber analyses.

A mass spectral quality of 80% or above was the criterion for compounds to be considered positively identified in headspace. Target compounds were identified using the National Institute of Standards and Technology (NIST) 2017 mass spectral reference library and verified with external calibration standards. Calibration curves were created utilizing solutions with concentrations ranging from 5 to 100 ppm. The solutions were auto injected into the GC/MS system and analyzed using the aforementionedmethod.

### *2.4. Data Analysis*

Agilent Technologies' ChemStation software (Santa Clara, CA, USA) was utilized to analyze generated data. Given this multivariant data, principal component analysis (PCA) was conducted with JMP Pro Student Edition 19 software (SAS Institute Inc., Cary, NC, USA, 2021) to monitor clustering based on compound abundance. Principal Component Analysis (PCA) was performed to evaluate patterns in volatile organic compound (VOC) profiles and to visualize similarities and differences between samples collected from the two blade types, the 5-inch Tajima blade and the 1-inch Excel blade. PCA was conducted using the primary VOC dataset, with principal components selected based on the proportion of total variance explained. Score plots were examined to assess clustering of replicate samples according to blade type, while loading plots were evaluated to identify the VOCs contributing most strongly to sample separation. To determine whether individual VOCs differed significantly between blade types, a one-way analysis of variance (ANOVA) was performed independently for each identified compound using blade type as the grouping variable. Statistical significance was defined as $p < 0.05$. Compounds exhibiting significant differences were considered potential discriminatory VOCs contributing to the observed separation in PCA.

## 3. Results

Given the novelty of characterizing VOCs from bladed substrates, method optimization was necessary to establish extraction conditions that maximized VOC recovery. Determining the optimal extraction time provides a foundational methodology for future investigations while generating the first exploratory data describing the chemical profiles associated with bladed substrates. Across the seven replicates for each bladed substrate, greater accumulation was observed with the larger Tajima blade than with the smaller Excel one. There were seven hundred eighty (780) compounds detected from the headspace, with thirty-nine (39) compounds exhibiting spectral quality of 80% or higher ($n \geq 20$). The

extraction time that provided the most VOC accumulation was 15 h across the two groups as Figure 3 depicts.

Based on the time optimization data, a 15 h extraction time was used on twenty-five (25) replicates of each blade type. Across the Excel samples, six (6) compounds were considered frequent with an 80% or higher occurrence across replicates ($n \geq 20$). Across Tajima blade replicates thirty-three (33) compounds were considered frequent across all replicates at the same occurrence rates. Most importantly five (5) compounds were detected in both blades' odor profile, which Figure 4 summarizes. Namely, the five compounds are decanal, eicosane, nonadecane, nonanal, and octadecane.

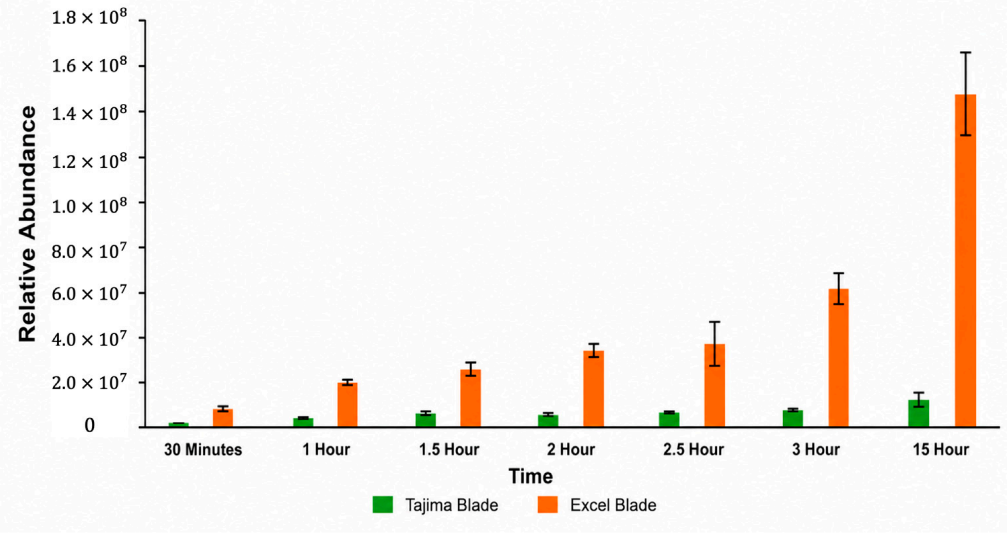



**Figure 3.** Average VOC Accumulation from Two Knife Types Across Seven Sampling Time Points.

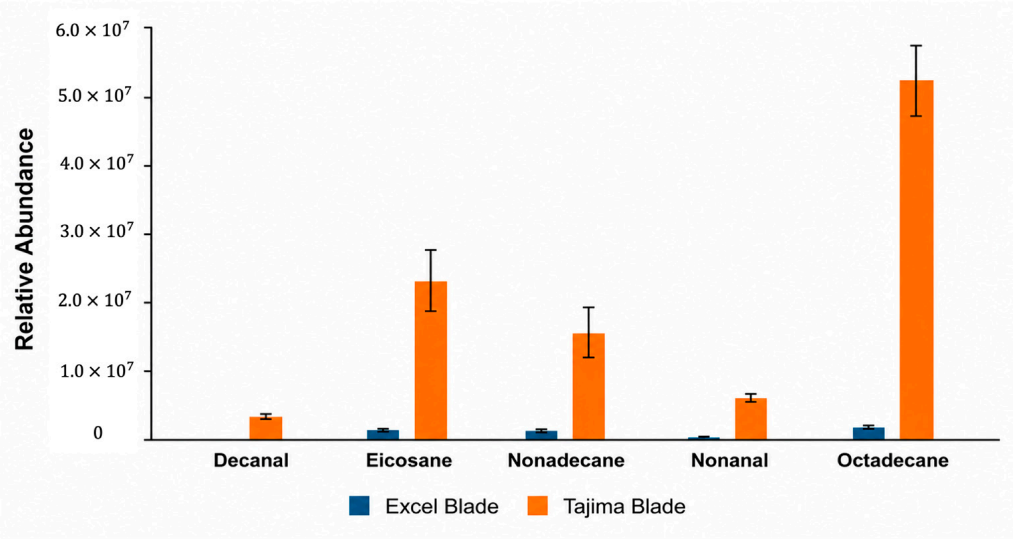



**Figure 4.** Average Relative Abundance of Five Shared VOCs Detected in Both Blade Types (Spectral Quality $\geq$ 80%; $n \geq 20$).

First, the average weight of Tajima blades was 1.8125 g ($\pm$0.0067) and while the mean weight of Excel blades was 0.7383 ($\pm$0.0030). An analysis of variance (ANOVA) followed by a Tukey–Kramer HSD post hoc test was conducted to assess differences among the sample weights of the Tajima and Excel blades and the keys. The ANOVA revealed a significant difference among groups (F = 338.93, df = 72, $p < 0.01$). The Tukey–Kramer HSD post hoc test indicated significant differences between the keys and Excel blades ($p < 0.0001$), as

well as between the keys and Tajima blades ($p < 0.0001$). A significant difference was also observed between the two blade types—Tajima and Excel blades ($p = 0.0026$).

Keys were selected as a typical distractor odor that could represent common items on an individual. As a control group, VOCs profile of keys was analyzed using the same analytical method. Twenty (20) compounds were detected consistently ($n \geq 20$) with spectral qualities of 80% or higher that could be signature VOCs of metal keys, and which are depicted in Figure 5.

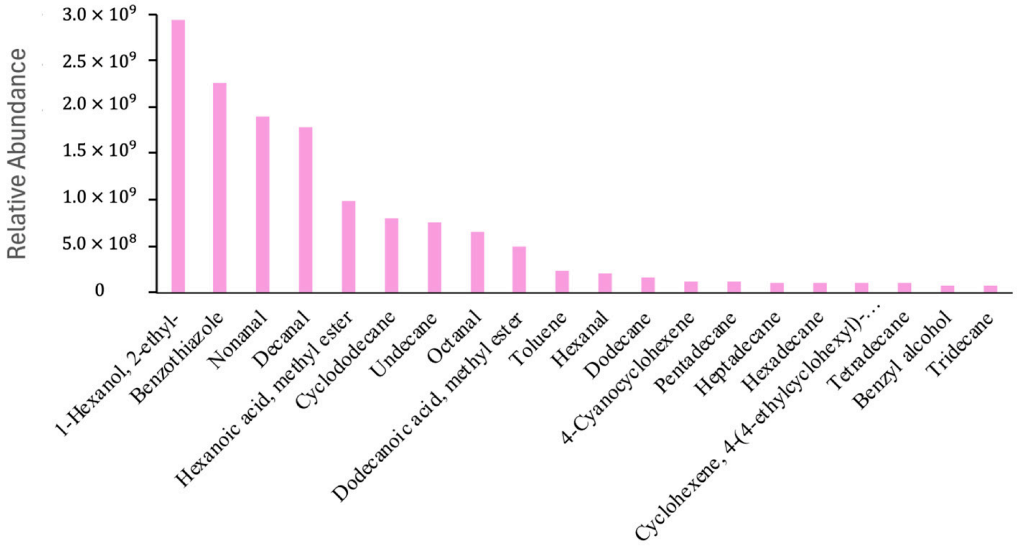



**Figure 5.** Average abundance of key VOCs consistently detected across replicates ($n \geq 20$; spectral quality $\geq 80\%$).

To further evaluate differences in overall VOC abundance among the three sample types, an analysis of variance (ANOVA) was conducted, followed by post hoc pairwise comparisons. The ANOVA indicated that mean VOC accumulation differed significantly among the three groups ($p < 0.01$, df = 72, F = 871.42). Because the overall test was significant, post hoc comparisons were performed to determine which sample types differed from one another. VOC accumulation differed significantly between Excel and Tajima replicates ($p < 0.0001$), between Keys and Tajima replicates ($p < 0.0001$), and between Keys and Excel blades ($p = 0.0127$). Thus, all three sample types showed statistically significant differences in VOC accumulation, demonstrating that sample type was strongly associated with overall VOC abundance.

Beyond these quantitative differences, multivariate analysis further supports divergence in overall chemical profiles. Principal Component Analysis (PCA) revealed clear separation among keys and blade substrates, indicating that both qualitative composition and relative abundance patterns differ across sample groups, consistent with the observed univariate statistical outcomes.

Principal Component Analysis was conducted to simplify all data sets as well as just the ones that are associated with bladed substrates, so variance could be easily visualized. The clustering of VOCs across all groups can be observed in Figure 6A, while variance among the Tajima blade (Bigger) and the Excel Blade (Smaller) groups is depicted in Figure 6B.

The resulting PCA score plots depict clear grouping tendencies among the different bladed sample types. The first two principal components accounted for 68.8% of the total variance, with PC1 contributing 54.7% and PC2 contributing 14.1%. Figure 6A presents the overall clustering structure across all analyzed groups, highlighting separation patterns driven by differences in VOC composition. This separation is driven primarily by the

heavy-chain alkanes (decanal, eicosane, nonadecane, octadecane) loading positively on PC1, whereas lighter aldehydes and shorter alkanes (e.g., hexanal, octane) load negatively.

To further evaluate variability within blade-specific samples, a focused PCA was conducted on the Tajima (5-inch) and Excel (1-inch) box cutter blade groups. The resulting variance structure is shown in Figure 6B, where differences in VOC profiles between the two blade types can be visually assessed. Within the blade cluster, Excel and Tajima blades form clusters along PC2. Tajima blade replicates exhibit higher PC2 scores, likely due to their large quantity of non-overlapping compounds, whereas Excel (small) blades occupy lower PC2 scores due to the presence of fewer overlapping compounds. In addition, the overtly negative values of PC1 references the share of variance associated with the high-chain versus low-chain VOC distinctions. PC2 captures within-blade variation related to size-dependent accessory compounds. Collectively, PC1 and PC2 suffice to discriminate against sample origin (blade vs. key) with high confidence and to a lesser extent blade size. Although the current dataset comprises relatively few replicates ($n$ = 25 per group), the high consistency of frequent compound occurrence (≥80%) and the clear PCA separation indicate robust variance structure.

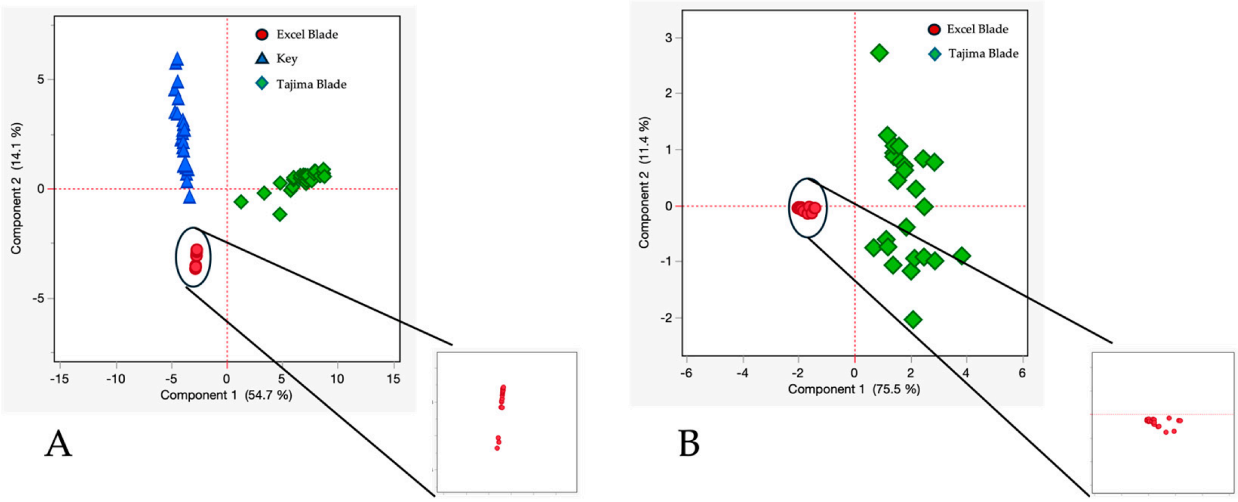



**Figure 6.** Principal component analysis (PCA) of VOC profiles. (**A**) PCA including all three sample groups: control (keys), Tajima blades (large blades), and Excel blades (small blades). (**B**) PCA including only the two blade groups (Tajima and Excel) to highlight differences in their VOC profiles.

## 4. Discussion

This study characterized the volatile organic compound (VOC) profiles associated with box cutter blades and evaluated their differentiation from a metal control substrate using headspace extraction and GC/MS analysis. Across all samples, reproducible chemical signatures were observed, with multiple VOCs consistently detected within blade groups. Multivariate analysis further demonstrated measurable separation between experimental and control samples, as well as distinct clustering between blade types of different sizes, indicating structured variability in odor profiles associated with these substrates.

The significant difference in blade size appeared to influence the resulting VOC profiles of the bladed objects. As shown in Figure 3, which summarizes the extraction time optimization results, Tajima blades exhibited greater total VOC accumulation compared with Excel blades across all evaluated extraction time points. Similarly, Figure 4 demonstrates that the overlapping compounds detected between the two blade types exhibited higher relative peak areas for the Tajima blades, further supporting a size-dependent trend in VOC abundance.

Evaluation of the overall VOC profiles also revealed differences in compound diversity between blade types. A total of 245 unique VOCs were detected from the larger Tajima blades, compared with 121 VOCs detected from the smaller Excel blades. Additionally, Tajima blades exhibited 28 frequently detected compounds that were not observed in Excel blades at the same occurrence threshold. The greater chemical diversity and increased VOC abundance associated with Tajima blades may be attributed to their larger surface area, which provides greater capacity for the retention of manufacturing residues, material additives, and environmental contaminants. Alternatively, differences in blade composition, manufacturing processes, or surface treatments may also contribute to the observed chemical variations. In contrast, only one frequently detected compound, dimethyl phthalate, was uniquely observed in the Excel blade samples. Phthalates are commonly associated with plastic materials, packaging, and ambient laboratory contamination, suggesting that differences in handling, storage materials, or environmental exposure may have contributed to its presence in the Excel blade VOC profile [26].

The five compounds that were frequently detected ($n \geq 20$) between blades—decanal, eicosane, nonadecane, nonanal, and octadecane—suggest a core blade substrate VOC signature. Decanal and nonanal are both aldehydes whereas eicosane, nonadecane, and octadecane are straight-chain alkanes. Aldehydes serve uses in industrial scenarios for the production of plastics, resins, solvents, and perfumes [27]. Similarly, alkanes are used for various engine fuels and lubricants [28]. The presence of these chemicals may reflect residual organic film layers applied onto the blades to protect the surface from corrosion. They can signal the presence of residual waxes and oils from packaging and manufacturing, and protective coatings or machining residues. Decanal and nonanal, which both have been categorized as human scent related compounds, were also present in the control group's VOC profile [29]. Their presence was hardly a surprise, as they have been identified in the odor profile of other metal weapons before, suggesting that metal weapons utilized by humans will likely emit these two aldehydes [21]. Examining them separately, nonanal is a highly frequent compound found in bullets, magazines, and firearms and decanal is found in large quantities in magazines and firearms [21]. The presence of these five recurrent compounds indicates that they may represent manufacturing-related residues and may contribute to volatile signatures similar to those observed from metallic firearm substrates. Overall, the consistent detection of these five compounds across both blade sizes implies consistency in the chemical fingerprint.

Upon examining the similarities and differences among the control and experimental groups, distinct chemical patterns emerged that further differentiate blade-associated odor profiles from those of common metal substrates. As depicted in Figure 5, the metal key controls exhibited 20 consistently detected, high spectral quality VOCs, primarily consisting of cyclic alkanes, low molecular weight aldehydes, and phthalate esters, none of which were consistently observed in the blade replicates. The VOC profile associated with the key controls was characterized by lighter, lower molecular weight compounds, including aldehydes and shorter-chain alkanes, which are consistent with contributions from human skin oils and routine handling residues. In contrast, the blade samples demonstrated a predominance of higher molecular weight alkane compounds, consistent with residues associated with industrial lubricants, manufacturing processes, or surface treatments.

Although several alkane compounds were detected across all sample types, their relative abundances differed substantially, indicating that the overall chemical signature was influenced not only by compound presence but also by variations in abundance and distribution. It is acknowledged that differences in headspace volume and container geometry between sample groups may influence VOC partitioning, concentration, and extraction efficiency, which could contribute to observed differences in compound abundance. These

factors should be considered in future studies employing standardized sampling configurations to further validate substrate-specific VOC signatures. Principal component analysis further demonstrated clear separation between the control and blade groups, suggesting that the observed VOC differences represent distinct chemical profiles rather than random variation. Collectively, these findings provide evidence that bladed objects possess a unique odor profile distinguishable from common metal substrates, highlighting the potential for VOC-based chemical characterization to support the development of improved analytical approaches for blade identification and detection applications.

From an applied perspective, these findings represent a critical first step toward the development of odor-based detection strategies for bladed objects. The presence of consistent and differentiable VOC signatures demonstrates that sharp-edged metal items can emit reproducible chemical cues that may be leveraged for operational detection systems. These findings provide a chemical foundation for the development of canine training aids by identifying potential odor components and characteristic profiles associated with bladed objects. Translation of these chemical signatures into controlled training materials could support the systematic development of canine detection capabilities, enabling more rapid, mobile, and adaptable screening approaches in environments where traditional detection methods are limited or impractical.

Importantly, the successful deployment of canine detection requires not only the identification of target odor signatures but also an understanding of how variability in object characteristics influences odor presentation. The observed size-dependent differences in compound abundance and chemical diversity highlight the need to evaluate a broader range of blade types, materials, manufacturing processes, and surface conditions to ensure that training aids accurately represent the diversity of objects encountered operationally. Establishing this chemical framework will be essential for developing robust odor generalization strategies, reducing potential training bias toward a single blade type, and improving canine reliability across diverse detection scenarios. Future research integrating analytical VOC characterization with controlled canine performance evaluations will be critical to validate whether these chemically distinct profiles translate into biologically detectable cues and ultimately support the implementation of canine-based detection programs for bladed object interdiction in security and law enforcement settings.

## 5. Conclusions

This exploratory experiment represents the first systematic study of blade substrate VOC emissions using a SPME-GC/MS approach. The hypothesis that box cutter blades have an odor profile that is distinguishable from common metal objects, such as metal keys was tested through two-phase experimental design—comprising time optimization and replicate analyses. Optimization showed that a 15 h extraction interval maximizes cumulative VOC recovery for both blade sizes, capturing a suite of high-chain alkanes and aldehydes that collectively serve as a core blade fingerprint. It was demonstrated that both Excel and Tajima box cutter blades emit robust, size-dependent VOC profiles. Tajima blades exhibited a richer assemblage of compounds, likely reflecting greater surface area and manufacturing-related residues. In contrast, metal key control samples released a distinguishable profile of lighter aldehydes and low-chain alkanes, enabling clear separation from blade samples in multivariate PCA space. There are five compounds that frequently overlapped between blade types (decanal, nonanal, octadecane, eicosane, nonadecane), which offers a starting point for constructing blade-specific canine training aids. There is support for continuing research to determine with more certainty which compounds are distinct from common non-blade metal substrates, but the current study provides the possibility of distinction between the groups.

As an exploratory characterization study, several limitations should be acknowledged. The study evaluated a limited number of blade manufacturers and compared them to a single non-blade metallic substrate, and therefore the identified VOC profile should not be considered universally representative of all bladed weapons or metal objects. Additionally, while manufacturing residues are proposed as a likely source of several VOCs, the precise origin of these compounds was not investigated and warrants further study. Finally, although the identified VOCs provide a chemical foundation for future canine detection research, chemical characterization alone does not establish canine perception relevance. Additional validation through controlled canine studies will be necessary to determine which compounds or odor mixtures are behaviorally relevant and operationally useful.

Despite these limitations, the results provide an important foundation for future applications in public safety, law enforcement, and forensic science. Future work should expand the analysis to additional blade materials and manufacturers, incorporate a broader range of metallic distractor substrates, investigate the persistence and origin of the identified VOCs, and evaluate the translation of these chemical signatures into canine detection training and operational performance. Overall, this study advances the understanding of olfactory signatures associated with bladed weapons and provides a scientific basis for continued research into odor-based detection strategies addressing the growing threat of knife crime.

**Author Contributions:** Methodology, investigation, data analysis, writing—original draft, writing—review and editing, C.A.M., I.B.; conceptualization, writing-review and editing, B.M.; conceptualization, resources, writing—original draft, writing—review and editing, supervision, P.A.P.-T. All authors have read and agreed to the published version of the manuscript.

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**Conflicts of Interest:** Brian Mence was employed by Knife Detection Dogs, Ltd. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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