Forensic Chemistry 4 (2017) 1–8

Contents lists available at ScienceDirect

Forensic Chemistry

journal homepage: www.elsevier.com/locate/forc

Full length articles

Variation in duct tape products over time: Physical measurements and adhesive compositional analysis by Fourier transform infrared spectroscopy ☆

Andria H. Mehltretter *, Diana M. Wright, Michael A. Smith

Federal Bureau of Investigation, Laboratory Division, Chemistry Unit, 2501 Investigation Parkway, Quantico, VA 22135, United States

ARTICLE INFO

Article history:
Received 25 August 2016
Received in revised form 10 February 2017
Accepted 10 February 2017
Available online 14 February 2017

Keywords:
Duct tape
Fourier transform infrared spectroscopy
Statistical analysis

ABSTRACT

Four commonly available duct tape products manufactured and sold in North America were analyzed both physically and chemically to determine if parameters such as scrim count, width, thickness (overall and backing/film), or adhesive composition vary for a single product manufactured over a span of several months. Chemical composition of the adhesive was determined using Fourier transform infrared spectroscopy (FTIR). In a previous study, these same products were analyzed to evaluate the intra-roll and intra-jumbo roll differences observed over the lengths and widths of duct tape rolls produced at single points in time, and minimal variation was noted in the recorded features. For this study, wider variation in some parameters was observed between jumbo rolls of the same product manufactured over time. While the means were found to differ in some limited instances, frequently the individual replicates/samples overlapped. Therefore, the intra-product population differences, even when statistically significant, were typically not considered a reliable basis for discrimination of individual samples.

Published by Elsevier B.V.

1. Introduction

Duct tape is the most commonly received type of tape in most North American forensic laboratories due to its prevalence in crimes such as kidnappings, homicides, and construction of improvised explosive devices (IEDs). Most commonly, an investigator would like to know whether duct tape recovered from a crime scene originated from a roll of tape found in the possession of or with the belongings of a particular subject. Forensic tape examiners then analyze the tapes using common microscopical and instrumental techniques. A number of publications exist that address the features and variations observed between duct tape products of different types or by different manufacturers [1–8]. Marked differences can indicate that tape specimens are not from the same product or product type and therefore did not originate from the same roll. Conversely, the absence of differences may suggest commonalities in the manufacturing process. If no detectable differences are observed between tape specimens, one can generally conclude that the tapes originated from the same roll or another roll manufactured in the same manner (i.e., same manufacturer and/or product) [1].

The number of duct tape manufacturers in North America is generally between five to ten producers at any given time. Each makes multiple retail-grade products and higher end commercial products, as well as commodity grade versions that can be sold to third party distributors for sale in discount stores and large outlet markets [J. Serra, tape industry consultant, personal communication, December 5, 2016]. Individual rolls are cut/slit from a much larger jumbo (master) roll (2000 yards in length on average) [2]. The number of individual rolls derived from one jumbo roll depends upon the width and individual roll lengths (typically sold in 10 to 60 yard increments), and the total number of rolls for a specific product depends on market-driven factors [J. Serra, tape industry consultant, personal communication, December 5, 2016]. For example, a single jumbo roll (60 inches wide) could produce ~30 individual rolls (~2″ wide each) for every 60 yards it was unraveled, resulting in ~1000 rolls per jumbo roll.

In addition to the variations exhibited between grades of duct tape, differences among products of the same grade make the material amenable to comparative analysis. In other words, characteristics that are controlled by the manufacturers and distributors

☆ This is the FBI Laboratory Division's publication number 16-23. Names of commercial manufacturers are provided for identification only, and inclusion does not imply endorsement of the manufacturer, or its products or services, by the FBI. The views expressed are those of the authors and do not necessarily reflect the official policy or position of the FBI or the U.S. Government.

* Corresponding author at: Federal Bureau of Investigation, Laboratory Division, 2501 Investigation Parkway, Room 4220, Quantico, VA 22135, United States.
E-mail address: andria.mehltretter@ic.fbi.gov (A.H. Mehltretter).

http://dx.doi.org/10.1016/j.forc.2017.02.002
2468-1709/Published by Elsevier B.V.

add to the diversity of available products and therefore can also be used for discrimination in duct tape comparisons. Some of these features include scrim count, width, overall product thickness, and backing film thickness [9]. Comparison of these and other physical features can provide discriminating power of over 99% [1].

In comparisons in which physical features fail to discriminate between tape samples, chemical analysis can be conducted on the components of a duct tape including the adhesive. Fourier transform infrared spectroscopy (FTIR) is an excellent technique for evaluating duct tape adhesive compositions [1,3,9] due to its ease of use, relative low cost to acquire and maintain, large and readily accessible libraries, and ability to distinguish between a variety of possible adhesive formulations. For these reasons, FTIR is regularly the first instrumental technique used in both industrial and forensic laboratories for adhesive compositional analysis.

Duct tape adhesives can be produced in three primary categories: acrylics, potentially as a copolymer; silicone; or most commonly, as a multi-component system. This latter group is comprised of elastomers, resins, fillers, and other additives. Elastomers are the rubber backbone of the adhesive, typically natural or synthetic isoprene-based. Resins provide the tack to the adhesive and are typically hydrocarbons or polyterpenes [3]. Fillers and pigments are added to the adhesive to provide bulk, reduce cost, or modify the adhesive (e.g., color); common examples include calcium carbonate, kaolin clay, talc, and titanium dioxide [4]. Based on the wide variety and combinations of components that can be used in duct tape adhesives, adhesive compositional analysis can be key in identifying a particular tape manufacturer or product [3] and has been found to provide added discrimination over physical characteristics alone [1].

Although there have been several publications highlighting the differences between different tape products, there has been only a single published study examining data obtained from simultaneously manufactured rolls of the same duct tape product. That study attempted to determine what differences the industry typically tolerates in a given product type by examining sets of individual duct tape rolls that had been cut from the same jumbo roll [9].

That study was designed and undertaken to 1) evaluate the within-roll variation of duct tapes, specifically documenting the observed and measured physical characteristics of the tape as well as the chemical composition of the adhesive via FTIR spectroscopy, 2) assess whether rolls removed from the middle and both edges of a jumbo roll have any observable or measureable differences, and 3) consider the impact of these observations on the association/discrimination criteria for the forensic analysis of duct tapes. Results from that research concluded that scrim count did not vary appreciably along the length of an individual tape roll nor between different individual rolls from the same jumbo roll. Width differences were noted between rolls cut from the same jumbo roll, but the width did not vary to a great extent along the length of a given individual roll. Warp yarn offset exhibited large variations along the length of a roll and was therefore not considered to be a reasonable point of comparison for discrimination between tape specimens. Statistical analysis was performed on the collected thickness measurements and the adhesive chemical compositional data; however, the observed differences were concluded to be minor and would not likely have resulted in an exclusion in a forensic comparison case. Specific details as to the statistical approach used in the previous study were addressed in the resultant publication. Some statistically significant differences in adhesive chemical composition by FTIR were noted for some samples along the length of an individual duct tape roll and more commonly across a jumbo roll. In all instances, the visually observable differences in these spectra were judged not to be large enough to result in exclusion if an analyst were visually comparing the sample spectra. Further, the differences detected within a single tape product were clearly much smaller than the differences commonly seen in adhesive chemical composition between different products.

For the present study, width, scrim count, thickness measurements, and adhesive composition were once again evaluated for four of the original five tape products made by North American manufacturers. Rolls were voluntarily submitted by the manufacturers on approximately a monthly basis and represented specific production runs collected over timeframes of up to about five months. The locations chosen for testing on the submitted rolls were selected randomly and tested in random order. In this way, discrete areas spanning the length and width of each jumbo roll could be assessed using these individual rolls. The purpose of the current work was to determine if significant differences (i.e., differences resulting in discrimination) could be detected within the same product/manufacturer over time.

2. Materials and methods

2.1. Tape collection

The major North American manufacturers of duct tape were contacted and asked to submit three rolls of a popular, commodity-grade duct tape product each month over the course of several months. These three rolls were to come from the left, middle, and right side of the same jumbo roll of their selected product. In total, four products were received from three different manufacturers, over a four to five month timeframe totaling 69 rolls of tape. All were silver-backed, nominally two inches wide, placed on manufacturer or brand name labeled cores, and 50 to 60 yards in length.

These rolls were unwound, cut into five yard increments, and placed on plastic tubular roll stock. This process resulted in eleven to thirteen pieces of tape for each roll.

The nomenclature used for each piece of tape was as follows:

Character	Comments
1	Product identifier (C, I, M, or S)
2	Collection time (0 indicates initial collection time; 1 indicates next collection time, which was approximately 1 month after initial collection, etc.)
3	Individual roll (A = left, B = middle, C = right)
4–5	Number of yards cut from the leading edge of the tape roll

For instance, C2B15 indicates that this particular piece of tape originated from product C, at the third collection time (~2 months after initial), from the middle individual roll collected from the jumbo roll, and that the piece was cut beginning at 15 yards from the leading edge of the roll. Each piece was then prepared and analyzed as described herein.

2.2. Scrim count

Each roll was measured three times: on the leading piece, a middle piece, and the final piece removed from the roll. A portion of the adhesive was removed as needed with suitable solvent and cotton swabs/Kimwipes® to expose enough of the fabric to measure one square inch. Scrim count was measured using an English/Imperial ruler with the number of warp yarns (machine direction) and the number of fill or weft yarns (cross direction) counted per inch in each direction, and recorded as a measure of warp/fill (w/f). To ensure consistency of measurement, the zero point of the ruler was lined up with a yarn, which was not counted. If a yarn lined up with the 1″ point of the ruler, it was counted.

2.3. Width

Widths were measured on the same pieces used for scrim count assessments using a metric ruler scaled to 1 mm gradations. A single width measurement was taken of each piece and recorded to the nearest 0.5 mm.

2.4. Thickness (Overall and Film)

Eight pieces of each product were randomly selected for thickness measurements from each of the production month's samples using a random number generator. Since full jumbo rolls were not received, it was assumed that the three individual rolls representing the left, right and center of each jumbo roll were reasonably representative of the parent roll. Each tape piece selected