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**Final Research Report for**  
**Award #: 2019-DU-BX-0134**

**Project Title: Forensic Evidence from Chemical Imaging of**  
**Triacylglycerols in Latent Fingerprints**

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## Summary of the project

- Major goals and objectives

Currently, there is no reliable method to determine the time since deposition of latent fingerprints, which is a crucial bottleneck to convict a suspect based on fingerprint evidence. We hypothesize that fingerprint triacylglycerols (TGs) can be used to determine fingerprint aging as well as individual health information. The goal of this project is to test our hypothesis by systematically studying fingerprint aging under controlled environment and finding correlation between fingerprint TGs and individual health information.

- Research questions

Fingerprints are a result of the sweat released from the finger pores and gland secretions. Fingerprints have been used for over one hundred years and are still one of the most powerful means of biometric identifications. In spite of the wide use and success, there are a number of cases it cannot produce fruitful outcomes. Among those, the determination of how long a fingerprint is left at a crime scene is often controversial and is subject to heavy scrutiny as court evidence. It would be desirable to obtain extra information from the latent fingerprints, especially the time-since-deposition, that can be used as forensic evidence in addition to a fingerprint database search for identification.

Matrix-assisted laser desorption ionization mass spectrometry (MALDI-MS) is an analytical technique that can analyze the chemical composition of fingerprints directly from the surface. In this project, we attempt to obtain forensic evidence from fingerprint triacylglycerols (TGs), a major component of fingerprint compounds, using MALDI-MS. More specifically, we are trying to

determine the age of a fingerprint from the degradation of TGs by ambient ozonolysis and health information of an individual from the fatty acyl patterns of TGs.

- Research design, methods, analytical and data analysis techniques

As we and others have previously demonstrated, carbon-carbon double bonds, or unsaturations, of TG fatty acyl chains react with ambient ozone and degrade over time. The kinetics of fingerprint aging was studied from the degradation of unsaturated TGs in a mixture of standard TGs and fingerprint TGs using an environment chamber. Environmental effects such as humidity, temperature, ozone concentration and light were systematically studied, and kinetics model was developed and tested by monitoring the decay of unsaturated TGs over time. A large-scale study was performed on fingerprint TGs of diabetic patients, and an attempt was made to find the correlation between health information and fingerprint TGs. MALDI-MS was used for the data acquisition at Lee laboratory, Iowa State University. Diabetic patients were recruited at University of Iowa Medical School for the collection of fingerprints and blood samples.

- Expected applicability of the research

The current study is an early-stage basic science research, but it could eventually lead to provide valuable forensic information of fingerprints that are often neglected. Fingerprint aging information can be used to determine whether the collected fingerprint samples are matching with the associated timeline for a crime. Health information of fingerprints can be used to provide an additional information about the person who left fingerprints, which could be useful when there is no matching in FBI fingerprint database as additional suspect profiling information.

## **Participants and other collaborating organizations**

Several graduate students are involved in this project, partially or fully, in various parts of the projects. Dr. Yumi Imai at University of Iowa Medical School served co-PI of the project and involved in recruiting and collecting samples from diabetic patients.

## **Changes in approach from original design and reason for change, if applicable**

COVID pandemic disrupted many of the research plans, especially in recruiting volunteers. The project was extended for 1.5 years, yet some issues were not resolved. Some research plans had to cut back including population study, the target number and exclusion criteria in diabetic patients, and the fingerprint aging of diabetic patients. To compensate these cutbacks, physical activity study was performed where the correlation was attempted between the physical activity of an individual and fatty acyl patterns in fingerprint TGs. Due to the difficulty recruiting diabetic patients, sample and data collection for diabetic patients had to be continued until the project end date. As a result, the data interpretation is not completed but will be done in the next few months.

## **Outcomes**

- Activities/accomplishments

1. A high-resolution mass spectrometry tool, Kendrick mass defect analysis, was successfully applied to fingerprint aging for the first time to i) validate our hypothesis that ambient ozonolysis is a major decay mechanism of unsaturated TGs and ii) explore new discoveries in fingerprint aging reactions.

2. A simple kinetics model is developed to explain fingerprint aging based on ambient ozonolysis.
3. A machine-learning is used to find the correlation between physical activity of an individual and fatty acyl chains in fingerprint TGs.
4. An effort is currently being made to find correlation between fingerprint TGs and diabetic patients.

- Results and findings

1. As detailed in our recent paper (ACS Central Science, 2022, 8 (9), 1328-1335), Kendrick mass defect analysis resulted in three major findings. First, we validated that ambient ozonolysis is the major mechanism for the decay of fingerprint lipids including not only TGs but also wax esters, fatty acids, and diacylglycerols. Second, we discovered an unexpected new aging trend, which is attributed to ambient epoxidation induced by singlet oxygen. Its effect in aging, however, was minimal compared to ambient ozonolysis. Third, we discovered a new late aging marker, capric acid, produced by ozonolysis of fatty acyl chains.
2. In a systematic environmental chamber experiment, TG degradation is found mostly affected by ozone concentration and ambient temperature whereas there is almost no effect by light and humidity. A simple kinetics model is developed with pseudo-first order kinetics and Arrhenius equations, to predict fingerprint age based on ozonolysis of unsaturated TGs. This model requires only ozone concentration and temperature in the mathematical formulation. This work is submitted for publication and the revision is currently in pending.
3. Machine learning is used to find the correlation between fingerprint TGs and physical activity. A rough but partial correlation was made (accuracy of ~70%) from the fingerprints of

100 individuals. A k-nearest neighbor classification machine learning model gave the best result so far. Further optimization is still ongoing to improve the accuracy of the machine learning model, with the goal to reach at least 80% accuracy.

4. An attempt is currently being made to find the correlation between diabetic patients and fingerprint TGs. Through the collaboration with the University of Iowa, a total of 156 participants were recruited, 95 healthy individuals and 61 diabetic patients. Data collection is completed for each individual to obtain the information about fingerprint TGs, blood TGs, and diabetes marker compounds. Data interpretation is still ongoing with the publication of results as the final goal.

- Limitations

1. There is a major limitation in our simple kinetics model. While this model works well for each individual, there is a significant person-to-person variation in the initial amount of unsaturation and decay rate. Nevertheless, a rough estimation of fingerprint age can be initially made, and the estimation can be refined further once the suspect is identified.
2. Due to significant delays from the pandemic and reluctance of patients to participate the study, data interpretation for diabetic patient experiment is not yet completed but will be finished in the coming months.
3. Saturated vs unsaturated fat in fingerprints is affected by many variables of each individual, not only physical activity and diabetes, but also diet and possibly genetics. As a result, machine learning accuracy is limited, and a much larger sampling size might be necessary to improve the accuracy with diverse samples. However, current efforts are focusing on improving the accuracy of the model with the data already collected.

## Artifacts

- List of products (e.g., publications, conference papers, technologies, websites, databases), including locations of these products on the Internet or in other archives or databases

### Publications:

1. A. Paulson, **Y.J. Lee\***, Novel Ambient Oxidation Trends in Fingerprint Aging Discovered by Kendrick Mass Defect Analysis, ACS Central Science, 2022, 8 (9), 1328-1335.  
<https://pubs.acs.org/doi/10.1021/acscentsci.2c00408>
2. Daphne R. Patten, Andrew E. Paulson, Trevor T. Forsman and Young Jin Lee, Predicting Fingerprint Age based on Ozonolysis Kinetics of Unsaturated Triacylglycerol Degradation, revision pending in Analytical Chemistry.

### Manuscripts in preparation:

- "Determination of an Individual's Physical Activity based on Fingerprint Compounds using Machine Learning Techniques", Daphne R. Patten, Trevor T. Forsman, Andrew E. Paulson, and Young Jin Lee
- "Linking Fingerprint Compounds to Diabetic Disease Markers for Forensic Profiling Applications", Daphne R. Patten, Trevor T. Forsman, Luke Fredericks, Young Jin Lee

### Invited talks:

1. Pittcon, NIJ Forensic Symposium, Philadelphia, PA, Mar 19th, 2023.
2. Indiana Division of the International Association for Identification (INIAI) annual educational conference, Indianapolis, IN, Oct 13-15, 2021.



3. American Society of Crime Laboratory Directors (ASCLD) Forensic Research Committee (FRC), virtual lightning talk, Apr 1st, 2021.
4. Pittcon, NIJ Symposium-Advancements in the Analysis of Forensic Trace Evidence, Mar 11, 2021, virtual.
5. National Institute of Justice Forensic Science and Development Symposium in parallel to AAFS, Feb 16, 2021, virtual.
6. Pittcon, National Institute of Justice-Forensic Science Symposium for Emerging Technologies, Mar 1-5, 2020, Chicago, IL.

Contributed Oral Conference presentations:

1. "Determining Fingerprint Age with Mass Spectrometry Imaging via Ambient Ozonolysis of Triacylglycerols", 68th ASMS Conference on Mass Spectrometry and Allied Topics, Jun 15th-Jun 19th, 2020, virtual.
2. "Toward fingerprint age determination: Exploring fingerprint chemical complexity and degradation processes with high-resolution mass spectrometry" A. E. Paulson and Y.J. Lee. ACS Midwest Regional Meeting 2022; Iowa City, IA, April 19, 2022.
3. "Expansion of fingerprint aging model: development of an advanced kinetic model using triacylglycerol standards", Daphne R Patten; Andrew E Paulson; Young Jin Lee, 70<sup>th</sup> ASMS Conference on Mass Spectrometry and Allied Topics, Jun 5<sup>th</sup>-Jun 9<sup>th</sup>, 2022, Minneapolis, MN.
4. "Novel Ambient Oxidation Trends in Fingerprint Aging Discovered by High-Resolution Mass Spectrometry ", Andrew Paulson, Young Jin Lee, NIJ Symposium, American Association of Forensic Science, Feb 13-18, 2023, Orlando, FL.

Conference Poster presentations:

1. "Application of Machine-learning to Predict Physical Activity from Endogenous Fingerprint Compounds", Daphne R Patten, Trevor T Forsman, Andrew E Paulson, Young Jin Lee, 71st ASMS Conference on Mass Spectrometry and Allied Topics, Jun 4th-Jun 8th, 2023, Houston, MN.
2. "Development of an Empirical Fingerprint Aging Model using Fingerprints analyzed with Laser Desorption/Ionization Mass Spectrometry", Daphne Patten, Young Jin Lee, NIJ Symposium, American Association of Forensic Science, Feb 13-18, 2023, Orlando, FL.
3. "Application of the Ambient Ozonolysis Kinetics Model to Determine Fingerprint Age in a Large Population", Trevor Forsman, Daphne Patten, Andrew Paulson, Young Jin Lee, Pittcon, 2022, virtual.
4. "Kendrick Mass Defect Plots: Guided Selection of Compounds for Fingerprint Aging Models", Andrew E. Paulson, Young Jin Lee, Pittcon, 2022, virtual.
5. "Reaction Kinetics in Fingerprint Aging Studied by Laser Desorption/Ionization Mass Spectrometry", Daphne R. Patten, Young Jin Lee, 2022 NIJ Forensic Science R&D Symposium, Virtual, Mar 1 and 2, 2022.
6. "Kendrick Mass Defect Plots: Guided Selection of Compounds for Fingerprint Aging Models", Andrew Paulson, Young Jin Lee, 2022 NIJ Forensic Science R&D Symposium, Virtual, Mar 1 and 2, 2022.
7. "Investigating ozonolysis reaction kinetics of unsaturated triacylglycerols to determine fingerprint ages using MALDI-MS ", Daphne Patten, Andrew E. Paulson, Young Jin Lee, ASMS Conference on Mass Spectrometry and Allied topics, Pennsylvania, PA, Oct 31-Nov 4, 2021.

- Data sets generated (broad descriptions will suffice)

Several sets of data were generated: (1) high-resolution mass spectrometry data for Kendrick mass defect analysis, (2) aging kinetics data of unsaturated TGs from 11 individuals and TG standards, (3) physical activity data, (4) diabetic and healthy patient data. The data set used in published result is available as supporting information in the journal web site.

- Dissemination activities

As summarized above in Artifacts, a total of two publications, two manuscripts in preparation, six invited talks, four contributed talks, and seven poster presentations were made from this project to disseminate the progress and outcomes. These disseminating activities were made mostly through peer-reviewed publications and conference presentations.