# Volatile profiling of raw almonds: Comparison and classification of California almonds

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## Introduction

The California almond industry grows 80% of the almonds (*Prunus dulcis*) consumed worldwide, with an annual production of approximately 1.9 billion pounds that contributes $21.5 billion to the California economy. Over the past ten years the number of almonds grown in California has increased in response to consumer demand. During this period, the crop yield more than doubled, increasing from approximately 800 million pounds in 2006 to approximately 1800 million pounds in 2016. During this time, changes in the acreage committed to different almond varieties also changed, reflecting changes in consumer demand. Knowledge of the volatile compounds in the different almond varieties, as well as any aroma properties of the volatiles, would help growers and industry officials to more fully understand consumer preference for differing almond varieties. Additionally, knowledge of the volatile profile of raw almonds would help researchers and industry to understand the flavor profile of roasted almonds, how these flavor profiles develop, and how they change during storage.

Headspace-solid phase microextraction (HS-SPME) couple to gas chromatography mass spectrometry (GC-MS) has become a standard analytical technique for the analysis of volatiles. HS-SPME GC-MS has been shown to be a sensitive and robust analytical platform and has been used in the analysis of the volatiles in many different types of foods, including both raw and roasted almonds (1, 2). Prior analysis of raw almonds by HS-SPME GC-MS identified 41 volatiles in one variety, Butte/Padre (2). The research presented here expands on this by using an optimized HS-SPME extraction method to profile the volatile compounds in ten almond varieties grown throughout California: Aldrich, Butte/Padre, Carmel, Independence, Monterey, Nonpareil, Price, Sonora, Wood Colony, and Fritz.

## Materials and Methods

Aldrich, Butte/Padre, Carmel, Independence, Monterey, Nonpareil, Price, Sonora, Wood Colony, and Fritz

Grind and sieve

1 gram almond
700uL saturated NaCl

Incubate 15 hours at 25˚C

### HS-SPME GC-MS

- Agilent 7000B GC-MS/MS with Extractor EI source
- Agilent 7890A Gas Chromatograph
- Gerstel MPS 2 autosampler
- Column: Agilent DB-WAX (30m x 0.25mm i.d. x 0.25um film)
- SPME fiber: 1 cm DVB/CAR/PDMS
- SPME extraction time: 45 minutes
- GC run time: 45 minutes
- Data analysis: Agilent MassHunter Quantitative Analysis and Unknowns Analysis, JMP Pro 13

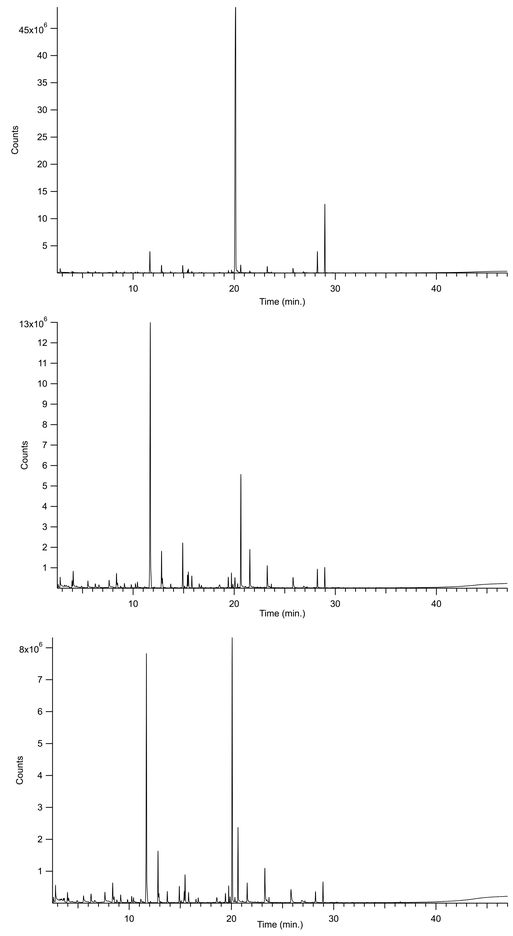


Figure 1. Total ion chromatograms for Aldrich (top), Independence (middle), and Nonpareil (bottom) almonds as representative chromatograms.

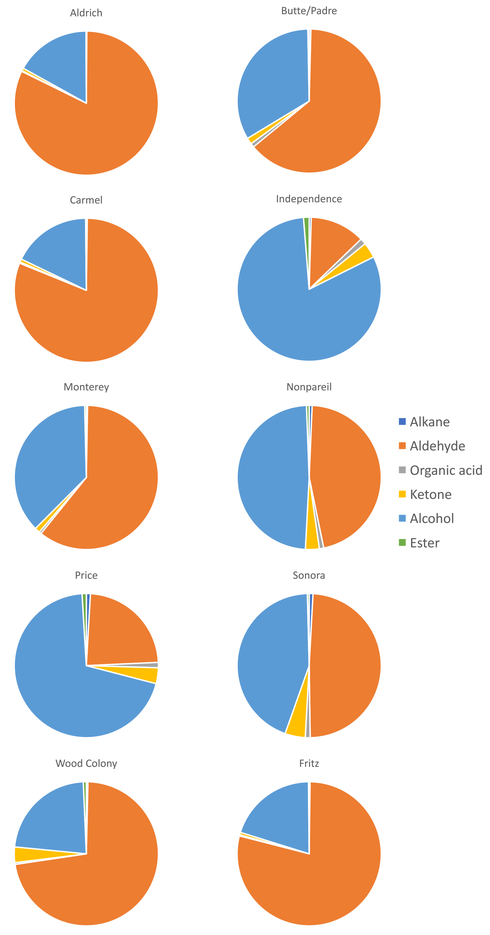


Figure 2. Relative distribution of volatiles by chemical class in the ten almond varieties.

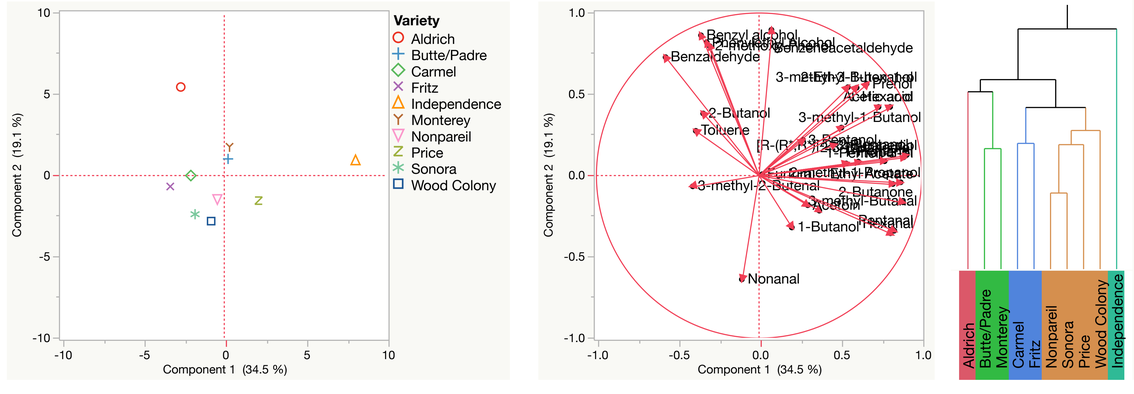


Figure 3. Principal component analysis of the ten almond varieties, showing the relationship between varieties based on the volatile profiles. Shown are the scores plot (left) and loadings plot (middle). Hierarchical cluster analysis (right) shows five clusters of almond varieties based on volatile profiles.

## Results

- HS-SPME GC-MS allowed the volatile profiles of ten almond varieties to be reproducibly measured. Total ion chromatograms for three of the ten varieties are shown in Figure 1.
- A total of 51 volatiles were identified and confirmed. Based on functional groups these volatiles can be classified as alkane, aldehyde, organic acid, ketone, alcohol, and ester.
- Both the concentration and distribution of volatiles varied between varieties (Figure 2).
- In all varieties either alcohols or aldehydes were the primary volatile.
- Alkanes, organic acids, ketones, and esters were measured at much lower concentrations.
- Comparison of the varieties based on volatiles was performed using multivariate methods (Figure 3).
- Principal component analysis (PCA) showed separation of the varieties, with Aldrich and Independence being the most separated.
- Separation of Aldrich was driven primarily by benzaldehyde and benzaldehyde derivatives. The separation of Independence was driven by alcohols.
- Hierarchical clustering (HCA) showed that the varieties cluster into five groups based on volatile profiles.

## Conclusion

- Differences were observed in the volatile profiles of ten almond varieties grown in California.
- Fifty-one volatiles were detected and confirmed
- Detected volatiles can be classified as aldehyde, alcohol, ketone, alkane, carboxylic acid, and esters.
- The most abundant volatiles present in all varieties belonged to the chemical classes of aldehydes and alcohols.
- Based on the volatile profiles the ten varieties could be separated into five groups.

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california almonds
Almond Board of California

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