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Assessment of Similarity in Chemically Complex Samples

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Assessment of Similarity in Chemically Complex Samples

by

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Abstract

Concern within the public health community is mounting regarding what some deem as “candy-flavored tobacco”. A recent study by King et al. (2014) found that >40% of middle and high school student smokers use flavored cigarettes or flavored little cigars. This study investigated the validity of the “candy-flavored tobacco” designation by comparing flavor profiles of 18 flavored tobacco products with 15 candy and Kool-Aid products using gas chromatography mass spectrometry (GC/MS). Significant compositional overlap was found; nearly 75% of the compounds detected were present in at least one flavored tobacco and one candy or Kool-Aid product. Benzaldehyde and or benzyl alcohol were measured in cherry candies, Kool-Aid and tobacco. Similar levels of benzaldehyde were measured in the cherry Kool-Aid and wild cherry Cheyenne cigars at 3338 ± 623 and 3937 ± 251 μg/serving. Methyl anthranilate, 1-hexanol, γ-decalactone, and raspberry ketone were found in all grape, apple, peach and berry products, respectively. Vanillin and or ethyl vanillin were constituents of all flavored tobacco products analyzed.

Many flavorants, such as limonene, are also volatilizable biogenic organic compounds (VBOCs). A more comprehensive understanding of the identities and properties of VBOCs, precursors to secondary organic aerosol (SOA), would support air quality and climate change research and management. Our knowledge is limited by extreme compositional diversity within the VBOC class. Only recently have techniques such as two-dimensional gas chromatography time of

flight mass spectrometry (GCxGC/TOFMS) been employed, and the complexity of the data poses analysis challenges. To address this, agglomerative hierarchical cluster analysis (HCA) was performed on data generated by GCxGC/TOFMS analysis of air samples collected during the Particle Investigations at a Northern Ozarks Tower: NO_x, Oxidant, Isoprene Research (PINOT NOIR) study. HCA resulted in the assignment of 204 compounds into 27 clusters: these clusters were grouped into 4 distinct types making the data significantly more manageable. The assignment of a cluster to a type was mostly based on the frequency with which compounds appeared in samples. Type I clusters contained compounds that were present in only one sample, suggesting meteorological influence.

Dedication

This work is dedicated to the memory of Lorne Isabelle, who enthusiastically trained me on the GC/MS and laboratory work, encouraged me to practice self-care and always made me smile and laugh in the lab. I will always be grateful for and remember Lorne, and his family will remain my thoughts.

Acknowledgements

My deepest gratitude to my research advisor and committee chair, Dr. James Pankow, for challenging, encouraging and believing in me and for providing me with numerous opportunities for academic and career development as well as hours of assistance with writing. I feel honored to have had the opportunity to learn from you.

I would also like to acknowledge Dr. Wentai Luo and Lorne Isabelle for making time in their busy schedules to assist me with all aspects of my research. They made themselves consistently available to address my many questions.

To committee member Dr. Kelley Barsanti for your valuable insights and direction in regards to the HCA analysis.

Thank you to my committee member, Dr. Todd Rosenstiel, for meeting with me and offering assistance.

Thank you to Maysoun Hameed for spending several hours helping me with the statistical analysis portion of this thesis.

I would also like to thank my mother, Deanna, for her consistent and unconditional support, acceptance and love. Thank you to my father, Jeff, for always encouraging me to excel and pursue the sciences, to Julie and Kathy for all of their support and encouragement, and to my siblings Matt and Olivia for giving me so much joy.

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1. Flavorant Analyses

1.1. Introduction:

For many, tobacco use begins at a young age. In the U.S, among adults who had ever smoked cigarettes daily, 88% reported trying their first cigarette before the age of 18 (Center for Disease Control and Prevention 2012a). The World Health Organization (2011) estimates the number of smokers in the world at 1 billion, that tobacco use leads to 6 million deaths per year, and that 50% of contemporary smokers will ultimately die from a tobacco-related illness. The U.S. Center for Disease Control and Prevention (2008) has estimated the death rate attributed to U.S. cigarette smoking at 443,000 per year and that direct medical expenses as a result of tobacco were more than $96 billion. It is therefore important to understand product design factors that may attract new tobacco users, including flavorant chemicals in product formulations.

Table A.1 outlines relevant prevalence of use and sales of cigars and moist snuff. Sales of large cigars and moist snuff have been increasing. The Government Accountability Office (2012) reports a 49% percent increase of sales in large cigars, with 10.27 billion sticks sold in 2010, up from 6.88 billion in 2008. Delnevo et al. (2012) report a 72% and 334% increase in flavored moist snuff and pouched moist snuff from 2005-2011, respectively, noting that 73% of pouched moist snuff is flavored. In 2011, 11.6% and 7.3% of U.S. high school students reported use of cigars and smokeless tobacco respectively within the last 30 days at the time of survey (Center for Disease Control and Prevention 2012b). This is in contrast to the 18 or older adult population, where 5.2% and 3.3% reported use of cigars and smokeless

products, respectively (Substance Abuse & Mental Health Services Administration 2012).

A recent study found that 42.4% of U.S. middle school or high school student self-identified smokers reported use of flavored cigarettes or flavored little cigars, that these users were less likely to report plans to quit than individuals smoking unflavored cigarettes at 9.8% and 18.4% respectively, and that 60% used "cigarettes" with flavors other than menthol (King et al. 2014). Many cigars, such as the Cheyenne cigars analyzed in this study, are similar in appearance to cigarettes. King et al. (2014) note that the youth reporting use of flavored cigarettes may actually be using flavored cigars; in 2009, flavored cigarettes (with the exception of menthol) were banned in the U.S. About 40% of flavored cigarette smokers reported using mentholated cigarettes, indicating that the remaining 60% used "cigarettes" with other flavors (King et al. 2014).

There is increasing concern within the public health community that these flavored tobacco products are "candy-flavored tobacco", marketed to children and make tobacco more attractive and palatable to youth (Miami Dade County 2012; Alpert, Koh, and Connolly 2008). This study investigated the validity of the "candy-flavored tobacco" designation through comparison of flavorant profiles in tobacco and candy/Kool-Aid. The composition information of these products is proprietary, and to the best of our knowledge have not been analyzed by an outside party. Portions of this thesis are reproduced with permission from (Brown, J.E., W. Luo, L.M. Isabelle, and J.F. Pankow. 2014. "Candy Flavorings in Tobacco." *New England Journal of Medicine* 370 (23): 2250–52.), Copyright Massachusetts Medical Society.

1.2. Methods

Tobacco, candy and soft drink products were selected based on the availability of flavors falling into the apple, berry, cherry, grape and peach flavor categories. Efforts were made to analyze several candy and tobacco products in each flavor category. A product was placed in a flavor category based on its name; for example, "wild cherry", "peach mango" and "blueberry" were respectively placed in the cherry, peach and berry flavor category. Table A.2 provides the tobacco, confectionary and soft drink products analyzed and the corresponding sample amounts used for extraction.

1.2.1. Confectionary and Soft Drink Procedure

Individually wrapped Jolly Ranchers (apple, cherry, grape, peach and raspberry), and Life Savers (cherry and raspberry) in multi-flavor packages were purchased in Portland, OR during August 2013 along with packets of unsweetened Kool-Aid powder (cherry, peach mango, grape and raspberry lemonade). Zotz (apple, blueberry, grape and cherry) were purchased in February 2014. Products were stored in zip lock bags at 4°C prior to analysis.

Analyses were carried out in triplicate. The amounts extracted using a combination of water and methyl tert-butyl ether (MTBE) were: Life Savers, 2 candies; Jolly Ranchers, 1 candy; and Kool-Aid mix, 100 mg. For each analysis, 50 μL of a surrogate standard (SS) solution (1,3,5-trichlorobenzene (1,3,5-TCB) at 4000 ng/μL in MTBE) was included to monitor recoveries. Also included in the vials were 450 mg, 700 mg, or 350 mg of trisodium citrate, respectively to raise the pH of each

water extract from about 2-3 to the 5-7 range to avoid acid hydrolysis of some flavor chemicals. Analytes were "salted out" from the water into the MTBE through addition of 2.0 g of sodium chloride. Extraction of each sample proceeded in a 40 mL amber VOA vial using 10 mL of deionized water to dissolve the sample, and 10 mL of MTBE to extract the flavor chemicals. Kool-Aid sample vials were placed on the shaker for 0.5 h. Life Saver and Jolly Rancher samples were allowed to sit for 8 h at 4°C to allow product dissolution then placed on the shaker for 0.5 h. Each sample vial was then subjected to vortex mixing 3× for 10 s each, and allowed to sit for 2 h for phase separation. A 1 mL aliquot of each extract was placed in an autosampler vial with 10 μL of an internal standard (IS) solution (1,2,3-trichlorobenzene (1,2,3-TCB) at 2000 ng/μL in MTBE).

The calibration standards contained the target analytes at concentrations ranging from 1 to 50 ng/μL per compound. The target analyte list included 85 compounds obtained from Sigma Aldrich Inc. (St. Louis, MO), the Good Scents Company, Inc. (Oak Creek, WI), and other vendors. The target analytes were determined through solid phase microextraction (SPME) analysis and subsequent GC/MS analysis of most products except Kool-Aid and Cheyenne, in which preliminary extractions were performed. Table A.3, created by W. Luo and edited by J. Brown, gives the 70 analytes found in one or more of the samples. In addition to the 70 chemicals listed in Table A.3, a combination of *o*- and/or *m*-tolualdehyde as isomers of *p*-tolualdehyde was found in cherry Life Savers.

1.2.2. Tobacco Procedure

The analysis of 18 flavored tobacco wraps, large cigars and moist snuff are described in this work (Table A.2). Most of the tobacco products were purchased in August 2013 at retail stores in Portland, OR. Grape Kayak moist snuff as well as grape and blueberry Zig Zag Wraps were purchased in Portland, OR February 2014. Cheyenne brand large cigars were purchased online in January 2013. These products were stored at 4°C in zip lock bags until analyzed. An unflavored reference moist snuff ("CRP2") was obtained from North Carolina State University in July 2012 for use as an unflavored tobacco control material; it was stored as received (in cans) at 4°C until analyzed.

Analyses were carried out in triplicate. Sample amounts were as follows: a) 1 stick for the Cheyenne products (each filter was removed and analyzed separately; the final values in the data tables are the sum of filter and tobacco); b) 1 cigarillo for Swisher Sweet products (plastic tip removed prior to analysis); c) 1.0 g cylinder cut from the center for the Phillies Blunt cigars; d) 1 blunt wrap for Zig Zag Wraps and Royal Blunt Wraps; and e) 1.0 g for the moist snuff products. Except for the moist snuff products, each sample was cut into small pieces with clean medical suture scissors and placed in a 40-mL amber glass "VOA" vial fitted with a Teflon septum in a screw cap. For most samples, added to each vial were 50 μL of the 4000 ng/μL 1,3,5-TCB SS solution, plus 10 mL = V_1 of MTBE as the extraction solvent. For the Cheyenne filters, the amounts were 25 μL of surrogate standard solution and V_1 = 5 mL of MTBE. For the Swisher Sweet cigarillos (2.3-2.7 g each, tobacco only), 100 μL of the SS solution and V_1 = 20 mL of MTBE. Extraction proceeded with gentle

shaking for 1 h, quiescence at 4 °C for 8 h, and gentle shaking at room temperature for 0.5 h.

1.2.3. Instrument Information

Analyses for candy, Kool-Aid and tobacco MTBE extracts were performed using an Agilent (Santa Clara, CA) 7690 autosampler, Agilent 7890A gas chromatograph (GC), and Agilent 5975C mass spectrometer (MS). A volume of 1.0 μL of each extract was injected by the autosampler through the septum and into the inlet. The injection operated with a 5:1 split; for every 5 parts injected, 1 part went to the column. The split functions to decrease the total mass entering the column, thereby allowing for improved separation of compounds. Helium was used as the carrier gas. The total flow was 6.5636 mL/min with 1.000 mL/min directed out the septum purge. A flow of 4.6363 mL/min exited the split vent and the remaining flow of 0.9273 mL/min proceeded through the column attached to the inlet in a temperature-controlled oven. The GC column type was Agilent DB-5MS UI (ultra inert), of 30 m length, 0.25 mm internal diameter (i.d.), and 0.25 μm film thickness. The relatively nonpolar column has a stationary phase composition of 5% phenyl and 95% dimethyl polysiloxane.

W. Luo developed the instrument method. A suitable temperature program was determined experimentally. Within minor variations, the GC temperature program for all analyses was: 45°C hold for 3 min; 5°C/min to 100°C; 2°/min to 130°C; 5°C/min to 160°C; then 20°C/min to 300°C. Excellent separation was achieved for most compounds, and those that coeluted had distinct ions allowing for quantification.

1.2.4. Quality Control

A blank containing MTBE and 20 ng/μL IS was run at the beginning of each series of runs to ensure a clean GC column and check for contaminants in the solvent. All candy/Kool-Aid SS recoveries were in the range 83 to 114%; no SS-based adjustments were made. Quality assurance (QA) steps besides the use of the SS and IS compounds in each analysis included verification of adequate extraction efficiency by removal of as much of the 1st extract as possible and a subsequent 2nd extraction with MTBE, as well as spike-recovery efficiency tests with the actual products. The equation used to calculate extraction efficiencies (EE) for each detected compound (*i*) is shown below:

$$\mathrm{EE}_i = \frac{c_{1_i} v_1}{c_{1_i} v_1 + c_{2_i}(v_2 + v_R) - c_{1i} v_R} \bullet 100\% \qquad \text{Equation 1.}$$

The concentration in the 1st and 2nd extract are denoted by c_1 and c_2, respectively; v_1 and v_2 represents the volume of MTBE added for the 1st and 2nd extraction, respectively; v_R corresponds to approximate volume of extract left over after removal.

Recoveries (*R*) for each compound (*i*) were calculated using the following equation:

$$R_i = \frac{c_{SPi} - c_{Si}}{c_{STDi}} \bullet 100\% \qquad \text{Equation 2.}$$

Where c_{SP}, c_S and c_{STD} refer to the concentration measured in the spiked extract, the average concentration of i in the unspiked sample and the concentration originally added, respectively.

For the above-trace compounds in the Supplementary Tables, the 1st extraction efficiencies were >88% for all compounds for Jolly Rancher candies; >94% for Life Saver candies except for furfural (85%) and furfuryl alcohol (88%); 100% for Kool-Aid. For recovery experiments, spiking occurred into samples that already contained some amounts of the analytes being spiked. The pre-spike levels were estimated as the averages reported here. The average spike recoveries for Jolly Ranchers were in the range 82-116% for all analytes, with most >90%. For Zotz, the spike recoveries were 82-115%, with most >90%, except for furfuryl alcohol and α–terpineol, at 71% and 78% respectively.

All tobacco SS recoveries were in the range 87-114%. 1st extraction efficiencies were: for Skoal Cherry moist snuff, >92% for all compounds except amyl butyrate (83%) and isoamyl butanoate (86%); for Zig Zag Apple blunt wraps, >98% for all compounds; for Cheyenne Xotic Berry "large cigars", >81% for all compounds (as the net for the separate rod and filter extractions). Spike-recovery efficiency values for the tobacco samples were estimated as 88-115% for all analytes. Adjustments were not made for SS recovery, extraction efficiency, or spike recovery.

Some of the compounds found in the analyses here can arise naturally in tobacco (Rodgman and Perfetti 2013). Vanillin has been reported at 0.9 to 1.8 μg/g in a range of types of tobacco leaf (Barbu A. Demian 1993). Since we did not have access to the unflavored versions of the tobacco products we examined, the "CRP2" reference moist snuff was analyzed as an unflavored tobacco control.

1.2.5. Data Processing and Quantification

The base peak was used as the quantitation ion unless it was associated with noise (such as mass 44 for CO_2) or in the case of coelution where the distinct ion was not the base peak. In this case, the next most abundant ion was selected. The relative ratios of 3 qualifying ions were used verify identification. The peak area, or response, of each analyte quantitation ion was recorded and imported into an excel spreadsheet. A response factor (RF) was calculated for each analyte (*i*) in the calibration standards using:

$$\mathrm{RF}_i = \frac{A_{ci}}{C_{ci}} \bullet \frac{C_s}{A_s} \qquad \text{Equation 3.}$$

Where A_c was the response of the particular calibration standard analyte quantitation ion, C_c was the calibration standard concentration specific to the analyte, C_s was the concentration of the IS (20 ng/μL) and A_s was the response of the IS.

The unknown concentration (C_x) was then calculated using the average response factor (RF_{avg}) and the equation:

$$C_x = \frac{A_x}{\mathrm{RF}_{\mathrm{avg}}} \bullet \frac{C_s}{A_s} \qquad \text{Equation 4.}$$

Where A_x was the unknown analyte response.

The calibration standards (1, 2, 5, 20 and 50 ng/μL) were run twice and the RF_{avg} from each compound was calculated from all 10 runs. If the relative standard deviation of the RF_{avg} was greater than 15%, adjustments were made to lower the value by deleting outliers or narrowing the concentration range.

Compounds detected with a calculated concentration of <0.3 ng/μL were defined as trace. Individual detection and quantitation limits were not measured due to

the number of compounds analyzed. In looking at a 1 ng/μL standard, the lowest response of all the analytes had an estimated signal to noise ratio of 1/300.

1.3. Results

A total of 63 compounds were found in the candy/Kool-Aid products analyzed. Of the 59 target analytes discovered in the tobacco products, 52 were also found in the candy/Kool-Aid. Tables A.4.1-A.4.4 in Appendix A provide the levels found in each product in μg per serving. The concentration of each compound in a sample is reported as the average of three replicates along with the sample standard deviation. In the reference moist snuff CRP2, the analytes cis-linalool oxide, trans-linalool oxide, methyl salicylate and phenethyl alcohol were found at 0.3, 0.5, 0.5, and 2.7 μg/g, respectively.

Products in each flavor category (e.g. grape, cherry, berry, apple and peach) shared the same flavorants. Figure 1.A-E gives a bar graph for concentrations of benzaldehyde and benzyl alcohol, methyl anthranilate, 1-hexanol, γ-decalactone and γ-undecalactone, and raspberry ketone present in each product assigned to that flavor category. A trace amount of benzaldeyde and γ-decalactone was detected in cherry Swisher Sweet cigarillo and peach Kool-Aid, respectively; this is not shown in the figure. The error bars give the standard deviation for 3 replicates. Serving size values are defined in appendix A, table A.4.1-A.4.5. In Figure 1.B methyl anthranilate levels represent 1 g of the approximately 7 g serving size of the Phillies Blunt.

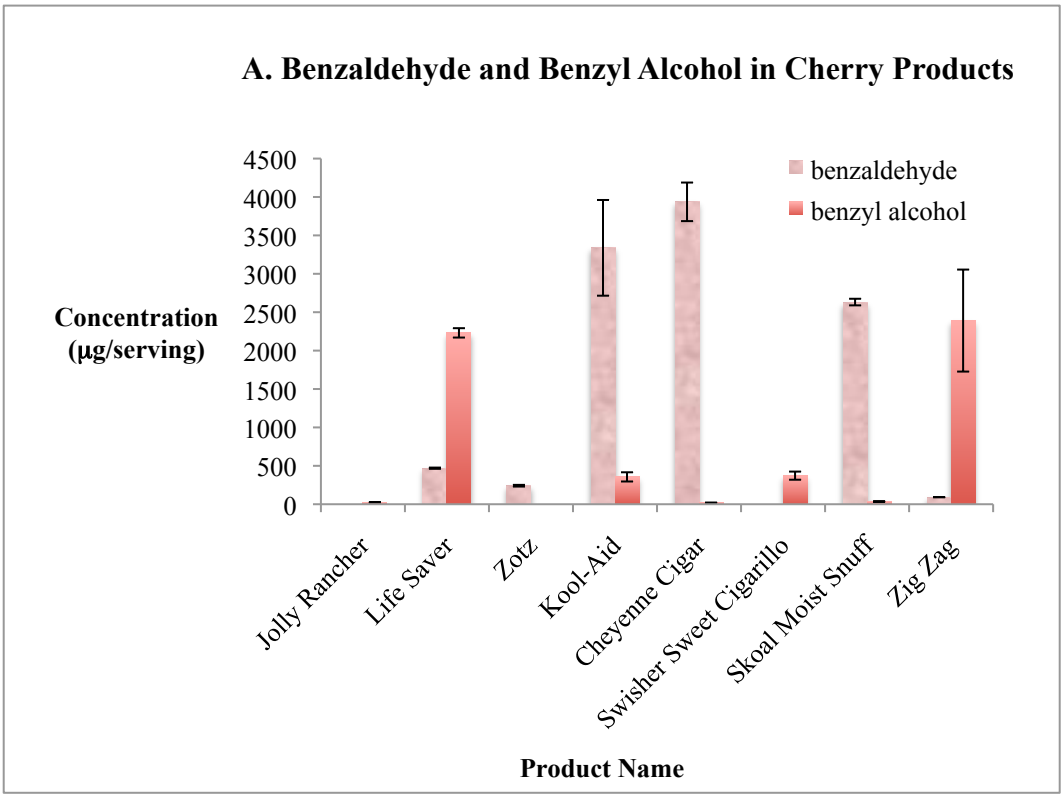
All cherry products contained benzaldehyde and or benzyl alcohol (Figure 1.A). The Jolly Rancher and Zotz had markedly less of these flavorants, with Jolly Rancher having the least. Kool-Aid and Zig Zag had the largest standard deviations in the figure. Similar levels of benzaldehyde were found in Cherry Kool-Aid, wild cherry Cheyenne cigars and cherry Skoal moist snuff at 3338 ± 623, 3937 ± 251, 2632 ± 43

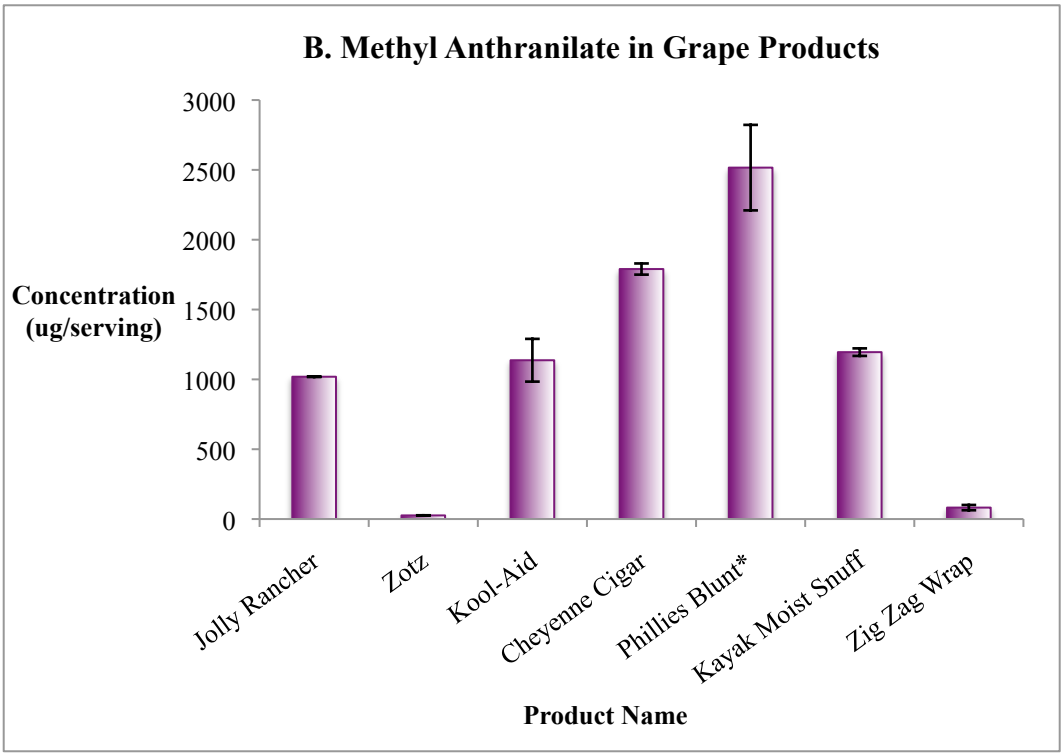
μg/unit, respectively. Cherry Life Savers had comparable levels of benzyl alcohol as cherry Zig Zag Wraps, at 2231 ± 61 μg/unit and 2391 ± 664 μg/unit. The flavorants p-tolualdehyde, p-anisaldehyde and piperonal were also observed in multiple products. Vanillin or ethyl vanillin were found in all cherry flavored samples except Life Saver, with higher levels in tobacco products. These vanilla flavorants were detected in all tobacco products, often at appreciable levels, but not in grape, apple or peach candy and Kool-Aid.

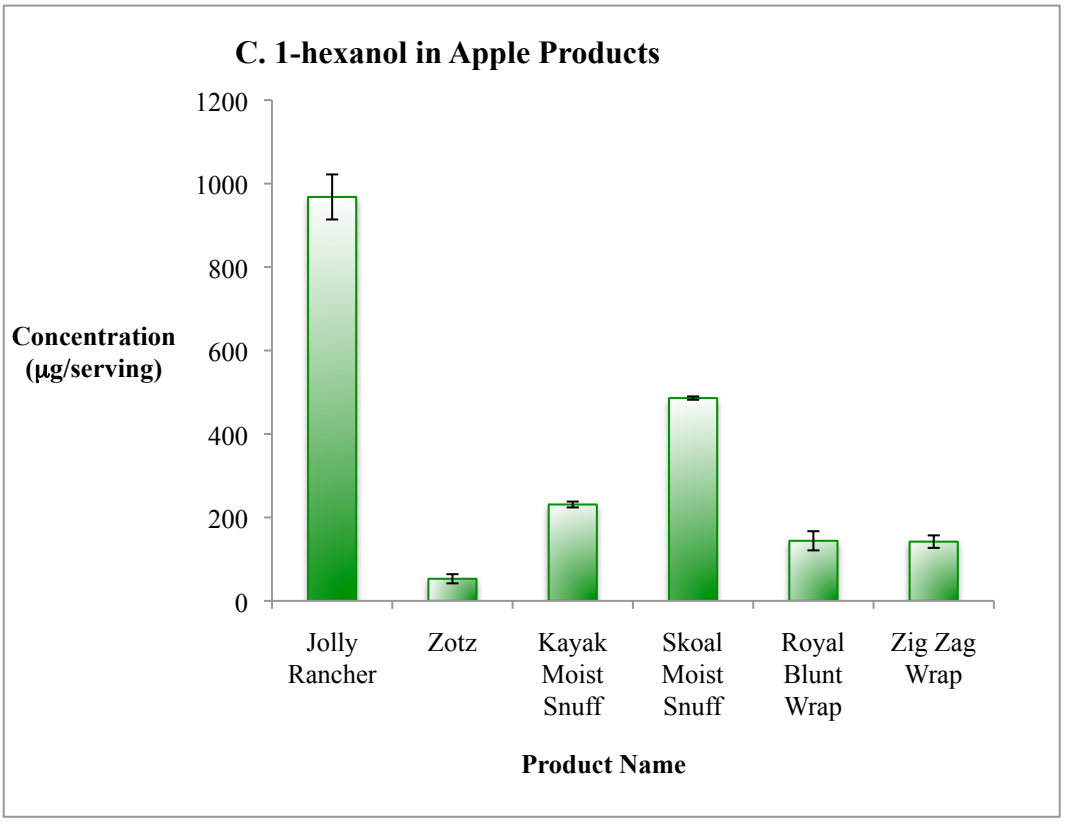
All products designated in the grape category contained methyl anthranilate (Figure 1.B), a common grape flavor compound. Grape Jolly Rancher, Kool-Aid, Cheyenne cigar, and Kayak moist snuff were found to have similar levels of methyl anthranilate, at 1019 ± 2, 1137 ± 153, 1790 ± 40, and 1195 ± 27 μg/unit respectively. The largest standard deviations corresponded to the Phillies Blunt and Kool-Aid. Ethyl butanoate was detected in most of the grape products.

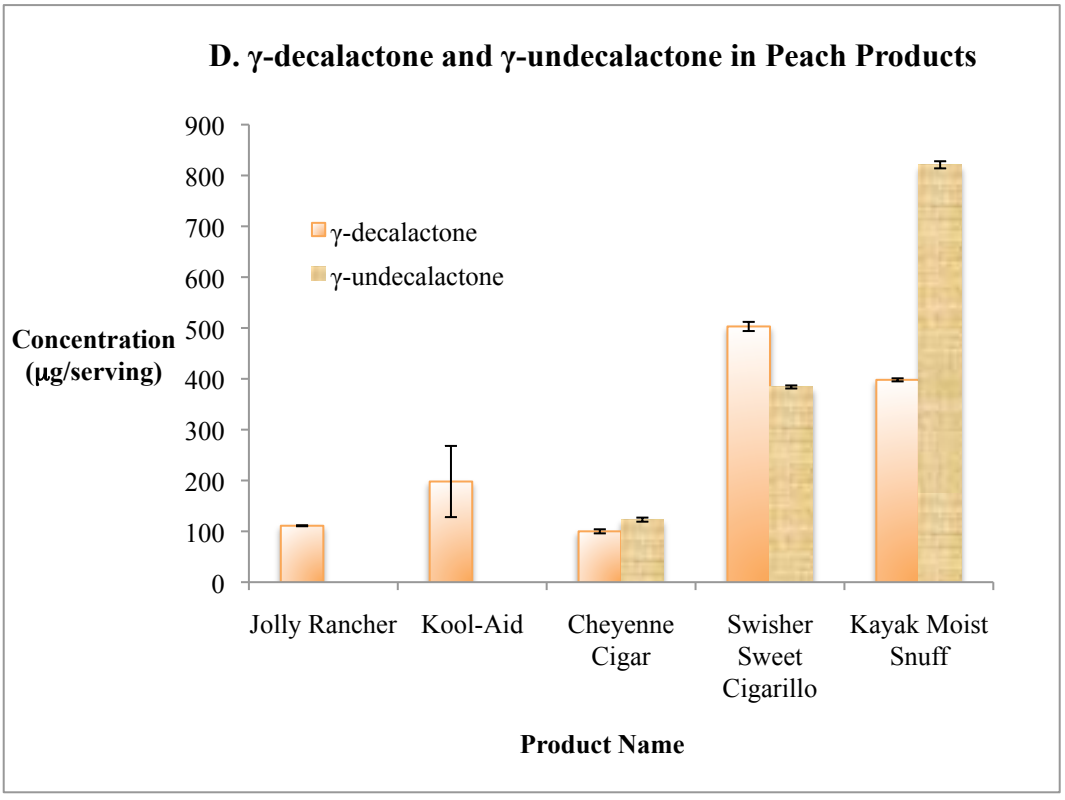
All apple products contained 1-hexanol (Figure 1.C) at 968 ± 54, 53 ± 11, 143 ± 3, 486 ± 4, 144 ± 23 and 142 ± 15 μg/unit in Jolly Rancher, Zotz, Kayak moist snuff, Skoal moist snuff, Royal Blunt Wraps XXL, and Zig Zag wrap, respectively. Every peach product analyzed contained γ-decalactone, benzaldehyde and benzyl alcohol benzaldehyde. The peach flavorant γ-undecalactone was found in all peach tobacco products and is shown in Figure 1.D along with γ-decalactone; Kool-Aid had the highest standard deviation. Raspberry ketone was measured in all berry products (Figure 1.E), with levels ranging from 123 ± 4 μg/unit in the raspberry Life Saver to 784 ± 39 μg/unit in berry blend Skoal snuff and with Kool-Aid again having the largest standard deviation for this compound.

Figure 2 provides a bar graph of total μg of flavorants per serving for each product, except the Phillies blunt. For Phillies blunt, the bar represents about 1/7th of the total mass of the unit in order to normalize portion sizes. A serving size was defined as 1 candy (Jolly Rancher, Life Saver, Zotz), 0.5-0.8 g of Kool-Aid powder (depending on flavor), 1 g of moist snuff (Skoal and Kayak), 1 cigar (Cheyenne, Swisher Sweet and Phillies Blunt), and 1 blunt wrap (Zig Zag and Royal Blunt). The highest total flavorants were detected in the large grape Phillies blunt (~35 mg/serving) with about 18 mg/serving of methyl anthranilate; however, the Phillies Blunt weighed between 2-5 times that of the other cigars. Cherry Skoal moist snuff had about 13 mg/serving and berry blend Skoal moist snuff about 11 mg/serving of total flavorants with methyl salicylate and or ethyl salicylate contributing to the bulk of the mass. About 11 mg/serving of total flavorants were found in raspberry lemonade Kool-Aid, with limonene contributing about 10 mg/serving. Berry, cherry and peach flavored Kool-Aid had more total flavorants than the candies, with levels similar to most tobacco products. Tobacco products assigned to the cherry, apple, peach and berry categories had greater total flavorant than the candies products within these designations.


A. Benzaldehyde and Benzyl Alcohol in Cherry Products
Concentration (µg/serving)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
benzaldehyde
benzyl alcohol
Jolly Rancher
Life Saver
Zotz
Kool-Aid
Cheyenne Cigar
Swisher Sweet Cigarillo
Skoal Moist Snuff
Zig Zag
Product Name


B. Methyl Anthranilate in Grape Products
Concentration (ug/serving)
3000
2500
2000
1500
1000
500
0
Jolly Rancher
Zotz
Kool-Aid
Cheyenne Cigar
Phillies Blunt*
Kayak Moist Snuff
Zig Zag Wrap
Product Name


C. 1-hexanol in Apple Products
Concentration (µg/serving)
1200
1000
800
600
400
200
0
Jolly Rancher
Zotz
Kayak Moist Snuff
Skoal Moist Snuff
Royal Blunt Wrap
Zig Zag Wrap
Product Name


D. γ-decalactone and γ-undecalactone in Peach Products
Concentration (µg/serving)
900
800
700
600
500
400
300
200
100
0
γ-decalactone
γ-undecalactone
Jolly Rancher
Kool-Aid
Cheyenne Cigar
Swisher Sweet Cigarillo
Kayak Moist Snuff
Product Name

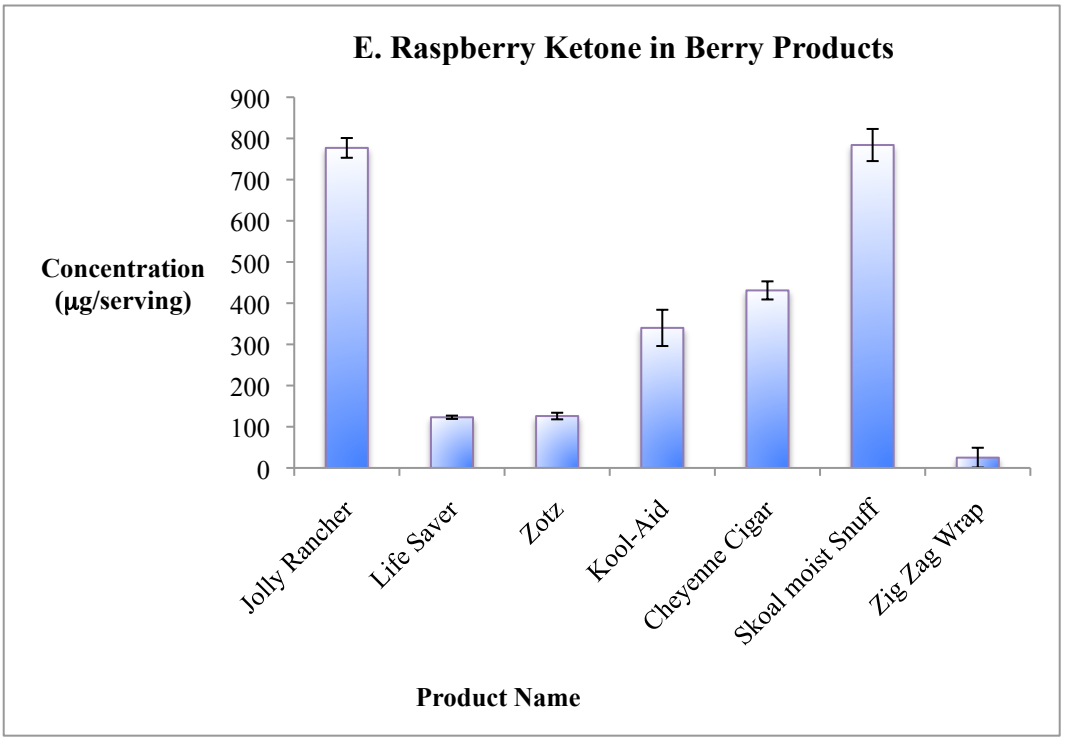


Figure 1.A-E. Bar graphs of the mass of benzaldehyde and benzyl alcohol, methyl anthranilate, 1-hexanol, γ-decalactone and γ-undecalactone, and raspberry ketone found per serving in each product assigned to the cherry, grape, apple, peach and berry flavor categories. Trace amounts were not plotted. The error bars give the standard deviation for 3 replicates. See Appendix A, tables A.4.1-A.4.5, for serving size definitions.
*In Figure 1.B flavorant levels represent 1 g of the approximately 7 g Phillies Blunt.

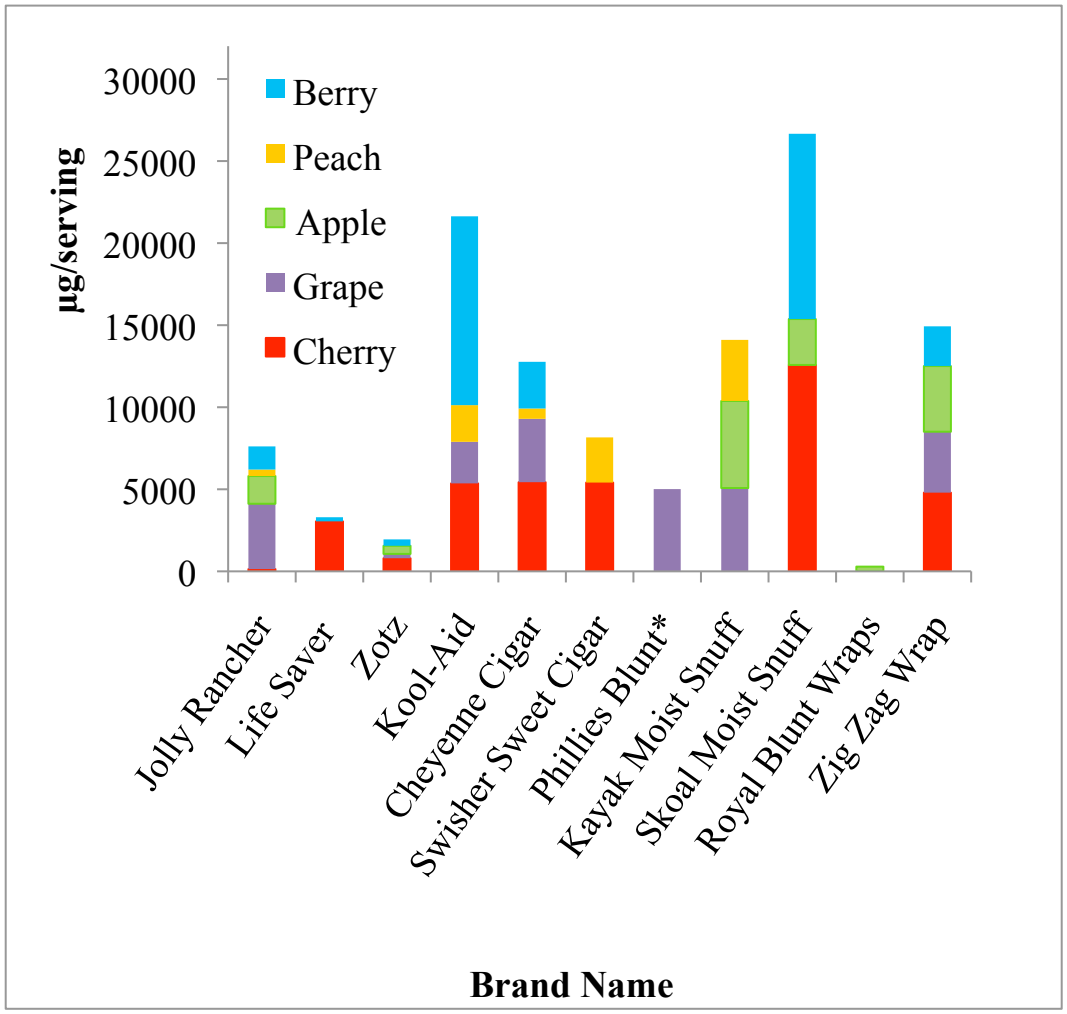


Figure 2. A bar graph of total µg of flavorants per serving for each product tested. Trace levels were not included in the total flavorant calculations. See Appendix A, tables A.4.1-A.4.5, for serving size definitions.
* Total flavorant levels represent 1 g of the approximately 7 g Phillies Blunt.

1.4. Discussion

Table A.2 gives the average of the relative standard deviation (RSD) of each above trace compound (generated by analysis of three replicates) detected in a sample, along with the range of RSD. Above trace compounds were found at ≥0.3 ng/μL in solution. With the exception of the Phillies Blunt, apple Zotz and raspberry Jolly Rancher, all cigars and candies had a low average RSD of <15% with most <10%. Cherry and peach-mango Kool-Aid, grape Phillies Blunt and all blunt wraps had higher average RSDs (>15%) than the other samples.

Reproducibility appears to be dependent on homogeneity within and between each product, and seems to vary between brands. The high RSD values for the Kool-Aid products indicate uneven flavorant distribution throughout the powder; only a portion of the powder within each packet was analyzed. A 1 g cylinder was removed from the Phillies Blunt (~7 g) for analysis, and the high average RSD may have resulted from lack of within sample homogeneity. The average RSD for moist snuff was generally much lower even though the analyses involved measurement of 1 g of snuff from each can, indicating a greater within sample homogeneity for moist snuff than Kool-Aid and Phillies Blunt. For the candies, blunt wraps and cigars, the entire unit was analyzed. The high average RSD for blunt wraps may have therefore been a result of lack of consistency of the flavor application between each product.

Compounds detected in tobacco at trace or low levels (roughly <5 μg/g) may be naturally occurring. The "CRP2" reference tobacco was found to have low levels of several analytes. GC/MS analysis of flue-cured tobacco measured 0.17 μg/g of benzyl

alcohol (Wu et al. 2013), along with other compounds not included in our target analyte list.

The levels of flavorants found in moist snuff tobacco products are similar in magnitude to that found in a study of mint smokeless tobacco products where menthone, menthol, ethyl salicylate, menthyl acetate, carvone and limonene were detected at levels ranging between 170 and 4140 μg/g (Chen et al. 2010). A recent study also used MTBE to extract 10 analytes including ethyl salicylate, methyl salicylate, L-menthol and eugenol from U.S. cigar filler and snuff products, Southeast Asian products and clove cigarette fillers; comparable levels were found and the authors noted the identification of benzaldehyde and piperonal in a wild cherry cigar filler (Lisko, Stanfill, and Watson 2014).

Some have raised concerns regarding toxicity associated with flavor additives (Chen et al. 2010; Lisko, Stanfill and Watson 2014). The chemistry of flavorant compounds and nicotine is largely unknown, along with the health risks of consuming large quantities of flavorants via smoking and chewing tobacco. Research investigating the effect of tobacco additives on toxicity is limited and often sponsored by the tobacco industry. Several tobacco industry studies on additives including flavor compounds concluded that toxicity was unaffected (Carmines 2002; Gaworski et al. 2011; Coggins et al. 2011). The 2002 study by Carmines concluded that 333 additives, including flavorants, did not increase the toxicity of cigarettes. A subsequent analysis of Carmines data found increased total particulate matter and levels of toxins with the introduction of additives; the authors argue "industry scientific research on the use of cigarette additives cannot be taken at face value" (Wertz et al. 2011). More studies are

needed to fully understand the effect of additives, including flavor chemicals, on toxicity.

There are several limitations to this study. A more complete analysis should include limits of detection and quantitation, but this was not feasible due to the number of analytes. Reproducibility increases with more replicates, but this requires a significant amount of resources and labor. Ideally the internal and surrogate standards would better correspond to the structure of the analytes, but the complexity of the samples made finding a more representative standard difficult.

1. 5. Conclusions

Significant compositional overlap was found between flavored tobacco products and Jolly Ranchers, Life Savers, Zotz and Kool-Aid. The results of this study indicate that "candy-flavored tobacco" is a chemically valid designation. Many of the compounds listed in Table A.3 are included in the flavorant compilation in Burdock (2009) with some entries including "usual" and "maximum" levels in hard candy, soft candy and or non-alcoholic beverages. Toxicological concerns regarding flavorant additives should be addressed. Further areas for research include the characterization and quantification the constituents of novel products such as electronic cigarettes, toxicological assessment of flavorant additives, and their impact on youth tobacco users.

2. HCA Analysis

2.1. Introduction

2.1.1. The Environmental Relevance of VBOCs

Many flavorants, such as p-cymene, linalool, limonene, β-myrcene, α-pinene, and γ-terpinene, are also volatilizable biogenic organic compounds (VBOCs). Plants emit an estimated 1100 $TgCyr^{-1}$ of VBOCs into the atmosphere, a mass 7 to 10 times that of anthropogenic emissions (Muller 1992; Piccot, Watson, and Jones 1992; Guenther et al. 1995). VBOCs have been defined based on vapor pressure comprising non-methane volatile organic compounds (VOCs) with vapor pressure $\geq 10^{-4}$ atm and semivolatile organic compounds (SVOCs) with vapor pressure between 10^{-4}-10^{-11} atm included due to evidence of SVOC contribution to particulate matter formation (Pankow et al. 2012). An important classification within the VBOC group includes the terpenes. The hemiterpene isoprene (C_5H_8), comprises about half of the annual VBOC emissions, with estimates ranging between 500 and 560 $TgCyr^{-1}$ (A. Guenther et al. 2006; Wang and Shallcross 2000; Muller 1992) and functions to protect leaves from rapid temperature changes due to sunlight and reactive oxidation species (Sharkey, Wiberley, and Donohue 2007). Monoterpenes ($C_{10}H_{16}$) such as α-pinene, β-pinene, sabinene and limonene have been estimated to comprise 40-80% of non-isoprene terpene emissions (Kanakidou et al. 2005; Pankow et al. 2001). Sesquiterpenes ($C_{15}H_{24}$) and oxygenated or hydrogenated terpenes are also environmentally significant.

A more comprehensive understanding of the identities and properties of volatilizable biogenic organic compounds (VBOCs) would support air quality and climate change research and management (Porter et al. 2012; Guenther 2002). VBOCs react with nitrogen oxides (NO_x) to form ozone in the presence and sunlight. The oxidation and subsequent condensation of VBOCs yields secondary organic aerosol (SOA), a contributor to particulate matter (PM) (Amin, Hatfield, and Huff Hartz 2013; Claeys et al. 2004; Creasey, Heard, and Lee 2001; Pankow et al. 2001). Kanakidou et al. (2005) estimated that biogenic VOCs account for 9–50 $TgCyr^{-1}$of SOA produced assuming an organic matter to organic carbon ratio of 1:4.

Ozone and PM are the two criteria pollutants of greatest concern in the U.S. due to nonattainment of the National Ambient Air Quality Standards (NAAQS); about 40% of the U.S. population resided in counties exceeding NAAQS for PM and or ozone in 2010 (US EPA 2011). Tropospheric or ground level ozone is known to reduce lung function, cause respiratory symptoms, aggravate lung diseases and increase the risk of premature mortality; PM exposure has been shown to cause heart and lung disease aggravation and development as well as premature mortality (US EPA 2011).

Tropospheric ozone harms vegetation, can reduce CO_2 uptake by plants (US EPA 2011; Stocker et al. 2014) and is radiatively active as a greenhouse gas (Stocker et al. 2014). VBOCs have been shown to impact hydroxyl radical concentrations which may subsequently affect the lifetime of methane, a potent greenhouse gas (Collins et al. 2002; Hofzumahaus et al. 2009; Lelieveld, Crutzen, and Dentener 1998). The emission of VBOCs is a significant source of carbon entering the

atmosphere, affecting carbon cycling and calculations of carbon fluxes (Alex Guenther 2002). PM reduces visibility through scattering and absorption of solar radiation and it plays a largely uncertain role in radiative forcing (a measure of the solar radiation energy budget) through cloud nucleation and aerosol radiation interactions (Stocker et al. 2014; Schulz et al. 2006; Hansen and Sato 2001).

2.1.2. VBOC Uncertainty

Despite their abundance and importance, biogenic emissions and their atmospheric reaction products are extremely complex and largely uncharacterized. These uncertainties are demonstrated by GCxGC/TOFMS analysis of the emissions of two tree species resulting in thousands of VBOC peaks for which a large percentage remained unidentified; the authors argue that the total annual mass of VBOC emissions as well as the importance of unidentified compounds is an area of substantial uncertainty and that even studies measuring a relatively large number of VBOCs find that "the measured fluxes and atmospheric concentrations do not appear to account for total VBOC mass emissions" (Pankow et al. 2012). Researchers involved in atmospheric modeling indicate a need for more information regarding biogenic SOA precursors for modeling efforts (Guenther et al. 2012; Carlton et al. 2010; Aiyyer et al. 2007). Kanakidou et al. (2005) cite sources of uncertainties stemming from lack of understanding of specific emission factors by species and environmental conditions, and that the understanding of emissions of SOA precursors, such as sesquiterpenes, is unsatisfactory.

The compositional complexity captured by GCxGC/TOFMS poses data processing challenges (Roskamp 2013) and hinders pattern recognition. Cluster analysis is an unsupervised multivariate method that employs similarity measures to group variables together (Pérez Pastor, García Alonso, and Quejido Cabezas 2002). Agglomerative hierarchical cluster analysis (HCA) has been used to determine PM_{10} sources in Kathmandu Valley, Nepal (Giri et al. 2007) and aerosol sources in Mexico City (Miranda et al. 2004). The PINOT NOIR data analysis portion of this work uses HCA to group the data into clusters thereby making the data more manageable.

2.2. Methods

2.2.1. Data Description

This work employed HCA of data generated by M. Roskamp from air samples she collected during the Particle Investigations at a Northern Ozarks Tower: NO_x, Oxidant, Isoprene Research (PINOT NOIR) study. The ambient samples were collected on adsorption/thermal desorption (ATD) cartridges within the tree canopy during an "extreme drought" period, purged with 500 mL of dry ultra-pure helium to remove moisture and shipped to and stored at PSU. More information regarding the site, sampling and instrumentation procedures can be found in Roskamp (2013).

Roskamp's data processing yielded compounds identified in each sample and their corresponding concentrations. Samples were run using two-dimensional gas chromatography time of flight mass spectrometry (GCxGC/TOFMS) and the concentration for compounds of interest were calculated using standard response factors. The data was generated from 13 samples collected between July 29th and August 3rd, 2012. Table B.1 provides the file name, date, time and temperature and relative humidity measurements taken at the time of collection. In the case of duplicate samples, that with the highest number of compounds detected was selected for this analysis. The first and second column retention times were calculated as Kovats Retention Index Value (*I*) and Second Dimension Retention Ratio (*R*) as described by Pankow et al. (2012). In summary, the data included concentration as well as I and R values for compounds detected in 13 samples analyzed by GCxGC/TOFMS and collected in the northern Ozarks.

2.2.2. Procedure

The data was first formatted into a matrix. The *I* and *R* values were reduced into a one-dimensional combined retention time (RT_c) for ease of formatting the matrix and plotting results using:

$$RT_c = I + 0.1R \qquad \text{Equation 5.}$$

Constituents with the same *I* value and the same name were grouped as one compound; those with the same RT_c but a different identification were combined if they did not occur in the same sample simultaneously.

Agglomerative hierarchical clustering was selected as the best clustering method for the data in MATLAB. The spearman distance, average linkage and cophenetic correlation were all calculated in MATLAB (2014a). Appendix C provides the code used for the analysis. The pdist function produces a dissimilarity matrix (*Y*) by calculating the pairwise distance between pairs of objects. The Spearman distance grouped data more appropriately than Euclidean, Seuclidean, Mahalanobis, Minoski, correlation (Pearson) or Hamming metrics. The Spearman distance measures the strength of the monotonic relationship between paired data. It was calculated by using (MATLAB 2014a):

$$d_{st} = 1 - \frac{(r_s - \bar{r}_s)(r_t - \bar{r}_t)'}{\sqrt{(r_s - \bar{r}_s)(r_s - \bar{r}_s)'}\sqrt{(r_t - \bar{r}_t)(r_t - \bar{r}_t)'}} \qquad \text{Equation 6.}$$

Where r_s and r_t are the rank vectors of x_s and $x_{t,}$ and where

$$\bar{r}_s = \frac{1}{n}\sum_j r_{sj} = \frac{(n+1)}{2} \qquad \text{and} \qquad \bar{r}_t = \frac{1}{n}\sum_j r_{tj} = \frac{(n+1)}{2}$$

Where r_{sj} is the rank of x_{sj} taken over $x_{1j}, x_{2j}, \ldots.., x_{nj}$ and is computed by MATLAB's tiedrank function.

The linkage function in MATLAB yields matrix Z and represents the dendrogram based on the dissimilarity matrix calculated by pdist. Methods available for the Spearman distance were average, complete, single and weighted average linkages. Average linkage generated the highest cophenetic correlation of 0.79972 and was calculated using (MATLAB 2014a):

$$d_{(r,s)} = \frac{1}{n_r n_s} \sum_{i=1}^{n_r} \sum_{j=1}^{n_s} \text{dist}(x_{ri}, x_{sj}) \qquad \text{Equation 7.}$$

Where $d_{(r,s)}$ is the distance between clustered objects, $d(x_{ri}, x_{sj})$ is the distance between objects, and n_r and n_s are the number of objects in clusters r and s, respectively.

Cophenetic correlation (c) describes the degree of agreement between the dendrogram and dissimilarity produced by linkage and pdist, respectively. It was calculated using (MATLAB 2014a):

$$c = \frac{\sum_{i<j} (Y_{ij} - y)(Z_{ij} - z)}{\sqrt{\sum_{i<j} (Y_{ij} - y)^2 \sum_{i<j} (Z_{ij} - z)^2}} \qquad \text{Equation 8.}$$

Y_{ij} is the distance between objects i and j in Y, Z_{ij} is the cophenetic distance between objects i and j in Z, and y and z are the average of Y and Z, respectively.

The optimal number of clusters was determined by close examination of cluster solutions between 10 and 50 in an Excel spreadsheet. Once an appropriate range of possible solutions was narrowed down, the changes in compound assignment with progressively increasing clusters were carefully tracked. The maximum number of clusters was found when this writer deemed the movement of one or more

compounds to its own cluster (in this case sabinene and β-myrcene moving out of cluster 14) as unnecessary. Cluster validation options, such as Calinski-Harabasz, Davies-Bouldin, Gap and Silhouette criterion and the evalcluster function, were explored in MATLAB, but did not support the Spearman distance.

2.3. HCA Results

2.3.1. HCA Solution

27 clusters yielded an acceptable balance of data consolidation and similarity of temporal trends. In each cluster, there are between 1-39 distinct compounds appearing in 1-13 samples and having 1-91 entries, defined as a compound specific to a sample (Table B.2). Figure 3 is a color-coded dendrogram and presents the HCA solution of 27 clusters. The dendrogram was cut at an average linkage distance of about 0.4. Most clusters fall in between 0.2-0.4 (dashed line). The black branches connecting clusters give the distance between clusters, which range from approximately 0.42-1.11.

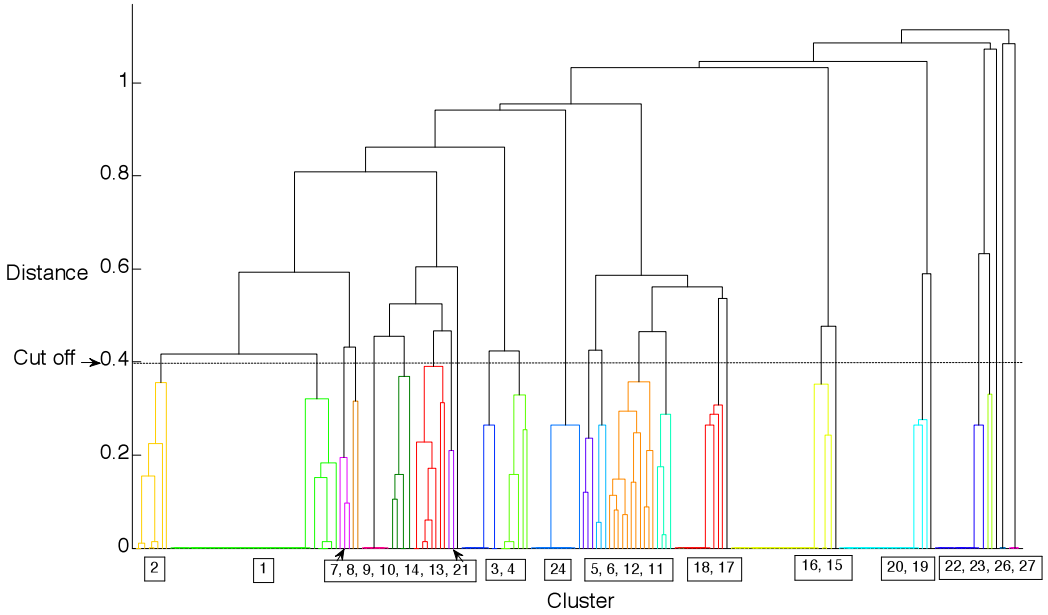


Figure 3. The dendrogram of 27 cluster solutions generated from HCA. Each cluster is separated by color and labeled. Black lines give the distance between each cluster. Individual compounds are embedded within each cluster. The dashed line gives the cut off distance used to generate the 27 clusters.

2.3.2. Cluster Types

To facilitate analysis, clusters were classified as type I, II, III or IV (see Figure 4.A-D). Each ordered pair represents a compound found in a sample; marker shape and color correspond to its assigned cluster. Table B.3 provides information pertaining to each cluster, including date, time of day, temperature and relative humidity. The identification and retention times of compounds in each cluster are shown in Table B.4.1-B.4.4.

Clusters 1, 3, 9, 16, 18, 20, 22, 24, 25, 26 and 27 have been identified as Type 1. As shown in Figure 4.A, most of the 11 type I clusters generally contain a wide range of individual compounds predominantly detected in only one sample. For example, the majority of compounds detected in cluster 1, 16 and 20 correspond to the sample collected on 7/31/12 at 4:30 PM, 7/30/12 at 2 PM and 7/31/12 at 2:30 PM, respectively. The standard deviation of the temperature and relative humidity averages for type I clusters are low, ranging from between ± 0.0-2.3 and 0.0-7.4, respectively. Compounds included in type I clusters had relatively low concentrations in contrast to the other cluster types, with the bulk measured at <1 μg m^{-3}, and the maximum at 2.8 μg m^{-3}. Compounds assigned to type I clusters include 1-decene (at two retention times), 2-methyl-2-butenal, 2,6-dimethyl-1-octene (at three retention times), at least 5 acid species, sabinene, terpinolene, undecanal, undecane, β-phellandrene and 10 unknown compounds. Cluster 25 contains only entry, a compound identified as 4,8-dimethyl-1,7-nonadien-4-ol and detected on 8/2/12 at 11:10 AM. Clusters 26 and 27 have 2 and 3 entries, respectively; all are distinct compounds. About 70% of the 204 compounds used in this analysis were assigned to the type I clusters; about 41% were

assigned to clusters 1, 16 and 20. All compounds found in type I clusters, including ones not listed here, are presented in Table B.4.1.

As shown in Table B.4.2, type II clusters (15, 17, 19 and 21) contain just one compound; all were found in ≥4 samples. Thus, as compared with type I clusters, type II clusters occupy a narrower range of RT (less compound diversity), but a wider range of sample numbers (Figure 4.B). Cluster 15 contains β-pinene, detected in samples collected on 7/29/12 at 2:00 PM and 4:30 PM, 7/30/12 at 2:00 PM and 7/31/12 at 2:30 PM. Trans-3-decene, α-thujene and 1,4-dimethyl cyclooctane (RT_c=1083.080056) were the identifications of the other three compounds isolated into their own clusters, respectively. Note that 1,4-dimethyl cyclooctane was identified at two other RT_cs, including 1571.0818 and 1551.0806; this compound likely was misidentified as it should only comprise two cis and trans isomers. As visualized by dendrogram presented in Figure 3, the distance of these 4 compounds to any other compound calculated by linkage was greater than 0.4. Compounds falling into type II clusters have an average concentration range of 0.08-2.60 $\mu g\ m^{-3}$.

Figure 4.C corresponds to type III clusters (2, 4, 7, 8, 10, 11, 13, 14 and 23). The number of compounds assigned to each cluster ranges from 2-8, all of which were detected in ≥2 but not all (<13) samples. For example, of the 8 compounds assigned to cluster 2, all were detected on 7/31/12 at 2:30 PM and 4:30 PM, with a few detected in 5 other samples. Compounds in this type include 2-decenol, 2-ethylhexyl salicylate, 3-carene, α-cedrene, decanal, dodecyl acrylate, geranyl acetone, homosalate, longifolene, sabinene (this compound was also identified at a different retention time

in a Type I cluster), thujospene, Z-ocimene, and β-myrcene. Type III clusters range in concentration from 0.03-25.5 μg m^{-3}.

Type IV clusters (5, 6 and 12) include one or more compounds detected in every sample, as depicted visually in figure 4.D. This cluster type comprised 8% of the compounds. Isoprene was grouped into cluster 5 with 3-methylene nonane and methyl 4,6-decadienyl ether. Cluster 6 contained methacrolein with methyl vinyl ketone and 3-methylheptal acetate. Limonene, p-cymene and α-pinene were detected in all samples and included in cluster 12 with 8 other compounds. The concentration of compounds in type IV clusters ranged from 0.02-92.05 μg m^{-3}, with isoprene, methacrolein and methyl vinyl ketone contributing to the bulk of the mass.

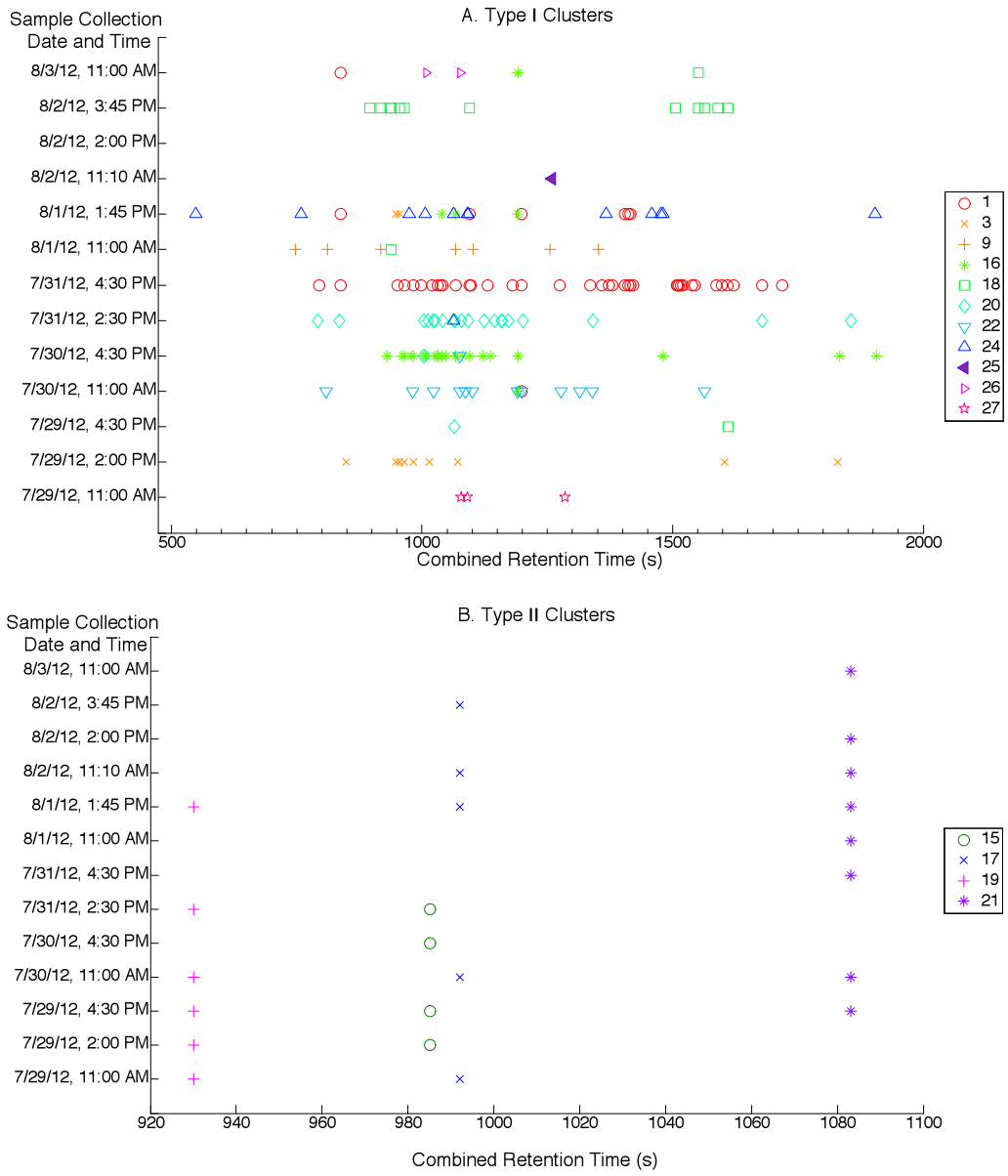


Figure 4. A-B. Figure 4 plots distinct compounds as defined by their combined retention time against the sample collection date and time. Figure 4.A. Clusters are distinguished by marker style and color. For most clusters, Figure 4.A and 4.B depict compound and sample diversity, respectively.

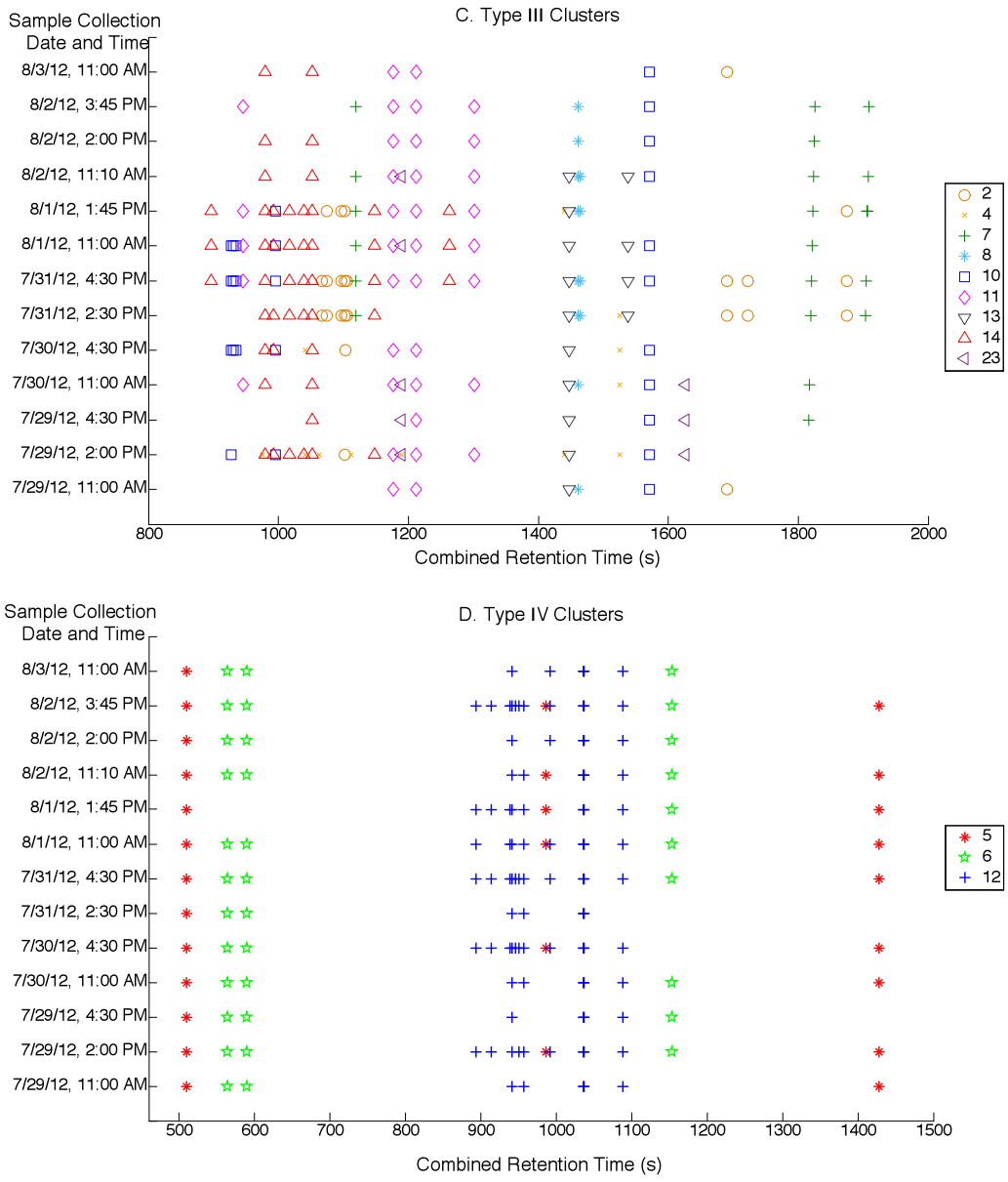


Figure 4.C-D. Figure 4.C show all compounds assigned to type III clusters. All compounds in these clusters were detected in more than one sample. Figure 4.D. includes type IV clusters, in which there was at least one compound entry in every sample.

2.4. Discussion

2.4.1 Cluster validation

The efficacy of the Spearman distance is depicted in Figure 5.A-B, where the sample versus concentration for compounds assigned to cluster 6 and 12 is plotted, respectively. The Spearman metric has captured temporal behavior; unlike the Euclidean distance, it is not sensitive to magnitude of concentration. The compounds in cluster 6 merge at an average linkage distance of about 0.27. Cluster 12 exhibits a higher distance between compounds, at approximately 0.36. Figure 5.B shows the effect of this distance graphically, and the compounds appear to be less correlated than those assigned to cluster 6. To generate clusters with greater similarity the distance criteria could be increased, but many more clusters would result. The challenge of cluster analysis is in finding the right balance of consolidation of data into as few clusters as possible while maintaining reasonable similarity between the clusters. Cluster validation options in MATLAB were explored, but functions such as evalcluster did not support the Spearman distance. Further work should utilize code or another program to validate cluster solutions.

Figure 5.A provides a plot of temperature on a second y-axis. Because the sampling occurred between 11:00 AM and 4:30 PM temperature remained fairly stable and the correlation between cluster 6 compound concentration and temperature was low. Sharp increases in concentration of most of the compounds shown in Figure 5A-B occurred on 8/1/12 and 8/2/12 at 11:00 AM and 3:45 PM; this also occurred for isoprene (not shown). The high concentration samples may have been a result of an

error; analysis of the duplicate sample taken on 8/2/12 3:45 PM yielded significantly lower concentrations. The incorporation of more samples, as well as their duplicates, would make the results more robust.

The discovery of four cluster types demonstrates the pattern recognizing power of HCA. The separation of those compounds emerging primarily in one sample from those that were detected in multiple samples provides information regarding which compounds were consistently present during the sampling time and which appeared likely result of some combination of environmental factors. The assignment of clusters to certain types allowed for dimension and noise reduction, and provided an opportunity to assess environmental effects on chemistry

A significant finding was that almost 30% of the compounds were designated to cluster 1 and 20, both type I clusters. Cluster 1 and 20 capture compounds primarily emerging on 7/31/12 at 4:30 PM and 2:30 PM, respectively. According to EPA data collected by Chris Geron (2012), wind direction was predominantly northeast and east-northeast on 7/31/12 (Figure 6.B) and on this day the highest temperature, lowest relative humidity, and lowest average wind speed (Figure 7) were recorded. Note that data was not collected on 7/30/12. Ashland is located 10 km east of the site (Roskamp 2013), and it is possible that anthropogenic sources of pollution were a contributing factor to the unique species observed on 7/31/12. At least 5 compounds containing benzene rings were present in cluster 1 and 20. The stagnant air, high temperature and low relative humidity likely contributed to the emergence of these compounds, most found only on 7/31/12, and was likely responsible for the highest measured

concentrations of the sunscreen compounds homosalate and 2-ethylhexyl salicylate (cluster 7).

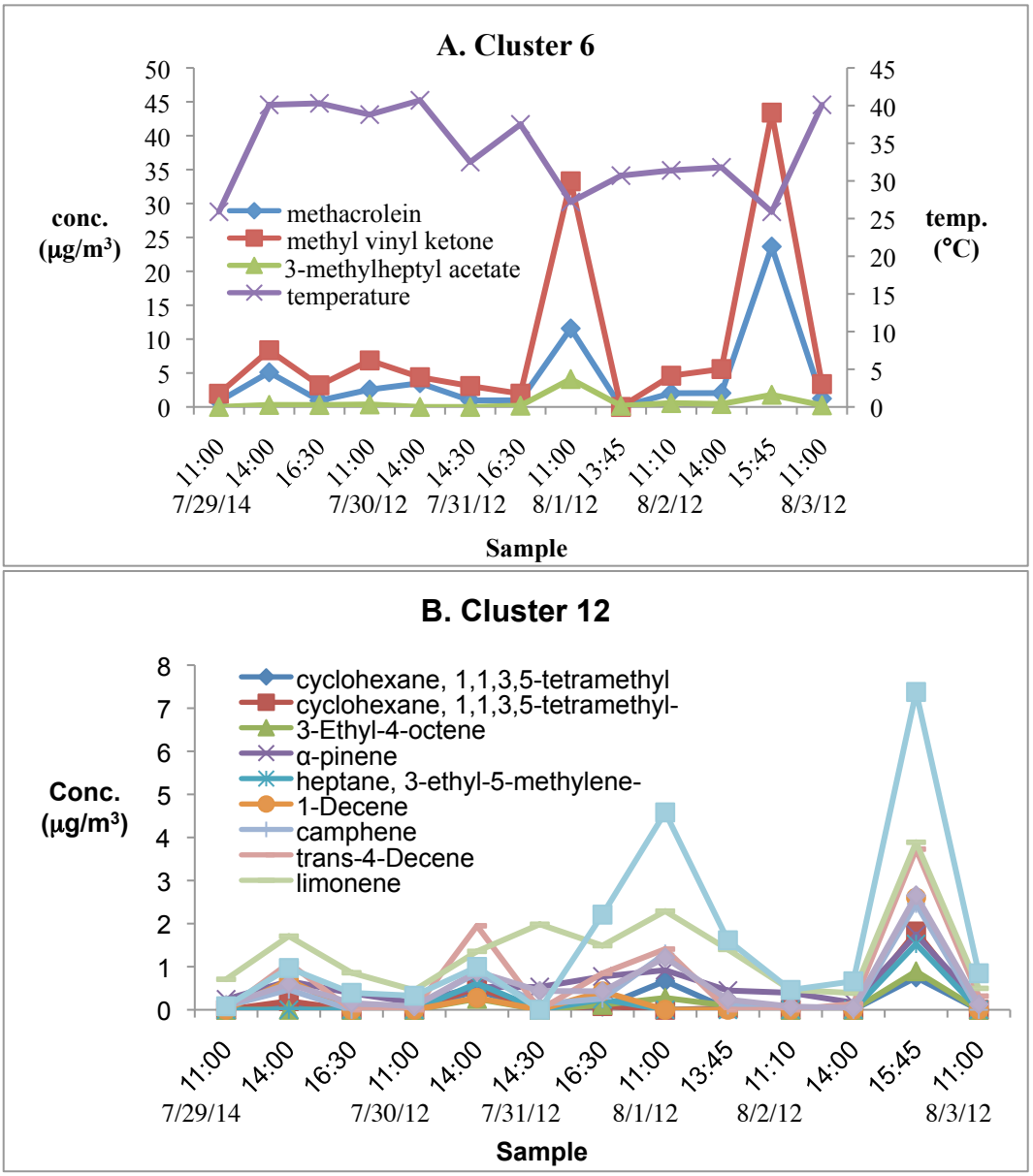


Figure 5.A-B. This figure shows how the spearman correlation was used to group variables. For Figure 5.A., the greatest distance of compounds is less than 0.3 in cluster 6 and the three compounds appear to be increasing and decreasing in a similar fashion. Temperature is also included, and was not well correlated with sample concentration. In Figure 5.B, the increased distance of just under 0.4 between some compounds in cluster 12 shows less agreement between compounds.

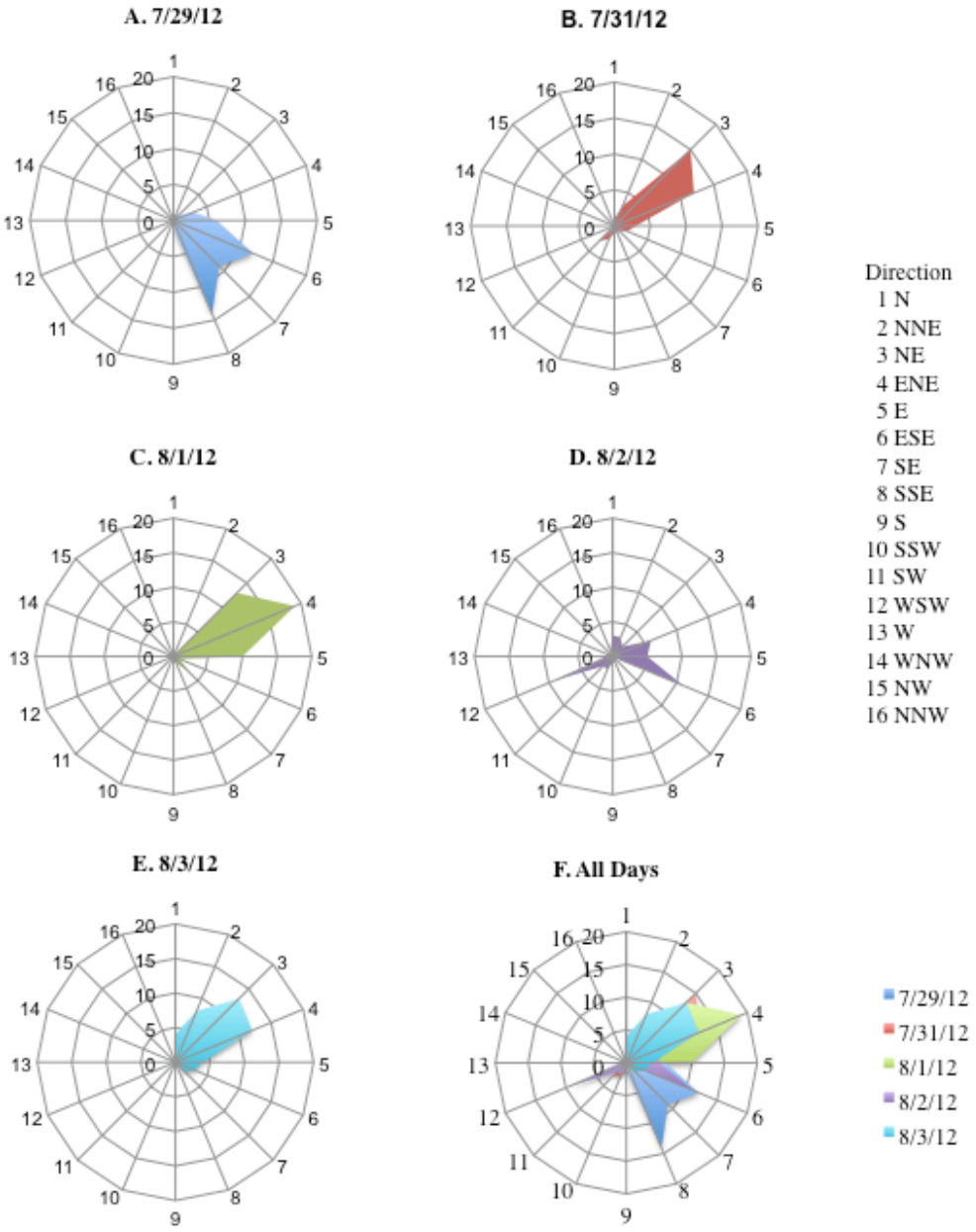


Figure 6.A-F. Site specific wind direction. Direction labels given by key on the right. Data was not available for 7/30/12.

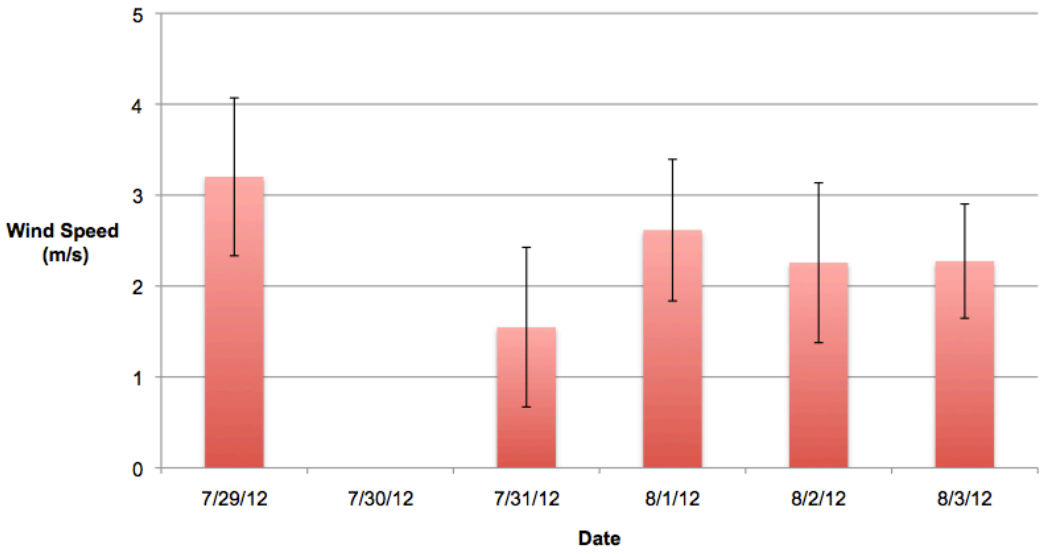


Figure 7. A bar graph of average wind speed data for each day. Data was not available for 7/30/12. The error bars give the standard deviation for each average.

2.5. HCA conclusions

HCA reduced 204 compounds in 13 samples to 27 clusters that describe temporal behavior of one or more compounds, demonstrating the usefulness of HCA in consolidating large amounts of data. Cluster analysis is sometimes paired with other statistical techniques such as principal component analysis (PCA) (Heringa et al. 2012; Saucy, Anderson, and Buseck 1991). For example, Saucy, Anderson, and Busbck (1991) wrote "PCA of such a data set can yield information about the temporal behavior of the particle types that were previously identified by cluster analysis". PCA requires more observations (samples) than variables (compounds) and could be used to understand how environmental variables such as relative humidity, temperature and anthropogenic sources of pollution contribute to cluster behavior.

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4. Appendix A. Flavorant Analysis Tables

4.1. Prevalence of Use and Sales of Tobacco Products

Table A.1. Recent U.S. Statistics for Cigars and Moist Snuff for Prevalence of Use and Sales. ("Use" defined as "having used once in the last 30 days" at time of survey; "Sales" defined as number of sticks or units; "Unit" defined as one tin or container).

Period	Category	% Sales	% Flavored	% Use Prevalence	Reference
"Large Cigars" and "Small Cigars"					
2008 to 2011	"small cigars" "large cigars"	-76%[a] +49%[b]			a.
2001 to 2008	"small cigars" "large cigars"	+145%[c] +36%[d]			
2011	ages 18+ ages 18-25 years ages 26+			5.2 10.9 4.2	b.
2009→ 2011	Afr. Am. male H.S. students			7.1→11.7	c.
2011	male H.S. students female H.S. students all H.S. students			15.7 7.4 11.6	
Smokeless Products					
2005→ 2011	flavored moist snuff moist snuff (including snus) pouched moist snuff pouched moist snuff long cut moist snuff fine cut moist snuff	+72%[e] +66%[f] +334%[g]	 73.0 65.8 23.9		d.
2011	ages 26+ ages 18+ ages 18-25 years			3.0 3.3 5.4	b.
2011	H.S. students male H.S students female H.S. students			7.3 12.9 1.6	c.

[a]3.35B → 0 .8B; [b]6.88B → 10.27B; [c]2.18B → 5.34B; [d]3.50B → 2.76B;
[e]329.4M → 567.4M; [f]610.6M → 1011.4M; and [g]33.6M → 146.7M.

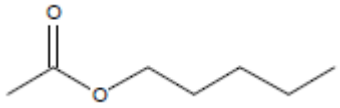
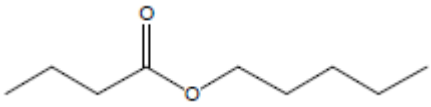
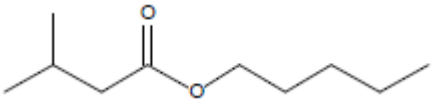
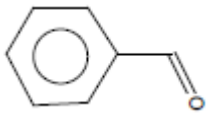
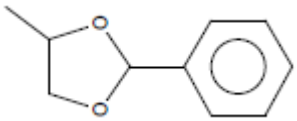
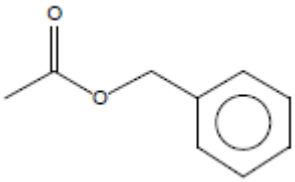
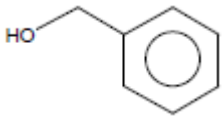
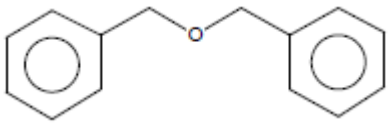
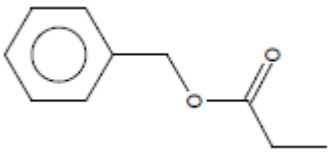
a. Government Accountability Office (2012)
b. Substance Abuse & Mental Health Services Administration (2012)
c. Center for Disease Control (2012b)
d. Delnevo et al. (2012)

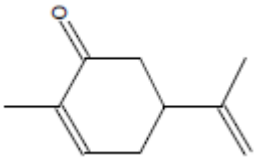
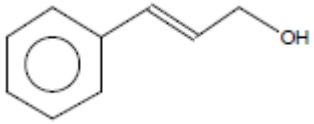
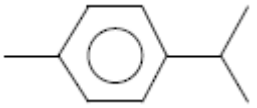
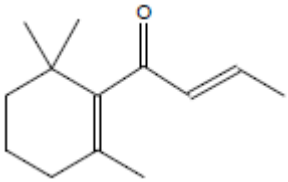
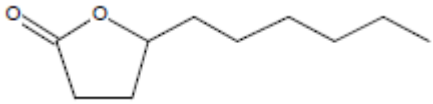
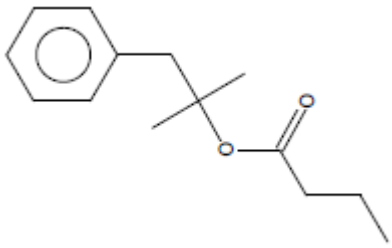
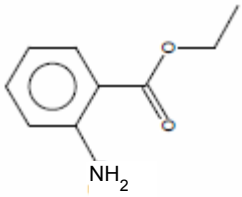
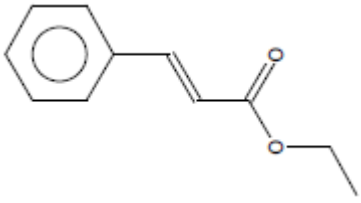
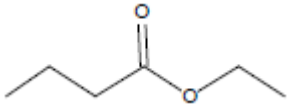
4.2. Products Tested

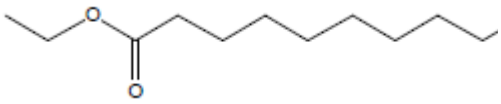
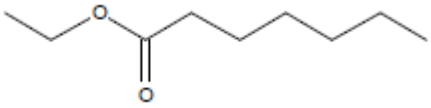
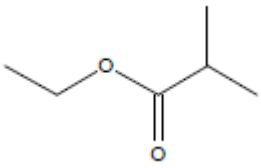
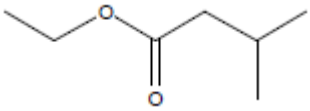
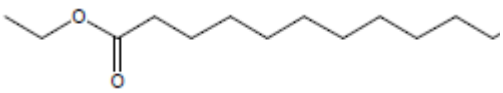
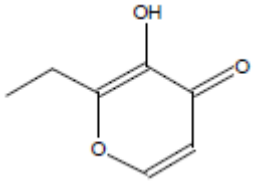
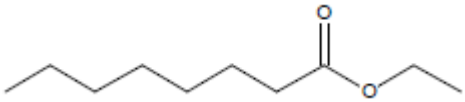
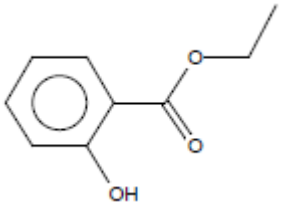
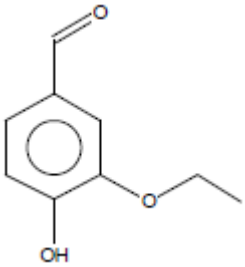
Table A.2. Tobacco, Candy and Kool-Aid Products Analyzed			
Product Brand Name	Product Flavor Name	Sample Size Used for Extractions	Average relative standard deviation (range) for above trace compounds (%)
Tobacco			
Tobacco Wraps			
Zig Zag	cherry grape apple blueberry	1 wrap, cut into pieces	30 (2 - 45) 20 (1 - 45) 22 (4 - 72) 31 (1 - 95)
Royal Blunt Wrap	sour apple XXL	1 wrap, cut into pieces	17 (10 - 26)
Large Cigars			
Phillies Blunt	grape	~ 1 g cylinder cut from center of cigar	22 (2 - 173)
Cheyenne Cigars	wild cherry grape peach xotic berry	1 cigar stick, with filter removed, cut into pieces, and extracted separately	14 (5 - 48) 12 (5 - 43) 10 (5 - 17) 8 (5 - 29)
Swisher Sweet Cigarillos	cherry peach	1 cigar, with tip removed (cherry)	7 (3 - 14) 11 (1 - 27)
Moist Snuff			
Skoal	cherry apple berry	~ 1 g	3 (1 - 11) 2 (1 - 7) 5 (1 - 57)
Kayak	grape apple peach	~ 1 g	13 (1 - 173) 4 (1 - 14) 2 (0 - 4)
Non-tobacco			
Candy			
Jolly Ranchers	cherry grape apple peach raspberry	1 candy	5 (3 - 6) 2 (0 - 4) 5 (4 - 8) 3 (1 - 8) 17 (2 - 135)
Life Savers	cherry raspberry	2 candies	6 (2 - 27) 10 (3 - 44)
Zotz	cherry grape apple blue raspberry	1 candy	5 (1 - 8) 12 (4 - 51) 33 (6 - 88) 9 (6 - 18)
Soft Drink			
Kool-Aid	Cherry grape peach mango raspberry lemonade	~ 100 mg	18 (1 - 25) 12 (3 - 15) 30 (2 - 43) 9 (3 - 17)
*where above trace corresponds to compounds ≥0.3 ng/μL in solution			

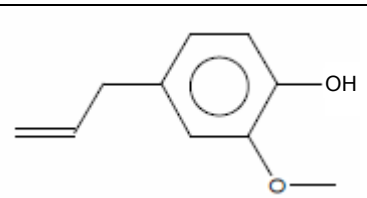
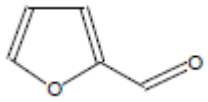
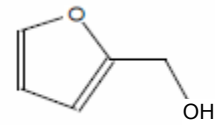
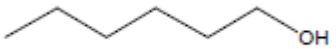
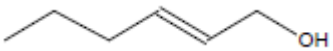
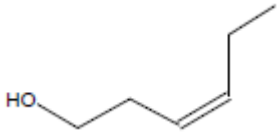
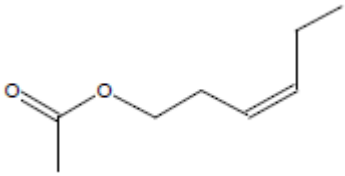
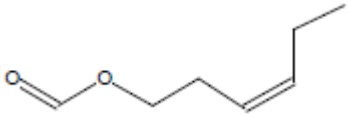
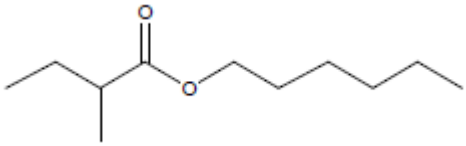
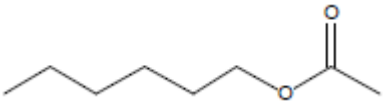
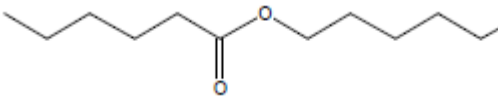
4.3. Target Analytes Found in Samples

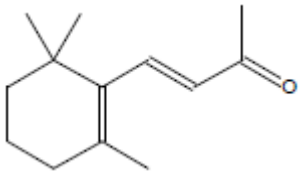
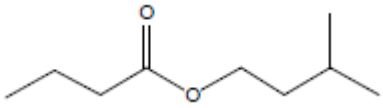
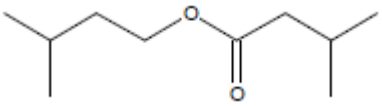
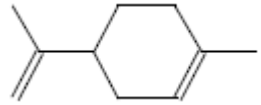
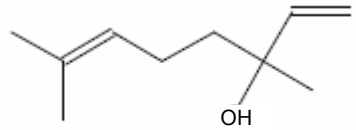
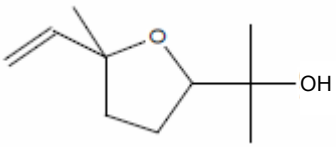
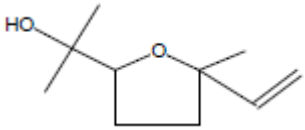
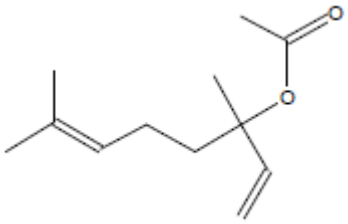
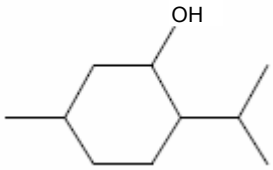
Table A.3. The 70 compounds found in selected candy, Kool-Aid, and tobacco products. For analytes with chirality, differentiation by chirality was not carried out. The Chemical Abstract Services Registry Number (CASRN) values given are those used to prepare the analytical standards.

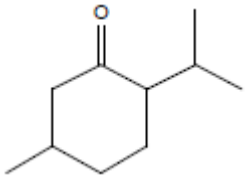
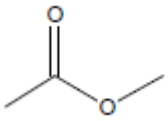
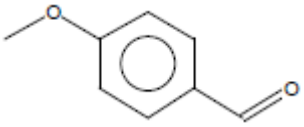
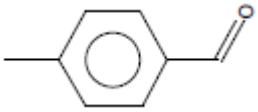
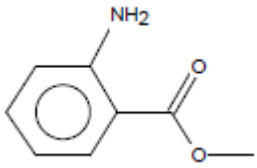
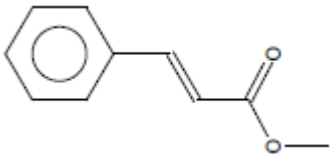
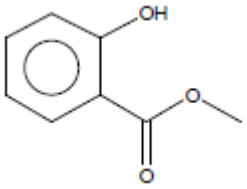
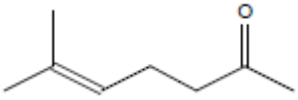
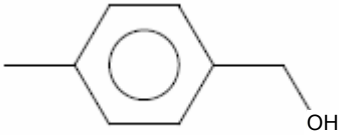
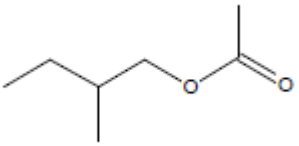
compound	CASRN for standard	structure
1 amyl acetate	628-63-7 $C_7H_{14}O_2$	
2 amyl butanoate	540-18-1 $C_9H_{18}O_2$	
3 amylisovalerate	25415-62-7 $C_{10}H_{20}O_2$	
4 benzaldehyde	100-52-7 C_7H_6O	
5 benzaldehyde propylene glycol acetal, mixture of isomers	2568-25-4 $C_{10}H_{12}O_2$	
6 benzyl acetate	140-11-4 $C_9H_{10}O_2$	
7 benzyl alcohol	100-51-6 C_7H_8O	
8 benzyl ether	103-50-4 $C_{14}H_{14}O$	
9 benzyl propionate	122-63-4 $C_{10}H_{12}O_2$	

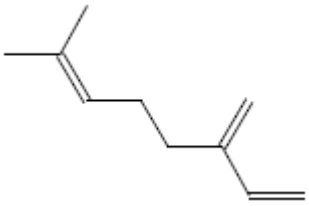
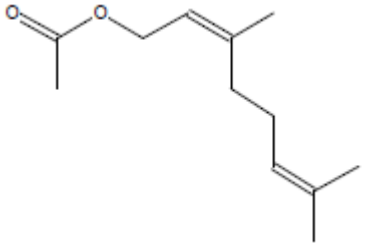
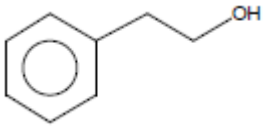
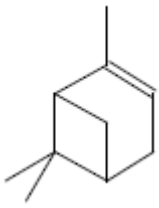
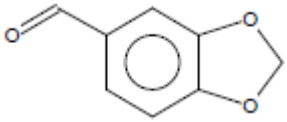
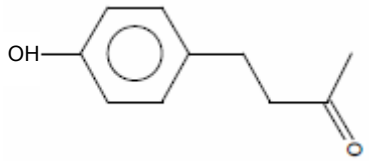
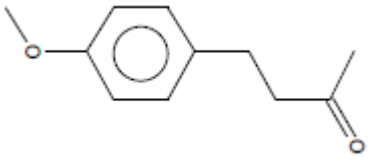
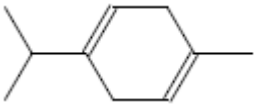
10	carvone	6485-40-1 $C_{10}H_{14}O$	
11	cinnamyl alcohol	104-54-1 $C_9H_{10}O$	
12	*p*-cymene	99-87-6 $C_{10}H_{14}$	
13	β-damascone	23726-91-2 $C_{13}H_{20}O$	
14	γ-decalactone	706-14-9 $C_{10}H_{18}O_2$	
15	dimethyl benzyl carbinyl butanoate	10094-34-5 $C_{14}H_{20}O_2$	
16	ethyl anthranilate	87-25-2 $C_9H_{11}NO_2$	
17	ethyl cinnamate	103-36-6 $C_{11}H_{12}O_2$	
18	ethyl butanoate	105-54-4 $C_6H_{12}O_2$	

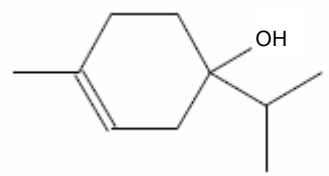
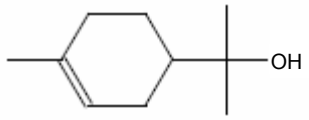
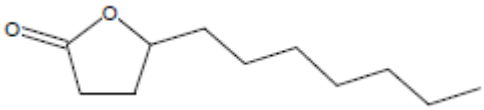
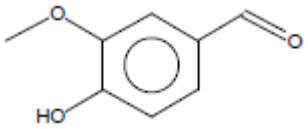
19 ethyl decanoate	110-38-3 $C_{12}H_{24}O_2$	
20 ethyl heptanoate	106-30-9 $C_9H_{18}O_2$	
21 ethyl isobutanoate	97-62-1 $C_6H_{12}O_2$	
22 ethyl isovalerate	108-64-5 $C_7H_{14}O_2$	
23 ethyl laurate	106-33-2 $C_{14}H_{28}O_2$	
24 ethyl maltol	4940-11-8 $C_7H_8O_3$	
25 ethyl octanoate	106-32-1 $C_{10}H_{20}O_2$	
26 ethyl salicylate	118-61-6 $C_9H_{10}O_3$	
27 ethyl vanillin	121-32-4 $C_9H_{10}O_3$	

28	eugenol	97-53-0 $C_{10}H_{12}O_2$	
29	furfural	98-01-1 $C_5H_4O_2$	
30	furfuryl alcohol	98-00-0 $C_5H_6O_2$	
31	1-hexanol	111-27-3 $C_6H_{14}O$	
32	(E)-2-hexen-1-ol	928-95-0 $C_6H_{12}O$	
33	(Z)-3-hexen-1-ol	928-96-1 $C_6H_{12}O$	
34	(Z)-3-hexen-1-yl acetate	3681-71-8 $C_8H_{14}O_2$	
35	(Z)-3-hexen-1-yl formate	33467-73-1 $C_7H_{12}O_2$	
36	hexyl 2-methylbutanoate	10032-15-2 $C_{11}H_{22}O_2$	
37	hexyl acetate	142-92-7 $C_8H_{16}O_2$	
38	hexyl hexanoate	6378-65-0 $C_{12}H_{24}O_2$	

39	β-ionone	14901-07-6 $C_{13}H_{20}O$	
40	isoamyl butanoate	106-27-4 $C_9H_{18}O_2$	
41	isoamyl isovalerate	659-70-1 $C_{10}H_{20}O_2$	
42	limonene	138-86-3 $C_{10}H_{16}$	
43	β-linalool	78-70-6 $C_{10}H_{18}O$	
44	*cis*-linalool oxide	5989-33-3 $C_{10}H_{18}O_2$	
45	*trans*-linalool oxide	23007-29-6 $C_{10}H_{18}O_2$	
46	linalyl acetate	115-95-7 $C_{12}H_{20}O_2$	
47	menthol	2216-51-5 $C_{10}H_{20}O$	

48	menthone	14073-97-3 $C_{10}H_{18}O$	
49	menthyl acetate	79-20-9 $C_3H_6O_2$	
50	*p*-methoxy benzaldehyde (*p*-anisaldehyde)	123-11-5 $C_8H_8O_2$	
51	*p*-methyl benzaldehyde (*p*-tolualdehyde)	104-87-0 C_8H_8O	
52	methyl anthranilate	134-20-3 $C_8H_9NO_2$	
53	methyl cinnamate	103-26-4 $C_{10}H_{10}O_2$	
54	methyl salicylate	119-36-8 $C_8H_8O_3$	
55	6-methyl-5-hepten-2-one	110-93-0 $C_8H_{14}O$	
56	4-methylbenzyl alcohol	589-18-4 $C_8H_{10}O$	
57	2-methylbutyl acetate	624-41-9 $C_7H_{14}O_2$	

58	myrcene	123-35-3 $C_{10}H_{16}$	
59	neryl acetate	141-12-8 $C_{12}H_{20}O_2$	
60	1-pentanol	71-41-0 $C_5H_{12}O$	
61	phenethyl alcohol	60-12-8 $C_8H_{10}O$	
62	α-pinene	80-56-8 $C_{10}H_{16}$	
63	piperonal	120-57-0 $C_8H_6O_3$	
64	raspberry ketone	5471-51-2 $C_{10}H_{12}O_2$	
65	raspberry ketone methyl ether	104-20-1 $C_{11}H_{14}O_2$	
66	γ-terpinene	99-85-4 $C_{10}H_{16}$	

67	4-terpineol	20126-76-5 $C_{10}H_{18}O$	
68	α-terpineol	10482-56-1 $C_{10}H_{18}O$	
69	γ-undecalactone	104-67-6 $C_{11}H_{20}O_2$	
70	vanillin	121-33-5 $C_8H_8O_3$	

4.4. Flavorant Analyses Results

Table A.4.1. Compounds Found in "Cherry" Products

product	compound	CASRN[1] for standard	micrograms (μg) per "serving"
Jolly Rancher "Cherry" 1 serving = 1 candy (~6.1 g)	benzyl alcohol	100-51-6	25 ± 1
	furfural	98-01-1	25 ± 1
	furfuryl alcohol	98-00-0	8 ± 1
	p-methoxy benzaldehyde (*p*-anisaldehyde)	123-11-5	14 ± 1
	p-methyl benzaldehyde (*p*-tolualdehyde)	104-87-0	47 ± 2
	piperonal	120-57-0	6 ± 0
	vanillin	121-33-5	13 ± 1
Life Saver "Cherry" 1 serving = 1 candy (~3.6 g)	amyl acetate	628-63-7	33 ± 1
	amyl butanoate	540-18-1	34 ± 1
	benzaldehyde	100-52-7	469 ± 8
	benzyl acetate	140-11-4	9 ± 0
	benzyl alcohol	100-51-6	2231 ± 61
	eugenol	97-53-0	8 ± 0
	furfural	98-01-1	46 ± 1
	furfuryl alcohol	98-00-0	2 ± 0
	β-ionone	14901-07-6	Trace[2]
	limonene	138-86-3	24 ± 2
	β-linalool	78-70-6	3 ± 0
	methyl salicylate	119-36-8	2 ± 0
	p-methyl benzaldehyde (*p*-tolualdehyde)	104-87-0	140 ± 4
	2-methylbutyl acetate	624-41-9	38 ± 2
	raspberry ketone	5471-51-2	2 ± 1
	γ-terpinene	99-85-4	Trace
	γ-undecalactone	104-67-6	Trace
Zotz "Cherry" 1 serving = 1 candy (~5.1 g)	amyl acetate	628-63-7	170 ± 7
	amyl butanoate	540-18-1	Trace
	benzaldehyde	100-52-7	241 ± 11
	benzaldehyde propylene glycol acetal§	2568-25-4	78 ± 6
	ethyl butanoate	105-54-4	14 ± 0
	ethyl decanoate	110-38-3	5 ± 0
	ethyl laurate	106-33-2	25 ± 1
	eugenol	97-53-0	15 ± 1
	furfural	98-01-1	30 ± 0
	furfuryl alcohol	98-00-0	120 ± 7
	limonene	138-86-3	3 ± 0
	vanillin	121-33-5	91 ± 5
Kool-Aid Mix "Cherry"	amylisovalerate	25415-62-7	33 ± 8
	benzaldehyde	100-52-7	3338 ± 623

1 serving = 0.5 g as for 8 oz of drink	benzyl acetate	140-11-4	185 ± 34
	benzyl alcohol	100-51-6	356 ± 60
	benzyl ether	103-50-4	51 ± 7
	ethyl butanoate	105-54-4	377 ± 89
	ethyl laurate	106-33-2	Trace
	ethyl vanillin	121-32-4	126 ± 18
	eugenol	97-53-0	Trace
	isoamyl butanoate	106-27-4	215 ± 53
	isoamyl isovalerate	659-70-1	78 ± 19
	p-methoxy benzaldehyde (*p*-anisaldehyde)	123-11-5	133 ± 22
	p-methyl benzaldehyde (*p*-tolualdehyde)	104-87-0	72 ± 13
	piperonal	120-57-0	185 ± 28
	vanillin	121-33-5	194 ± 34
Cheyenne "large cigars" "Wild Cherry" 1 serving = 1 "cigar" (~1.4 g)	benzaldehyde	100-52-7	3937 ± 251
	benzaldehyde propylene glycol acetal	2568-25-4	42 ± 3
	benzyl acetate	140-11-4	Trace
	benzyl alcohol	100-51-6	19 ± 1
	ethyl maltol	4940-11-8	25 ± 1
	ethyl vanillin	121-32-4	119 ± 5
	eugenol	97-53-0	42 ± 2
	β-ionone	14901-07-6	32 ± 1
	isoamyl butanoate	106-27-4	8 ± 1
	β-linalool	78-70-6	Trace
	menthol	2216-51-5	5 ± 0
	p-methoxy benzaldehyde (*p*-anisaldehyde)	123-11-5	649 ± 36
	phenethyl alcohol	60-12-8	Trace
	piperonal	120-57-0	333 ± 17
	vanillin	121-33-5	219 ± 8
Swisher Sweet cigarillos "BLK Cherry" 1 serving = 1 "cigarillo" (~2.3 g)	benzaldehyde	100-52-7	Trace
	benzaldehyde propylene glycol acetal	2568-25-4	Trace
	benzyl acetate	140-11-4	39 ± 2
	benzyl alcohol	100-51-6	372 ± 53
	γ-decalactone	706-14-9	653 ± 35
	ethyl cinnamate	103-36-6	206 ± 12
	ethyl maltol	4940-11-8	Trace
	ethyl vanillin	121-32-4	1012 ± 43
	β-ionone	14901-07-6	15 ± 1
	menthol	2216-51-5	Trace
	p-methoxy benzaldehyde (*p*-anisaldehyde)	123-11-5	55 ± 6
	4-methylbenzyl alcohol	589-18-4	Trace
	phenethyl alcohol	60-12-8	Trace
	raspberry ketone	5471-51-2	241 ± 7
	γ-undecalactone	104-67-6	9 ± 1
	vanillin	121-33-5	2778 ± 128

Skoal moist snuff "Cherry" 1 serving = 1.0 g	amyl acetate	628-63-7	7 ± 0
	amyl butanoate	540-18-1	Trace
	benzaldehyde	100-52-7	2632 ± 43
	benzyl alcohol	100-51-6	35 ± 0
	ethyl butanoate	105-54-4	34 ± 3
	ethyl salicylate	118-61-6	3923 ± 67
	ethyl vanillin	121-32-4	112 ± 2
	eugenol	97-53-0	25 ± 1
	furfuryl alcohol	98-00-0	3 ± 0
	1-hexanol	111-27-3	31 ± 1
	hexyl acetate	142-92-7	23 ± 0
	isoamyl butanoate	106-27-4	8 ± 0
	methyl salicylate	119-36-8	4227 ± 93
	p-methoxy benzaldehyde (*p*-anisaldehyde)	123-11-5	360 ± 3
	2-methylbutyl acetate	624-41-9	13 ± 0
	p-methyl benzaldehyde (*p*-tolualdehyde)	104-87-0	381 ± 6
	1-pentanol	71-41-0	19 ± 1
	phenethyl alcohol	60-12-8	37 ± 0
	piperonal	120-57-0	279 ± 2
	vanillin	121-33-5	426 ± 7
Zig Zag Wraps blunt wraps "Cherry" 1 serving = 1 wrap (~0.7 g)	benzaldehyde	100-52-7	92 ± 2
	benzaldehyde propylene glycol acetal	2568-25-4	3 ± 0
	benzyl acetate	140-11-4	6 ± 2
	benzyl alcohol	100-51-6	2391 ± 664
	benzyl propionate	122-63-4	Trace
	γ-decalactone	706-14-9	17 ± 6
	ethyl butanoate	105-54-4	3 ± 1
	ethyl cinnamate	103-36-6	149 ± 52
	ethyl vanillin	121-32-4	19 ± 7
	β-ionone	14901-07-6	222 ± 91
	isoamyl butanoate	106-27-4	10 ± 2
	limonene	138-86-3	21 ± 2
	β-linalool	78-70-6	13 ± 3
	p-methoxy benzaldehyde (*p*-anisaldehyde)	123-11-5	Trace
	p-methyl benzaldehyde (*p*-tolualdehyde)	104-87-0	71 ± 14
	piperonal	120-57-0	276 ± 89
	raspberry ketone	5471-51-2	321 ± 126
	α-terpineol	10482-56-1	Trace
	γ-undecalactone	104-67-6	230 ± 87
	vanillin	121-33-5	944 ± 346

[1]CASRN = Chemical Abstracts Services Registry Number.

[2]"Trace" indicates the compound was confirmed as present but detected at <0.3 ng/μL in solution. This corresponds to <3 μg/serving for all Jolly Ranchers, Zotz,

moist snuff and tobacco wrap products, <1.5 µg/serving for Life Savers, <4.5 µg/serving for Cheyenne cigars, <6 µg/serving for Swisher Sweet cigarillos, and <15 µg/serving for "cherry" Kool-Aid.

[§]Sum of syn and anti isomers of the acetal.

Table A.4.2. Compounds Found in "Grape" Products

product	compound	CASRN[1] for standard	micrograms (µg) per "serving"
Jolly Rancher "Grape" 1 serving = 1 candy (~6.0 g)	benzaldehyde	100-52-7	134 ± 2
	cinnamyl alcohol	104-54-1	837 ± 13
	ethyl anthranilate	87-25-2	47 ± 1
	ethyl butanoate	105-54-4	736 ± 8
	ethyl decanoate	110-38-3	25 ± 0
	ethyl isobutanoate	97-62-1	85 ± 2
	ethyl isovalerate	108-64-5	6 ± 0
	ethyl laurate	106-33-2	87 ± 1
	ethyl maltol	4940-11-8	57 ± 0
	ethyl octanoate	106-32-1	Trace[2]
	furfural	98-01-1	11 ± 0
	(E)-2-hexen-1-ol	928-95-0	9 ± 0
	hexyl acetate	142-92-7	34 ± 0
	limonene	138-86-3	483 ± 7
	β-linalool	78-70-6	Trace
	linalyl acetate	115-95-7	51 ± 1
	methyl anthranilate	134-20-3	1019 ± 2
	2-methylbutyl acetate	624-41-9	Trace
	myrcene	123-35-3	Trace
	neryl acetate	141-12-8	Trace
	phenethyl alcohol	60-12-8	5 ± 0
	raspberry ketone	5471-51-2	29 ± 1
	raspberry ketone methyl ether	104-20-1	315 ± 2
	α-terpineol	10482-56-1	Trace
Zotz "Grape" 1 serving = 1 candy (~5.0 g)	cinnamyl alcohol	104-54-1	15 ± 1
	ethyl butanoate	105-54-4	32 ± 7
	ethyl cinnamate	103-36-6	3 ± 0
	ethyl decanoate	110-38-3	7 ± 0
	ethyl heptanoate	106-30-9	25 ± 2
	ethyl octanoate	106-32-1	3 ± 0
	ethyl salicylate	118-61-6	Trace
	furfural	98-01-1	35 ± 2
	furfuryl alcohol	98-00-0	98 ± 50
	(Z)-3-hexen-1-ol	928-96-1	11 ± 0
	(Z)-3-hexen-1-yl acetate	3681-71-8	4 ± 0

	hexyl acetate	142-92-7	Trace
	β-linalool	78-70-6	Trace
	methyl anthranilate	134-20-3	26 ± 1
Kool-Aid Mix "Grape" 1 serving = 0.5 g as for 8 oz of drink	benzaldehyde	100-52-7	Trace
	ethyl butanoate	105-54-4	897 ± 134
	ethyl decanoate	110-38-3	Trace
	ethyl isobutanoate	97-62-1	330 ± 49
	ethyl isovalerate	108-64-5	22 ± 3
	ethyl octanoate	106-32-1	Trace
	(E)-2-hexen-1-ol	928-95-0	80 ± 11
	limonene	138-86-3	33 ± 4
	methyl anthranilate	134-20-3	1137 ± 153
Cheyenne "large cigars" "Grape" 1 serving = 1 "cigar" (~1.4 g)	benzaldehyde	100-52-7	34 ± 1
	benzaldehyde propylene glycol acetal§	2568-25-4	40 ± 1
	benzyl acetate	140-11-4	Trace
	benzyl alcohol	100-51-6	18 ± 0
	β-damascone	23726-91-2	7 ± 0
	dimethyl benzyl carbinyl butanoate	10094-34-5	232 ± 5
	ethyl butanoate	105-54-4	Trace
	ethyl cinnamate	103-36-6	5 ± 0
	ethyl maltol	4940-11-8	346 ± 33
	1-hexanol	111-27-3	41 ± 1
	hexyl 2-methylbutanoate	10032-15-2	Trace
	hexyl acetate	142-92-7	Trace
	β-linalool	78-70-6	88 ± 1
	menthol	2216-51-5	844 ± 8
	menthone	14073-97-3	Trace
	menthyl acetate	79-20-9	Trace
	methyl anthranilate	134-20-3	1790 ± 40
	methyl cinnamate	103-26-4	374 ± 6
	methyl salicylate	119-36-8	Trace
	p-methyl benzaldehyde (*p*-tolualdehyde)	104-87-0	26 ± 1
	vanillin	121-33-5	Trace
Phillies Blunt "large cigar" "Grape" 1 serving = 1 "cigar" (~7.6 g)	benzaldehyde	100-52-7	77 ± 13
	benzaldehyde propylene glycol acetal	2568-25-4	244 ± 16
	benzyl acetate	140-11-4	28 ± 6
	benzyl alcohol	100-51-6	5808 ± 655
	β-damascone	23726-91-2	486 ± 11
	dimethyl benzyl carbinyl butanoate	10094-34-5	2634 ± 85
	ethyl cinnamate	103-36-6	Trace
	ethyl maltol	4940-11-8	2950 ± 277
	ethyl vanillin	121-32-4	317 ± 123
	1-hexanol	111-27-3	441 ± 86
	β-ionone	14901-07-6	55 ± 3

	β-linalool	78-70-6	424 ± 15
	menthol	2216-51-5	1559 ± 180
	menthyl acetate	79-20-9	Trace
	methyl anthranilate	134-20-3	17552 ± 2135
	methyl cinnamate	103-26-4	Trace
	piperonal	120-57-0	41 ± 11
	raspberry ketone	5471-51-2	624 ± 75
	4-terpineol	20126-76-5	775 ± 82
	vanillin	121-33-5	673 ± 120
Kayak Moist Snuff “Grape” 1 serving = 1.0 g	amyl acetate	628-63-7	Trace
	amyl butanoate	540-18-1	43 ± 2
	benzaldehyde	100-52-7	10 ± 0
	benzaldehyde propylene glycol acetal	2568-25-4	16 ± 0
	benzyl acetate	140-11-4	Trace
	benzyl alcohol	100-51-6	78 ± 14
	cinnamyl alcohol	104-54-1	56 ± 4
	ethyl butanoate	105-54-4	193 ± 11
	ethyl decanoate	110-38-3	8 ± 0
	ethyl heptanoate	106-30-9	31 ± 1
	ethyl laurate	106-33-2	8 ± 0
	ethyl maltol	4940-11-8	54 ± 1
	ethyl octanoate	106-32-1	8 ± 0
	ethyl salicylate	118-61-6	Trace
	eugenol	97-53-0	5 ± 0
	furfuryl alcohol	98-00-0	69 ± 2
	isoamyl butanoate	106-27-4	93 ± 4
	limonene	138-86-3	171 ± 7
	β-linalool	78-70-6	547 ± 15
	cis-linalool oxide	5989-33-3	4 ± 1
	trans-linalool oxide	23007-29-6	4 ± 0
	menthol	2216-51-5	80 ± 15
	methyl anthranilate	134-20-3	1195 ± 27
	methyl salicylate	119-36-8	51 ± 1
	6-methyl-5-hepten-2-one	110-93-0	Trace
	2-methylbutyl acetate	624-41-9	10 ± 1
	1-pentanol	71-41-0	31 ± 2
	phenethyl alcohol	60-12-8	14 ± 3
	piperonal	120-57-0	4 ± 0
	raspberry ketone	5471-51-2	163 ± 6
	raspberry ketone methyl ether	104-20-1	77 ± 2
	4-terpineol	20126-76-5	14 ± 25
	vanillin	121-33-5	2046 ± 49
Zig Zag “blunt wrap" “Grape” 1 serving = 1 wrap (~0.7 g)	benzaldehyde	100-52-7	8 ± 0
	benzyl acetate	140-11-4	23 ± 5
	benzyl alcohol	100-51-6	2163 ± 99
	γ-decalactone	706-14-9	4 ± 2
	ethyl maltol	4940-11-8	72 ± 11

	ethyl vanillin	121-32-4	70 ± 4
	1-hexanol	111-27-3	19 ± 7
	(Z)-3-hexen-1-ol	928-96-1	151 ± 17
	(Z)-3-hexen-1-yl acetate	3681-71-8	6 ± 0
	hexyl acetate	142-92-7	Trace
	β-ionone	14901-07-6	9 ± 2
	β-linalool	78-70-6	51 ± 7
	methyl anthranilate	134-20-3	82 ± 19
	methyl cinnamate	103-26-4	5 ± 1
	p-methoxy benzaldehyde (*p*-anisaldehyde)	123-11-5	25 ± 2
	phenethyl alcohol	60-12-8	6 ± 2
	piperonal	120-57-0	Trace
	raspberry ketone	5471-51-2	745 ± 162
	α-terpineol	10482-56-1	8 ± 1
	γ-undecalactone	104-67-6	22 ± 9
	vanillin	121-33-5	240 ± 58

[1]CASRN = Chemical Abstracts Services Registry Number.

[2]"Trace" indicates the compound was confirmed as present but detected at <0.3 ng/μL in solution. This corresponds to <3 μg/serving for all Jolly Ranchers, Zotz, moist snuff and tobacco wrap products, <4.5 μg/serving for Cheyenne cigars, <21 μg/serving for Phillies Blunt cigars, and <15 μg/serving for "grape" Kool-Aid.

[§]Sum of syn and anti isomers of the acetal.

Table A.4.3. Compounds Found in "Apple" Products

product	compound	CASRN[1] for standard	micrograms (μg) per "serving"
Jolly Rancher "Apple" 1 serving = 1 candy (~6.1 g)	ethyl decanoate	110-38-3	121 ± 6
	ethyl laurate	106-33-2	67 ± 3
	ethyl maltol	4940-11-8	40 ± 2
	ethyl octanoate	106-32-1	68 ± 4
	furfural	98-01-1	9 ± 1
	1-hexanol	111-27-3	968 ± 54
	hexyl acetate	142-92-7	12 ± 0
	2-methylbutyl acetate	624-41-9	376 ± 30
	1-pentanol	71-41-0	3 ± 0
Zotz "Apple" 1 serving = 1 candy (~5.0 g)	dimethyl benzyl carbinyl butanoate	10094-34-5	Trace[2]
	ethyl butanoate	105-54-4	31 ± 9
	furfural	98-01-1	19 ± 8
	furfuryl alcohol	98-00-0	104 ± 27
	1-hexanol	111-27-3	53 ± 11
	(Z)-3-hexen-1-ol	928-96-1	35 ± 5
	(Z)-3-hexen-1-yl acetate	3681-71-8	72 ± 8

	hexyl acetate	142-92-7	95 ± 14
	isoamyl butanoate	106-27-4	29 ± 25
	β-linalool	78-70-6	Trace
	6-methyl-5-hepten-2-one	110-93-0	Trace
	2-methylbutyl acetate	624-41-9	26 ± 1
	γ-undecalactone	104-67-6	14 ± 2
Kayak moist snuff “Apple” 1 serving = 1.0 g	benzaldehyde	100-52-7	37 ± 2
	benzaldehyde propylene glycol acetal§	2568-25-4	37 ± 1
	benzyl acetate	140-11-4	3 ± 0
	benzyl alcohol	100-51-6	143 ± 3
	cinnamyl alcohol	104-54-1	10 ± 0
	ethyl butanoate	105-54-4	16 ± 2
	ethyl heptanoate	106-30-9	31 ± 2
	ethyl vanillin	121-32-4	1530 ± 41
	1-hexanol	111-27-3	231 ± 7
	(E)-2-hexen-1-ol	928-95-0	4 ± 0
	(Z)-3-hexen-1-ol	928-96-1	1435 ± 66
	(Z)-3-hexen-1-yl acetate	3681-71-8	81 ± 4
	(Z)-3-hexen-1-yl formate	33467-73-1	Trace
	hexyl 2-methylbutanoate	10032-15-2	78 ± 4
	hexyl acetate	142-92-7	859 ± 38
	hexyl hexanoate	6378-65-0	Trace
	isoamyl isovalerate	659-70-1	329 ± 17
	limonene	138-86-3	72 ± 5
	β-linalool	78-70-6	142 ± 4
	methyl salicylate	119-36-8	55 ± 2
	phenethyl alcohol	60-12-8	4 ± 0
	piperonal	120-57-0	13 ± 0
	vanillin	121-33-5	189 ± 8
Skoal moist snuff “Apple” 1 serving = 1.0 g	benzaldehyde	100-52-7	43 ± 0
	benzaldehyde propylene glycol acetal	2568-25-4	425 ± 7
	benzyl alcohol	100-51-6	42 ± 0
	β-damascone	23726-91-2	7 ± 0
	ethyl cinnamate	103-36-6	Trace
	ethyl heptanoate	106-30-9	9 ± 0
	ethyl vanillin	121-32-4	477 ± 21
	1-hexanol	111-27-3	486 ± 4
	(Z)-3-hexen-1-ol	928-96-1	124 ± 1
	(Z)-3-hexen-1-yl acetate	3681-71-8	9 ± 0
	hexyl acetate	142-92-7	176 ± 2
	hexyl hexanoate	6378-65-0	25 ± 1
	isoamyl isovalerate	659-70-1	395 ± 4
	2-methylbutyl acetate	624-41-9	Trace
	phenethyl alcohol	60-12-8	8 ± 0
	piperonal	120-57-0	112 ± 2
	raspberry ketone	5471-51-2	452 ± 21
	vanillin	121-33-5	Trace

Royal Blunt Wraps XXL "blunt wraps" "Sour Apple" 1 serving = 1 wrap (~0.9 g)	1-hexanol	111-27-3	144 ± 23
	menthol	2216-51-5	Trace
	1-pentanol	71-41-0	15 ± 4
	phenethyl alcohol	60-12-8	Trace
	vanillin	121-33-5	123 ± 12
Zig Zag Wraps "blunt wraps" "Apple" 1 serving = 1 wrap (~0.9 g)	benzaldehyde	100-52-7	20 ± 3
	benzaldehyde propylene glycol acetal	2568-25-4	Trace
	benzyl acetate	140-11-4	9 ± 1
	benzyl alcohol	100-51-6	3341 ± 150
	cinnamyl alcohol	104-54-1	5 ± 1
	γ-decalactone	706-14-9	13 ± 6
	ethyl cinnamate	103-36-6	Trace
	ethyl maltol	4940-11-8	46 ± 7
	ethyl vanillin	121-32-4	Trace
	eugenol	97-53-0	205 ± 18
	1-hexanol	111-27-3	142 ± 15
	hexyl 2-methylbutanoate	10032-15-2	Trace
	β-linalool	78-70-6	3 ± 1
	methyl cinnamate	103-26-4	12 ± 1
	phenethyl alcohol	60-12-8	Trace
	piperonal	120-57-0	Trace
	raspberry ketone	5471-51-2	19 ± 5
	γ-undecalactone	104-67-6	31 ± 22
	vanillin	121-33-5	139 ± 10

[1]CASRN = Chemical Abstracts Services Registry Number.

[2]"Trace" indicates the compound was confirmed as present but detected at <0.3 ng/μL in solution. This corresponds to <3 μg/serving for all Jolly Rancher, Zotz, moist snuff and tobacco wrap products.

[§]Sum of syn and anti isomers of the acetal.

Table A.4.4. Compounds Found in "Peach" Products

product	compound	CASRN[1] for standard	micrograms (μg) per "serving"
Jolly Rancher "Peach" 1 serving = 1 candy (~6.1 g)	benzaldehyde	100-52-7	102 ± 2
	benzyl acetate	140-11-4	106 ± 2
	benzyl alcohol	100-51-6	18 ± 0
	p-cymene	99-87-6	Trace[2]
	γ-decalactone	706-14-9	111 ± 1
	furfural	98-01-1	10 ± 0
	furfuryl alcohol	98-00-0	5 ± 0
	(E)-2-hexen-1-ol	928-95-0	7 ± 0
	limonene	138-86-3	25 ± 1

	β-linalool	78-70-6	Trace
	linalyl acetate	115-95-7	4 ± 0
	menthone	14073-97-3	5 ± 0
	γ-terpinene	99-85-4	Trace
Kool-Aid Mix “Peach Mango” 1 serving = 0.6 g as for 8 oz of drink	benzaldehyde	100-52-7	20 ± 7
	benzyl alcohol	100-51-6	27 ± 8
	carvone	6485-40-1	Trace
	γ-decalactone	706-14-9	198 ± 70
	ethyl butanoate	105-54-4	1268 ± 377
	1-hexanol	111-27-3	60 ± 21
	(Z)-3-hexen-1-ol	928-96-1	225 ± 79
	(Z)-3-hexen-1-yl acetate	3681-71-8	38 ± 13
	hexyl acetate	142-92-7	17 ± 5
	hexyl hexanoate	6378-65-0	24 ± 10
	limonene	138-86-3	288 ± 66
	β-linalool	78-70-6	Trace
	menthol	2216-51-5	Trace
	α-pinene	80-56-8	Trace
	γ-undecalactone	104-67-6	Trace
Cheyenne “large cigars” “Peach” 1 serving = 1 “cigar” (~1.4 g)	benzaldehyde	100-52-7	15 ± 0
	benzaldehyde propylene glycol acetal§	2568-25-4	11 ± 0
	benzyl alcohol	100-51-6	12 ± 0
	γ-decalactone	706-14-9	100 ± 4
	ethyl maltol	4940-11-8	208 ± 3
	ethyl vanillin	121-32-4	20 ± 1
	(Z)-3-hexen-1-ol	928-96-1	23 ± 0
	β-linalool	78-70-6	30 ± 1
	menthol	2216-51-5	Trace
	phenethyl alcohol	60-12-8	Trace
	raspberry ketone	5471-51-2	79 ± 4
	γ-undecalactone	104-67-6	123 ± 4
	vanillin	121-33-5	Trace
Swisher Sweet cigarillos “Peach” 1 serving = 1 “cigarillo (~2.7 g)	benzaldehyde	100-52-7	Trace
	benzaldehyde propylene glycol acetal	2568-25-4	30 ± 3
	benzyl acetate	140-11-4	Trace
	benzyl alcohol	100-51-6	914 ± 88
	γ-decalactone	706-14-9	503 ± 9
	ethyl maltol	4940-11-8	72 ± 8
	1-hexanol	111-27-3	Trace
	(Z)-3-hexen-1-ol	928-96-1	35 ± 8
	β-linalool	78-70-6	92 ± 11
	linalyl acetate	115-95-7	54 ± 4
	menthol	2216-51-5	14 ± 4
	phenethyl alcohol	60-12-8	Trace
	raspberry ketone	5471-51-2	Trace
	γ-undecalactone	104-67-6	384 ± 3
	vanillin	121-33-5	635 ± 34

Kayak moist snuff "Peach" 1 serving = 1.0 g	benzaldehyde	100-52-7	Trace
	benzyl acetate	140-11-4	Trace
	benzyl alcohol	100-51-6	308 ± 4
	benzyl propionate	122-63-4	70 ± 1
	β-damascone	23726-91-2	19 ± 0
	γ-decalactone	706-14-9	398 ± 3
	ethyl cinnamate	103-36-6	Trace
	β-linalool	78-70-6	761 ± 13
	cis-linalool oxide	5989-33-3	5 ± 0
	trans-linalool oxide	23007-29-6	4 ± 0
	menthol	2216-51-5	185 ± 2
	methyl salicylate	119-36-8	6 ± 0
	phenethyl alcohol	60-12-8	4 ± 0
	γ-undecalactone	104-67-6	821 ± 7
	vanillin	121-33-5	1137 ± 5

[1]CASRN = Chemical Abstracts Services Registry Number.

[2]"Trace" indicates the compound was confirmed as present but detected at <0.3 ng/μL in solution. This corresponds to <3 μg/serving for all Jolly Ranchers and moist snuff products, <4.5 μg/serving for Cheyenne cigars, <6 μg/serving for Swisher Sweet cigarillos and <18 μg/serving for "peach-mango" Kool-Aid.

[§]Sum of syn and anti isomers of the acetal.

Table A.4.5. Compounds Found in "Berry" Products

product	compound	CASRN[1] for standard	micrograms (μg) per "serving"
Jolly Rancher "Raspberry" 1 serving = 1 candy (~6.1 g)	benzaldehyde	100-52-7	Trace[2]
	β-damascone	23726-91-2	7 ± 0
	ethyl butanoate	105-54-4	Trace
	furfural	98-01-1	14 ± 1
	1-hexanol	111-27-3	26 ± 1
	(Z)-3-hexen-1-ol	928-96-1	120 ± 3
	(E)-2-hexen-1-ol	928-95-0	30 ± 1
	(Z)-3-hexen-1-yl acetate	3681-71-8	294 ± 7
	(Z)-3-hexen-1-yl formate	33467-73-1	20 ± 2
	hexyl acetate	142-92-7	91 ± 3
	β-ionone	14901-07-6	Trace
	limonene	138-86-3	24 ± 32
	raspberry ketone	5471-51-2	777 ± 24
Life Saver "Raspberry" 1 serving = 1 candy (~3.6 g)	benzyl acetate	140-11-4	31 ± 2
	benzyl alcohol	100-51-6	16 ± 3
	β-damascone	23726-91-2	3 ± 0
	furfural	98-01-1	Trace
	furfuryl alcohol	98-00-0	2 ± 1

	1-hexanol	111-27-3	Trace
	(Z)-3-hexen-1-ol	928-96-1	5 ± 0
	(Z)-3-hexen-1-yl acetate	3681-71-8	35 ± 2
	(Z)-3-hexen-1-yl formate	33467-73-1	14 ± 1
	hexyl acetate	142-92-7	13 ± 1
	β-ionone	14901-07-6	5 ± 0
	limonene	138-86-3	Trace
	methyl salicylate	119-36-8	Trace
	raspberry ketone	5471-51-2	123 ± 4
Zotz “Blue Raspberry” 1 serving = 1 candy (~4.9 g)	amyl butanoate	540-18-1	Trace
	benzyl acetate	140-11-4	4 ± 0
	benzyl alcohol	100-51-6	53 ± 9
	γ-decalactone	706-14-9	16 ± 1
	ethyl butanoate	105-54-4	4 ± 0
	furfural	98-01-1	41 ± 3
	furfuryl alcohol	98-00-0	67 ± 6
	1-hexanol	111-27-3	8 ± 1
	(Z)-3-hexen-1-ol	928-96-1	17 ± 2
	β-ionone	14901-07-6	Trace
	2-methylbutyl acetate	624-41-9	17 ± 2
	raspberry ketone	5471-51-2	126 ± 8
	4-terpineol	20126-76-5	Trace
	vanillin	121-33-5	31 ± 3
Kool-Aid Mix “Raspberry Lemonade” 1 serving = 0.8 g as for 8 oz of drink	*p*-cymene	99-87-6	40 ± 4
	β-ionone	14901-07-6	Trace
	limonene	138-86-3	9911 ± 583
	myrcene	123-35-3	104 ± 8
	neryl acetate	141-12-8	31 ± 2
	α-pinene	80-56-8	130 ± 11
	raspberry ketone	5471-51-2	340 ± 44
	γ-terpinene	99-85-4	595 ± 51
	4-terpineol	20126-76-5	Trace
	α-terpineol	10482-56-1	Trace
	vanillin	121-33-5	92 ± 16
Cheyenne “large cigars” “Xotic Berry” 1 serving = 1 “cigar” (~1.4 g)	benzaldehyde	100-52-7	31 ± 2
	benzaldehyde propylene glycol acetal§	2568-25-4	127 ± 9
	benzyl acetate	140-11-4	23 ± 1
	benzyl alcohol	100-51-6	1434 ± 118
	benzyl propionate	122-63-4	Trace
	ethyl cinnamate	103-36-6	5 ± 0
	ethyl maltol	4940-11-8	284 ± 19
	ethyl vanillin	121-32-4	44 ± 3
	1-hexanol	111-27-3	21 ± 1
	β-ionone	14901-07-6	131 ± 3
	β-linalool	78-70-6	158 ± 7
	menthol	2216-51-5	Trace

	phenethyl alcohol	60-12-8	Trace
	raspberry ketone	5471-51-2	431 ± 22
	vanillin	121-33-5	139 ± 8
Skoal moist snuff “Berry Blend” 1 serving = 1.0 g	benzaldehyde	100-52-7	375 ± 12
	benzaldehyde propylene glycol acetal	2568-25-4	869 ± 25
	benzyl acetate	140-11-4	6 ± 0
	benzyl alcohol	100-51-6	1519 ± 10
	ethyl butanoate	105-54-4	34 ± 2
	ethyl cinnamate	103-36-6	262 ± 9
	ethyl isovalerate	108-64-5	26 ± 0
	1-hexanol	111-27-3	20 ± 0
	(Z)-3-hexen-1-ol	928-96-1	128 ± 3
	(Z)-3-hexen-1-yl acetate	3681-71-8	21 ± 0
	hexyl acetate	142-92-7	4 ± 0
	β-ionone	14901-07-6	4 ± 0
	isoamyl butanoate	106-27-4	88 ± 4
	limonene	138-86-3	17 ± 1
	β-linalool	78-70-6	103 ± 3
	menthol	2216-51-5	424 ± 13
	p-methyl benzaldehyde (*p*-tolualdehyde)	104-87-0	111 ± 4
	methyl salicylate	119-36-8	6195 ± 149
	2-methylbutyl acetate	624-41-9	4 ± 2
	phenethyl alcohol	60-12-8	7 ± 0
	piperonal	120-57-0	63 ± 2
	raspberry ketone	5471-51-2	784 ± 39
	4-terpineol	20126-76-5	61 ± 3
	γ-undecalactone	104-67-6	8 ± 0
	vanillin	121-33-5	108 ± 3
Zig Zag “blunt wrap” “Blueberry” 1 serving = 1 wrap (~0.7 g)	benzaldehyde	100-52-7	5 ± 0
	benzyl acetate	140-11-4	3 ± 1
	benzyl alcohol	100-51-6	2032 ± 29
	γ-decalactone	706-14-9	92 ± 12
	ethyl cinnamate	103-36-6	Trace
	ethyl isovalerate	108-64-5	Trace
	ethyl maltol	4940-11-8	14 ± 2
	ethyl vanillin	121-32-4	5 ± 4
	(Z)-3-hexen-1-ol	928-96-1	7 ± 3
	limonene	138-86-3	23 ± 4
	β-linalool	78-70-6	16 ± 3
	methyl anthranilate	134-20-3	4 ± 2
	methyl cinnamate	103-26-4	3 ± 0
	piperonal	120-57-0	Trace
	raspberry ketone	5471-51-2	25 ± 24
	α-terpineol	10482-56-1	Trace
	γ-undecalactone	104-67-6	9 ± 7
	vanillin	121-33-5	175 ± 36

[1]CASRN = Chemical Abstracts Services Registry Number.

[2]"Trace" indicates the compound was confirmed as present but detected at <0.3 ng/μL in solution. This corresponds to <3 μg/serving for all Jolly Ranchers, Zotz, moist snuff and tobacco wrap products, <1.5 μg/serving for Life Savers, <4.5 μg/serving for Cheyenne cigars, and <24 μg/serving for raspberry lemonade Kool-Aid.

[§]Sum of syn and anti isomers of the acetal.

5. Appendix B. PINOT NOIR Tables

5.1. Sample Information

Table B.1. PINOT NOIR Sample Information

Data File	Day	Time	Temp (°C)	RH (%)
VBOC2012091005-2D	7/29/12	11:00	25.9	69.9
VBOC2012090702-2D	7/29/12	14:00	40.1	23.6
VBOC2012090614-2D	7/29/12	16:30	40.3	25.3
VBOC2012090615-2D	7/30/12	11:00	30.0	56.2
VBOC2012091006-2D	7/30/12	14:00	34.5	45.3
VBOC20120830010-2D	7/31/12	14:30	38.8	23.2
VBOC201203113-2D	7/31/12	16:30	40.7	20.0
VBOC20120830011-2D	8/1/12	11:00	32.5	43.6
VBOC201203108-2D	8/1/12	13:45	37.5	29.3
VBOC2012090606-2D	8/2/12	11:10	27.2	69.2
VBOC2012090504-2D	8/2/12	14:00	30.7	53.2
VBOC2012090611-2D	8/2/12	15:45	31.4	49.7
VBOC2012090513-2D	8/3/12	11:00	31.8	51.8

5.2. Cluster Results

Table B.2. Cluster Results					
Cluster No.	No. of compounds (by distinct retention time)	No. of points (used for plots)	No. of Samples or Majority (actual)	Average concentration ($\mu g/m^3$)	Concentration Range ($\mu g/m^3$) *rounded to 2 decimal places
Type I: Predominantly in one sample					
1	39	47	1 (4)	0.13 ± 0.14	0.02-0.63
3	9	11	1 (2)	0.21 ± 0.13	0.09-0.45
9	7	7	1	0.55 ± 0.58	0.11-1.69
16	24	29	1 (4)	0.27 ± 0.23	0.02-0.91
18	12	15	1 (4)	1.15 ± 0.78	0.34-2.81
20	21	23	1 (3)	0.11 ± 0.20	0.01-1.00
22	12	13	1 (2)	0.33 ± 0.31	0.04-0.99
24	12	13	1 (2)	0.12 ± 0.12	0.02-0.49
25	1	1	1	0.14	na
26	2	2	1	0.18 ± 0.21	0.03-0.34
27	3	3	1	0.38 ± 0.47	0.03-0.91
Type II: One compound per cluster					
15	1	4	4	0.08 ± 0.03	0.05-0.11
17	1	5	5	0.48 ± 0.39	0.20-1.14
19	1	6	6	0.14 ± 0.09	0.06-0.28
21	1	8	8	2.60 ± 2.74	0.69-8.88
Type III: Predominantly in two or more samples					
2	8	24	7	1.96 ± 5.45	0.03-25.5
4	7	12	2 (6)	2.36 ± 4.67	0.05-15.99
7	3	21	9	1.49 ± 1.46	0.07-5.26
8	2	12	8	0.71 ± 0.85	0.09-3.00
10	5	26	12	0.49 ± 0.32	0.10-1.39
11	4	36	12	3.37 ± 4.47	0.08-21.36
13	2	14	10	0.24 ± 0.26	0.04-0.82
14	8	47	11	0.36 ± 0.41	0.04-1.68
23	2	8	5	0.24 ± 0.18	0.10-0.60
Type IV: Cluster contains at least one compound in every sample					
5	3	28	13	13.97 ± 23.88	0.08-92.05
6	3	34	13	5.41 ± 9.53	0.17-43.41
12	11	91	13	0.88 ± 1.13	0.02-7.38

5.3. Cluster Environmental Variables

Table B.3. Environmental Variables by Cluster					
Cluster No.	Date	Time of Day	Temp (°C)	Relative Humidity (RH) (%)	Average Temp (°C) RH (%)
Type I: Predominantly in one **sample**					
1	7/30/12 **7/31/12** 8/1/12	11:00 **16:30** 13:45	30 **40.7** 37.5	56.2 **20** 29.3	39.9 ± 2.2 22.6 ± 7.4
3	**7/29/12** 8/1/12	**14:00** 13:45	**40.1** 37.5	**23.6** 29.3	39.6 ± 1.1 24.6 ± 2.3
9	8/1/12	11:00	32.5	43.6	32.5 ± 0.0 43.6 ± 0.0
16	**7/30/12** 8/1/12 8/3/12	11:00, **14:00** 13:45 11:00	30.0, **34.5** 37.5 31.8	56.2, **45.3** 29.3 51.8	34.6 ± 1.4 44.2 ± 5.7
18	7/29/12 8/1/12 **8/2/12** 8/3/12	16:30 11:00 **15:45** 11:00	40.3 32.5 **31.4** 31.8	25.3 43.6 **49.7** 51.8	32.1 ± 2.3 47.8 ± 6.5
20	7/29/12 7/30/12 **7/31/12**	16:30 14:00 **14:30**	40.3 34.5 **38.8**	25.3 45.3 **23.2**	38.7 ± 1.0 24.3 ± 4.6
22	7/30/12	**11:00**, 14:00	**30.0**, 34.5	**56.2**, 45.3	30.3 ± 1.2 55.4 ± 3.0
24	7/31/12 **8/1/12**	14:30 **13:45**	38.8 **37.5**	23.2 **29.3**	37.6 ± 0.4 28.8 ± 1.7
25	8/2/12	11:10	27.2	69.2	27.2 ± 0.0 69.2 ± 0.0
26	8/3/12	11:00	31.8	51.8	31.8 ± 0.0 51.8 ± 0.0
27	7/29/12	11:00	25.9	69.9	25.9 ± 0.0 69.9 ± 0.0
Type II: One compound per cluster					
15	7/29/12 7/30/12 7/31/12	14:00, 16:30 14:00 14:30	40.1, 40.3 34.5 38.8	23.6, 25.3 45.3 23.2	38.4 ± 2.7 29.4 ± 10.7
17	7/29/12 7/30/12 8/1/12 8/2/12	11:00 11:00 13:45 11:10, 15:45	25.9 30.0 37.5 27.2, 31.4	69.9 56.2 29.3 69.2, 49.7	30.4 ± 4.5 54.9 ± 16.7
19	7/29/12 7/30/12 7/31/12 8/1/12	11:00, 14:00, 16:30 11:00 14:30 13:45	25.9, 40.1, 40.3 30.0 38.8 37.5	69.9, 23.6, 25.3 56.2 23.2 29.3	35.4 ± 6.0 37.9 ± 20.1
21	7/29/12 7/30/12 7/31/12 8/1/12 8/2/12 8/3/12	16:30 14:00 16:30 11:00, 13:45 11:10, 14:00 11:00	40.3 34.5 40.7 32.5, 37.5 27.2, 30.7 31.8	25.3 45.3 20.0 43.6, 29.3 69.2, 53.2 51.8	33.8 ± 5.0 43.6 ± 17.2

Type III: Predominantly in two or more **samples**					
2	7/29/12	11:00, 14:00	25.9, 40.1	69.9, 23.6	38.3 ± 3.4 27.2 ± 12.0
	7/30/12	14:00	34.5	45.3	
	7/31/12	**14:30, 16:30**	**38.8, 40.7**	**23.2, 20.0**	
	8/1/12	13:45	37.5	29.3	
	8/3/12	11:00	31.8	51.8	
4	**7/29/12**	**14:00**	**40.1**	**23.6**	38 ± 3.3 30.4 ± 11.6
	7/30/12	11:00, 14:00	30.0, 34.5	56.2, 45.3	
	7/31/12	14:30, **16:30**	38.8, **40.7**	23.2, **20.0**	
	8/1/12	13:45	37.5	29.3	
7	7/29/12	16:30	40.3	25.3	34.5 ± 4.8 40.0 ± 17.2
	7/30/12	11:00	34.5	45.3	
	7/31/12	**14:30, 16:30**	**38.8, 40.7**	**23.2, 20.0**	
	8/1/12	**11:00, 13:45**	**32.5, 37.5**	**43.6, 29.3**	
	8/2/12	**11:10**, 14:00, **15:45**	**27.2**, 30.7, **31.4**	69.2, 53.2, 49.7	
8	7/29/12	11:00	25.9	69.9	33.9 ± 5.7 42.7 ± 20.5
	7/30/12	11:00	30.0	56.2	
	7/31/12	**14:30, 16:30**	**38.8, 40.7**	**23.2, 20.0**	
	8/1/12	**13:45**	**37.5**	**29.3**	
	8/2/12	**11:10**, 14:00, 15:45	**27.2**, 30.7, 31.4	**69.2**, 53.2, 49.7	
10	7/29/12	11:00, 14:00, 16:30	25.9, 40.1, 40.3	69.9, 23.6, 25.3	35.1 ± 4.5 39.2 ± 15.2
	7/30/12	11:00, **14:00**	30.0, **34.5**	56.2, **45.3**	
	7/31/12	**16:30**	**40.7**	**20.0**	
	8/1/12	**11:00**, 13:45	**32.5**, 37.5	**43.6**, 29.3	
	8/2/12	11:10, 14:00, 15:45	27.2, 30.7, 31.4	69.2, 53.2, 49.7	
	8/3/12	11:00	31.8	51.8	
11	7/29/12	11:00, 14:00, 16:30	25.9, 40.1, 40.3	69.9, 23.6, 25.3	33.5 ± 4.7 44.2 ± 16.1
	7/30/12	**11:00**, 14:00	**30.0**, 34.5	**56.2**, 45.3	
	7/31/12	**16:30**	**40.7**	**20.0**	
	8/1/12	**11:00, 13:45**	**32.5, 37.5**	**43.6, 29.3**	
	8/2/12	11:10, 14:00, **15:45**	27.2, 30.7, **31.4**	69.2, 53.2, **49.7**	
	8/3/12	11:00	31.8	51.8	
13	7/29/12	11:00, 14:00, 16:30	25.9, 40.1, 40.3	69.9, 23.6, 25.3	34.8 ± 5.5 40.1 ± 19.4
	7/30/12	11:00, 14:00	30.0, 34.5	56.2, 45.3	
	7/31/12	**14:30, 16:30**	**38.8, 40.7**	**23.2, 20.0**	
	8/1/12	**11:00**, 13:45	**32.5**, 37.5	**43.6**, 29.3	
	8/2/12	**11:10**	**27.2**	**69.2**	
14	7/29/12	14:00, 16:30	40.1, 40.3	23.6, 25.3	36.2 ± 4.1 34.6 ± 13.9
	7/30/12	11:00, 14:00	30.0, 34.5	56.2, 45.3	
	7/31/12	14:30, 16:30	38.8, 40.7	23.2, 20.0	
	8/1/12	**11:00, 13:45**	**32.5, 37.5**	**43.6, 29.3**	
	8/2/12	11:10, 14:00	27.2, 30.7	69.2, 53.2	
	8/3/12	11:00	31.8	51.8	
23	**7/29/12**	**14:00, 16:30**	**40.1, 40.3**	**23.6, 25.3**	35.1 ± 5.7 40.4 ± 18.4
	7/30/12	**11:00**	**30.0**	**56.2**	
	8/1/12	11:00	32.5	43.6	
	8/2/12	11:10	27.2	69.2	
Type IV: Cluster contains at least one compound in every sample					
5	7/29/12	11:00, 14:00, 16:30	25.9, 40.1, 40.3	69.9, 23.6, 25.3	33.7 ± 4.9 43.9 ± 16.8
	7/30/12	11:00, 14:00	30.0, 34.5	56.2, 45.3	
	7/31/12	14:30, 16:30	38.8, 40.7	23.2, 20.0	
	8/1/12	11:00, 13:45	32.5, 37.5	43.6, 29.3	
	8/2/12	11:10, 14:00, 15:45	27.2, 30.7, 31.4	69.2, 53.2, 49.7	
	8/3/12	11:00	31.8	51.8	

6	7/29/12	11:00, 14:00, 16:30	25.9, 40.1, 40.3	69.9, 23.6, 25.3	
	7/30/12	11:00, 14:00	30.0, 34.5	56.2, 45.3	
	7/31/12	14:30, 16:30	38.8, 40.7	23.2, 20.0	33.8 ± 5.0
	8/1/12	11:00, 13:45	32.5, 37.5	43.6, 29.3	43.6 ± 16.8
	8/2/12	11:10, 14:00, 15:45	27.2, 30.7, 31.4	69.2, 53.2, 49.7	
	8/3/12	11:00	31.8	51.8	
12	7/29/12	11:00, 14:00, 16:30	25.9, 40.1, 40.3	69.9, 23.6, 25.3	
	7/30/12	11:00, 14:00	30.0, 34.5	56.2, 45.3	
	7/31/12	14:30, 16:30	38.8, 40.7	23.2, 20.0	34.5 ± 4.7
	8/1/12	11:00, 13:45	32.5, 37.5	43.6, 29.3	41.3 ± 15.9
	8/2/12	11:10, 14:00, 15:45	27.2, 30.7, 31.4	69.2, 53.2, 49.7	
	8/3/12	11:00	31.8	51.8	

5.4. Compounds Assigned by Cluster

Table B.4.1. Compounds Assigned to Type I Clusters			
Cluster 1: Predominantly detected on 7/31/12 at 4:30PM			
Compound	RT_c	*I*	*R*
Unknown 15	794.3719	794	3.719
Heptane, 3-ethyl-5-methylene-	838.0806	838	0.806
Cyclopropane, 1-methyl-2-(3-methylpentyl)-	951.0801	951	0.801
4-Nonene, 5-methyl-	964.0812	964	0.812
1,4-Hexadiene, 3-ethyl-4,5-dimethyl-	983.0923	983	0.923
1,1'-Bicycloheptyl	998.0876	998	0.876
Benzene, (1-methylpropyl)-	1020.1527	1020	1.527
Benzene, 1-methyl-2-(1-methylethyl)-	1031.1542	1031	1.542
Cyclohexane, butyl-	1037.0882	1037	0.882
Cyclodecane	1041.0858	1041	0.858
Bicyclo[3.1.0]hex-2-ene, 4-methylene-1-(1-methylethyl)-	1067.1619	1067	1.619
Benzene, 2-ethyl-1,4-dimethyl-	1094.1697	1094	1.697
2-Octene, 4-ethyl-	1097.0773	1097	0.773
Ethanone, 1-(1,2,2,3-tetramethylcyclopentyl)-, (1R-cis)-	1131.0858	1131	0.858
Benzene, 1,2,4,5-tetramethyl-	1180.2059	1180	2.059
2-Decanone	1199.1712	1199	1.712
2-Decenal, (Z)-	1275.2241	1275	2.241
Cyclooctane, 1,4-dimethyl-, trans-	1336.0806	1336	0.806
Cyclohexanone, 3-butyl-	1359.0806	1359	0.806
2,4,4-Trimethyl-3-(3-methylbutyl)cyclohex-2-enone	1373.2225	1373	2.225
2-Undecenal	1379.2167	1379	2.167
1,2,4-Methenoazulene, decahydro-1,5,5,8a-tetramethyl-, [1S-(1à,2à,3aá,4à,8aá,9R*)]-	1405.1208	1405	1.208
Cyclopentanone, 2-cyclopentylidene-	1411.3760	1411	3.760
Cyclohexane, 1-methyl-2-propyl-	1415.0923	1415	0.923
2,4,4-Trimethyl-3-(3-methylbutyl)cyclohex-2-enone	1421.2266	1421	2.266
Cyclohexane, (1-methylpropyl)-	1508.0899	1508	0.899
Oxalic acid, di(cyclohexylmethyl) ester	1508.0923	1508	0.923
6,11-Dimethyl-2,6,10-dodecatrien-1-ol	1510.1250	1510	1.250
5-tert-Butylpyrogallol	1512.3306	1512	3.306
Cyclohexane, 1-isopropyl-1-methyl-	1516.0930	1516	0.930
Oxalic acid, cyclohexylmethyl isohexyl ester	1521.0948	1521	0.948
2-Pentanone, 3-[(acetyloxy)methyl]-3,4-dimethyl-, (.+-.)-	1538.0784	1538	0.784
Benzene, (1-butylhexyl)-	1544.1271	1544	1.271
Nonane, 3-methylene-	1587.0911	1587	0.911

1,4-Hexadiene, 2,3,4,5-tetramethyl-	1598.1250	1598	1.250
Cyclohexane, (1-methylpropyl)-	1609.0917	1609	0.917
Cyclohexane, 1-(cyclohexylmethyl)-2-methyl-, cis-	1621.1377	1621	1.377
Unknown 40	1678.3787	1678	3.787
Cyclohexane, 1-methyl-2-propyl-	1718.0973	1718	0.973
Cluster 3: 7/29/12 at 2:00PM			
Compound	RT_c	*I*	*R*
3-Heptene, 4-propyl-	848.0795	848	0.795
4-Nonene, 3-methyl-, (Z)-	948.0789	948	0.789
3,4-Diethyl-3-hexene	955.0852	955	0.852
4-Nonene, 3-methyl-, (Z)-	964.0823	964	0.823
4-Nonene, 5-methyl-	982.0818	982	0.818
3-Octene, 2,2-dimethyl-	1014.0835	1014	0.835
Nonane, 3-methylene-	1071.0823	1071	0.823
1,3-Benzodioxole, 5-(2-propenyl)-	1603.4196	1603	4.196
Unknown 16	1829.0521	1829	0.521
Cluster 9: 8/1/12 at 11:00 AM			
Compound	RT_c	*I*	*R*
2-Butenal, 2-methyl-, (E)-	748.2952	748	2.952
4-Nonene, 3-methyl-, (Z)-	811.0812	811	0.812
3,4-Diethyl-2-hexene	918.0751	918	0.751
Benzene, 1-methyl-2-propyl-	1067.1580	1067	1.580
Linalool	1102.2896	1102	2.896
5-Methyl-2-(2-methyl-2-tetrahydrofuryl)tetrahydrofuran	1255.0756	1255	0.756
Cyclohexane, 1-ethyl-1,3-dimethyl-, trans-	1352.0823	1352	0.823
Cluster 16: 7/30/12 at 2:00PM			
Compound	RT_c	*I*	*R*
3-Ethyl-4-octene	930.0784	930	0.784
3-Nonene, 3-methyl-, (E)-	961.0835	961	0.835
3-Octene, 4-ethyl-	964.0806	964	0.806
3-Ethyl-3-octene	979.0795	979	0.795
1,3-Heptadiene, 3-ethyl-2-methyl-	983.0930	983	0.930
Cyclohexane, 1,1,3,5-tetramethyl-, cis-	1004.0762	1004	0.762
2-Nonene, 3-methyl-, (E)-	1006.0846	1006	0.846
1,3-Heptadiene, 3-ethyl-2-methyl-	1006.0954	1006	0.954
3-Ethyl-4-octene	1009.0778	1009	0.778
3-Octene, 4-ethyl-	1026.0806	1026	0.806
Cyclohexane, 1,1,3,5-tetramethyl-, trans-	1030.0818	1030	0.818
Cyclohexane, 1,2-diethyl-, cis-	1033.0829	1033	0.829
Cyclodecane	1039.0870	1039	0.870

Cyclohexane, 1,1,3,5-tetramethyl-, trans-	1047.0852	1047	0.852
Ethanone, 1-(1,2,2,3-tetramethylcyclopentyl)-, (1R-cis)-	1048.0870	1048	0.870
Benzene, butyl-	1067.1603	1067	1.603
1-Hexene, 4,4-diethyl-	1081.0917	1081	0.917
5,7-Dimethyloctahydrocoumarin	1094.0818	1094	0.818
Unknown 16	1121.0852	1121	0.852
3-Octene, 2,2-dimethyl-	1136.0870	1136	0.870
1-Decene	1192.1285	1192	1.285
Cyclooctane, ethyl-	1480.0795	1480	0.795
Unknown 25	1833.0521	1833	0.521
Unknown 32	1906.0521	1906	0.521
Cluster 18: 8/2/12 at 3:45 PM			
Compound	RT_c	*I*	*R*
Ethanone, 1-(1,2,2,3-tetramethylcyclopentyl)-, (1R-cis)-	896.1105	896	1.105
3-Ethyl-4-octene	918.1065	918	1.065
3-Heptene, 4-propyl-	936.1115	936	1.115
[1,1'-Bicyclopentyl]-2-one	939.0823	939	0.823
4-Allyl-1,6-heptadiene-4-ol	955.1165	955	1.165
trans-4-Decene	964.1130	964	1.130
Ethanone, 1-(1,2,2,3-tetramethylcyclopentyl)-, (1R-cis)-	1094.1100	1094	1.100
3,4-Diethyl-2-hexene	1506.1095	1506	1.095
Cyclooctane, 1,4-dimethyl-, trans-	1551.0806	1551	0.806
Cyclopentane, (2-methylbutyl)-	1564.1100	1564	1.100
Octane, 3-methyl-6-methylene-	1590.1145	1590	1.145
Sabinene	1610.1134	1610	1.134
Cluster 20: 7/31/12 at 2:30 PM			
Compound	RT_c	*I*	*R*
2-Butenal, 3-methyl-	791.4282	791	4.282
1,5-Heptadien-4-one, 3,3,6-trimethyl-	834.0773	834	0.773
Benzene, tert-butyl-	1003.1565	1003	1.565
à-Phellandrene	1012.1181	1012	1.181
Oxalic acid, bis(isobutyl) ester	1023.0734	1023	0.734
à- Terpinene	1025.1188	1025	1.188
β-Phellandrene	1041.1271	1041	1.271
gamme terpinene	1064.1271	1064	1.271
Bicyclo[4.1.0]hept-3-ene, 3,7,7-trimethyl-, (1S)-	1066.1264	1066	1.264
2,2'-Bi-2H-pyran, octahydro-	1078.0734	1078	0.734
Terpinolene	1092.1321	1092	1.321
Benzene, 2-ethyl-1,3-dimethyl-	1124.1880	1124	1.880
Benzene, 1,2,3,4-tetramethyl-	1144.1848	1144	1.848

Benzene, 1-methyl-4-(1-methylpropyl)-	1158.1527	1158	1.527
1H-Indene, 2,3-dihydro-4-methyl-	1160.2167	1160	2.167
1H-Indene, 2,3-dihydro-4-methyl-	1172.2275	1172	2.275
Cyclohexanol, 3,3,5-trimethyl-, acetate, cis-	1201.1542	1201	1.542
Ethanone, 1-[4-(1-methylethyl)phenyl]-	1340.3615	1340	3.615
Menthol, 1'-(butyn-3-one-1-yl)-, (1S,2S,5R)-	1678.3774	1678	3.774
Unknown 9	1678.3801	1678	3.801
1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	1855.3536	1855	3.536
Cluster 22: 7/30/12 2:00 PM			
Compound	RT_c	*I*	*R*
Unknown 4	809.0876	809	0.876
Heptane, 2,2,3,5-tetramethyl-	981.0724	981	0.724
3-Cyclopentylpropionic acid, 2-tetrahydrofurylmethyl ester	1023.0745	1023	0.745
7-Octen-2-ol, 2,6-dimethyl-	1075.2375	1075	2.375
5-Methyl-2-(2-methyl-2-tetrahydrofuryl)tetrahydrofuran	1086.0745	1086	0.745
Undecane	1100.0767	1100	0.767
Bicyclo[3.1.1]heptan-3-one, 2,6,6-trimethyl-, (1à,2á,5à)-	1190.0812	1190	0.812
Undecane	1199.0784	1199	0.784
5-Undecanone	1277.1467	1277	1.467
Undecanal	1314.1642	1314	1.642
Undecane	1340.0756	1340	0.756
1-Octene, 3,7-dimethyl-	1564.0784	1564	0.784
Cluster 24: 8/1/12 1:45 PM			
Compound	RT_c	*I*	*R*
Bicyclo[2.1.0]pentane	548.0756	548	0.756
1-Octene, 3,7-dimethyl-	758.0767	758	0.767
1-Octene, 2,6-dimethyl-	975.0823	975	0.823
2-Octene, 3,7-dimethyl-, (Z)-	1006.0852	1006	0.852
Benzene, 1-methyl-3-propyl-	1063.1580	1063	1.580
Unknown 21	1091.0806	1091	0.806
1-Decene	1092.0846	1092	0.846
Ethanone, 1-(1,2,2,3-tetramethylcyclopentyl)-, (1R-cis)-	1367.0835	1367	0.835
Cyclohexane, 1-ethyl-1,3-dimethyl-, trans-	1459.0801	1459	0.801
Cyclooctane, 1,4-dimethyl-, trans-	1476.0806	1476	0.806
Cyclohexane, 1-ethyl-1,3-dimethyl-, trans-	1480.0801	1480	0.801
Unknown 50	1904.0530	1904	0.530
Cluster 25: 8/2/12 at 11:10 AM			
Compound	RT_c	*I*	*R*
1,7-Nonadien-4-ol, 4,8-dimethyl-	1259.1650	1259	1.650
Cluster 26: 8/3/12 at 11:00 AM			

Compound	RT_c	*I*	*R*
3,4-Diethyl-2-hexene	1009.0773	1009	0.773
Cyclohexane, 2,4-diisopropyl-1,1-dimethyl-	1077.0806	1077	0.806
Cluster 27: 7/29/12 at 11:00 AM			
Compound	RT_c	*I*	*R*
2H-Pyran, tetrahydro-2-[(tetrahydro-2-furanyl)methoxy]-	1078.0740	1078	0.740
Sabinene	1091.1134	1091	1.134
2-Decen-1-ol	1285.1650	1285	1.650

Table B.4.2. Compounds Assigned to Type II Clusters

Cluster No.	*Compound Name*	RT_c	*I*	*R*
15	β-Pinene	985.1094	985	1.094
17	trans-3-Decene	992.0829	992	0.829
19	à-Thujene	930.0948	930	0.948
21	Cyclooctane, 1,4-dimethyl-, trans-	1083.0801	1083	0.801

Table B.4.3. Compounds Assigned to Cluster Type III

Cluster 2			
Compound	RT_c	*I*	*R*
Benzene, 1-methyl-2-(1-methylethyl)-	1074.1634	1074	1.634
Benzene, 1-methyl-3-propyl-	1067.1588	1067	1.588
Benzene, 1-methyl-4-(1-methylethenyl)-	1105.2167	1105	2.167
Benzene, 2-ethyl-1,3-dimethyl-	1097.1720	1097	1.720
Benzene, 2-ethyl-1,3-dimethyl-	1102.1736	1102	1.736
Benzoic acid, 2-ethylhexyl ester	1722.2391	1722	2.391
Dodecyl acrylate	1690.1527	1690	1.527
Homosalate	1874.3024	1874	3.024
Cluster 4			
Compound	RT_c	*I*	*R*
trans-4-Decene	975.0818	975	0.818
2,4-Pentadien-1-ol, 3-pentyl-, (2Z)-	1041.0846	1041	0.846
Benzene, (1-methylpropyl)-	1063.1588	1063	1.588
1-Octyn-3-ol, 4-ethyl-	1112.1482	1112	1.482
Cyclohexanone, 4-(1,1-dimethylpropyl)-	1189.1760	1189	1.760
Longifolene	1440.1321	1440	1.321
Butylated Hydroxytoluene	1525.2051	1525	2.051

Cluster 7			
Cyclohexane, 2-ethenyl-1,1-dimethyl-3-methylene-	1119.1208	1119	1.208
2-Ethylhexyl salicylate	1814.2491	1814	2.491
Homosalate	1898.3229	1898	3.229
Cluster 8			
Compound	RT_c	*I*	*R*
Geranyl acetone	1461.2150	1461	2.150
Thujopsene	1464.1386	1464	1.386
Cluster 10			
Compound	RT_c	*I*	*R*
3,4-Diethyl-3-hexene	927.0773	927	0.773
Tricyclene	930.0942	930	0.942
2-Octene, 4-ethyl-	935.0795	935	0.795
trans-4-Decene	995.0835	995	0.835
Cyclooctane, 1,4-dimethyl-, trans-	1571.0818	1571	0.818
Cluster 11			
Compound	RT_c	*I*	*R*
3-Octene, 4-ethyl-	945.0795	945	0.795
2-Decen-1-ol	1177.1626	1177	1.626
Decanal	1212.1681	1212	1.681
[1,1'-Bicyclopentyl]-2-one	1301.2928	1301	2.928
Cluster 13			
à-Cedrene	1447.1278	1447	1.278
Benzene, 1-methyl-4-(1,2,2-trimethylcyclopentyl)-, (R)-	1538.1848	1538	1.848
Cluster 14			
Compound	RT_c	*I*	*R*
2-Pentanone, 3-[(acetyloxy)methyl]-3,4-dimethyl-, (.+-.)-	896.0778	896	0.778
Sabinene	979.1127	979	1.127
β-Myrcene	992.1147	992	1.147
3-Carene	1017.1114	1017	1.114
Z-Ocimene	1039.1236	1039	1.236
Z-Ocimene	1052.1278	1052	1.278
Benzene, 1,2,4,5-tetramethyl-	1148.1904	1148	1.904
Benzene, 1,3-bis(1,1-dimethylethyl)-	1263.1174	1263	1.174
Cluster 23			
Compound	RT_c	*I*	*R*
2-Propenoic acid, 2-ethylhexyl ester	1189.1437	1189	1.437
Methyl 4,6-decadienyl ether	1626.1452	1626	1.452

Table B.4.4. Type IV			
Cluster 5			
Compound	RT_c	*I*	*R*
Isoprene	510.0718	510	0.718
Nonane, 3-methylene-	986.0835	986	0.835
Methyl 4,6-decadienyl ether	1428.1042	1428	1.042
Cluster 6			
Methacrolein	564.1697	564	1.697
Methyl vinyl ketone	590.2591	590	2.591
3-Methylheptyl acetate	1153.1357	1153	1.357
Cluster 12			
Cyclohexane, 1,1,3,5-tetramethyl-, cis-	894.0784	894	0.784
Cyclohexane, 1,1,3,5-tetramethyl-, cis-	914.0801	914	0.801
3-Ethyl-4-octene	939.0806	939	0.806
à-Pinene	941.0942	941	0.942
Heptane, 3-ethyl-5-methylene-	946.0818	946	0.818
1-Decene	951.0806	951	0.806
Camphene	957.1048	957	1.048
trans-4-Decene	992.0823	992	0.823
Limonene	1036.1222	1036	1.222
p-Cymene	1037.1550	1037	1.550
1-Octene, 3,7-dimethyl-	1088.0801	1088	0.801

6. Appendix C. MATLAB Code for PINOT NOIR data

```
%Data is a matrix n x m, where each row (n) refers to one compound, columns
%(m) correspond to each sample and each entry give compound concentration
%(μg/m^3))
%Similiarity measure: Spearman; linkage metric: average
%Dendrogram compressed into 30 nodes
%T gives where each row (variable) falls into the node
Y=pdist(data,'spearman')
ZA=linkage(Y,'average')
figure(1)
[H,T,outperm]=dendrogram(ZA)

%To calculate cophenetic correlation (how well linkage matrix that codes the
%dendrogram represents the original data matrix)
ca=cophenet(ZA,Y)

%To generate dendrogram with all 204 variables
figure(2)
H193=dendrogram(ZA,204)

%Cluster into 27 groups (try many different clusters to determine optimal
%number)
C25 = cluster(ZA,'maxclust',27)

%To plot results create a matrix that collapses all concentrations into one column,
%with corresponding compounds, retention times and other variables such as
%temperature, relative humidity, time of day, date, etc in separate columns

%Example: 2D plot of two retention times with cluster number represented by
%color and symbol shape. Where c is the column of corresponding cluster
%number, RIX is retention index and RRY is second dimension retention ratio
h2d=gscatter(RIX,RRY,c,[],'ox+*sdv^<>ph.')

%For 3D plot with clusters represented by color and symbol shape, code modified
%from http://www.mathworks.com/matlabcentral/answers/92577-how-can-i-
%create-a-3d-grouped-scatter-plot-in-statistics-toolbox-7-2-r2009b
h = gscatter(x, y, c,[],'ox+*sdv^<>ph.');
%For each unique group in 'c', set the ZData
gu = unique(c);
for k = 1:numel(gu)
    set(h(k), 'ZData', z( c == gu(k) ));
end
view(3)
```