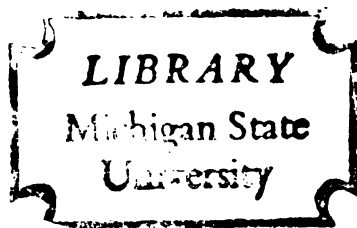




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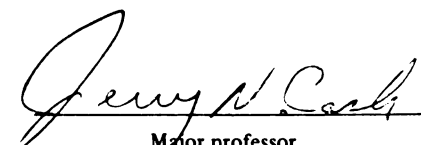
The Study of Aroma Characteristics
of Raw Carrots With the Use of
Factor Analysis

presented by

Mark Richard McLellan

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The Study of Aroma Characteristics of Raw Carrots
With the Use of Factor Analysis

By

Mark Richard McLellan

A DISSERTATION

Submitted to
Michigan State University
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for the degree of

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ABSTRACT

The Study of Aroma Characteristics of Raw Carrots With the Use of Factor Analysis

By

Mark R. McLellan

9/11/68

Raw carrot aromatic volatiles were collected and concentrated using the porous polymer, Tenax-GC. Some of the collected volatiles were identified using mass spectrometry and by comparing retention times with those of standards. Ratios of headspace volatiles were quite different from those previously reported in the literature, due to the mild collection conditions used in in this study.

Sensory evaluations on twenty aroma-related characteristics were performed on the raw carrot aroma of ten largely different carrot selections. The sensory evaluation data were collected through the use of a micro-computer built into the sensory evaluation booth. Factor analysis was applied to the sensory evaluations to determine true orthogonal descriptors which were derived from the original set of data.

Five distinctly different characteristics of the raw carrot aroma were determined: (1) an earthy organic aroma, (2) a basic raw carrot aroma, (3) the intensity level of aromatics other than carrot, (4) the desirability level of pleasant aromatics (non-earthy) in carrots and

(5) piney aroma. These aroma characteristics constitute an accounting of some 70% of the variation in raw carrot aroma. Through factor analysis, these new aroma characteristics were reconstructed in the form of a new data base to be evaluated with the headspace analysis data.

A second application of factor analysis was utilized to point to possible peaks in the headspace chromatographic profile which were tested using multiple regression techniques to determine relationships to the five new sensory characteristics. Only one of the regression equations had an indication of significance and it related to the earthy organic aroma and three trace level peaks. When further tested for inclusion of the regression variables in the equation, none proved significant.

These findings support the contention that the aroma constituents of raw carrots play a minor role when compared to the taste parameters in the acceptance of raw carrots.

THIS MANUSCRIPT IS DEDICATED
TO THE THREE PEOPLE I HOLD
CLOSEST TO MY HEART

My wife - Deanne
My son - Justin
AND
My Dad

ACKNOWLEDGMENTS

I am sincerely grateful to Dr Jerry N. Cash for his suggestions and support throughout the course of my education at MSU. As my major professor, he was a source of both guidance and friendship.

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INTRODUCTION

Our lack of knowledge concerning the mechanisms by which we perceive tastes and odors contrasts starkly with our understanding of the processes by which we perceive sounds and visual images. In general, we can store, retrieve, amplify, transmit, duplicate, and describe objectively the sights we see and the sounds we hear. Unfortunately, few if any of these operations can be duplicated for a single taste or odor.

For man, flavor and nutrition are simply two sides of the same coin. What smells and tastes good is eaten with sensual delight, many times irregardless of nutritional benefit. Man will reject the most nutritious and wholesome food, unless he got some degree of olfactory and sapid enjoyment.

In his attempt to understand the complexities of flavor, man has turned to the analytical chemist for insight into the chemical makeup of our food. We have asked the sensory analyst to evaluate our judgements on flavor, interpreting our responses as measurements of gustation and olfaction. Physiologists study the construction and "operation" of our flavor senses and the

behavioral-psychologists attempt to interpret the thought processes behind it all. Man has thrown the full weight of his scientific advancement against the barriers of ignorance preventing our understanding of these special senses. And so far, comparatively little progress can be shown for it all but studies continue investigating the relationships between the chemistry of food and its sensual characteristics.

Carrots, (Daucus carota L.) are a relatively important crop in the United States and are used extensively for fresh market and processing into canned, frozen, and dehydrated products. The Division of Economic and Statistical Analysis of USDA reports that including fresh, frozen, and canned carrots the population of the United States consumes some 9.6 grams of carrots/ capita/ day (Powel, 1981). Improving the culinary quality of raw carrots appeals to both the processor and consumer alike. Various phases of this research have been attempted with differing degrees of success. In most previous studies that involved sensory analysis of carrots, panelists were asked to taste the carrots and rate various attributes. These attributes varied; however, most measured the sapid attributes of the carrot tissue. Any aroma characteristics were for the most part measured using very general terms such as "flavor intensity" (Schreerens and Hosfield, 1976), "overall flavor and harsh flavor" (Simon et al., 1980). And even in these cases, the ability to distinguish

between taste and smell were not strived for.

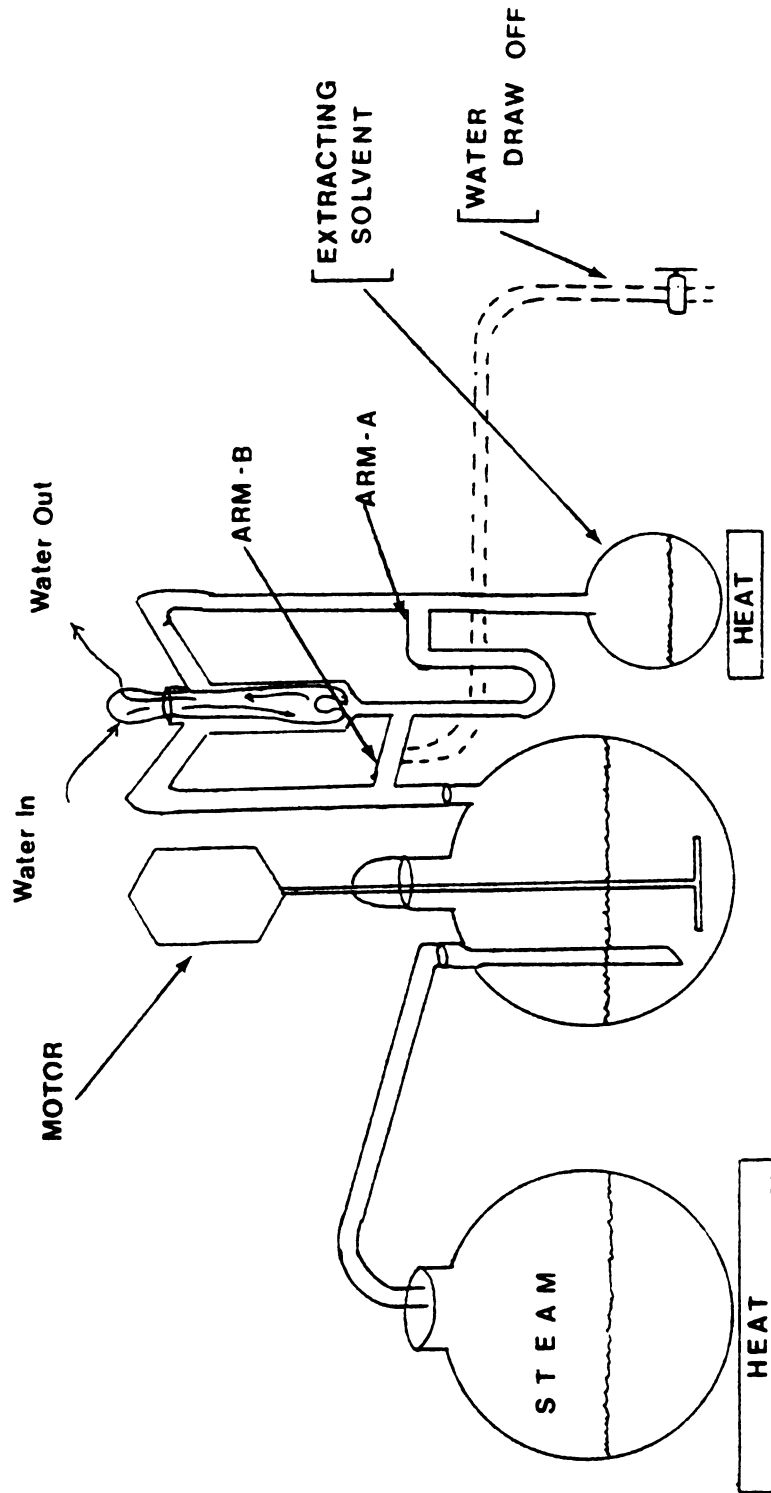
In this study, an attempt was made to evaluate the aroma attributes of raw carrots. No taste parameters were included. Sensory evaluations of the aromas were compared to objective measurements of aroma volatiles with the use of factor analysis.

LITERATURE REVIEW

A. Carrot Flavor Volatiles.

Extensive studies have been done on the composition of carrot seed oil (Seifert et al., 1968), but until 1968, virtually no studies were done on the composition of volatiles present in the carrot root. Buttery et al. 1968, published the results of their in-depth analysis of carrot root volatiles utilizing a steam volatile oil collected at atmospheric pressure with a continuous extraction apparatus as shown in Figure 1 (Liken and Nickerson, 1964). The apparatus allows simultaneous condensation of the steam distillate and an immiscible extracting solvent. The distillates return to their respective distillation flasks via arms at different levels. In Figure 1, the water phase returns through arm B and the low boiling alkane through arm A. The steam can be introduced into the system by heating the carrot slurry or by introducing it from an outside source. In the latter case a water draw off valve and drain is included in the design. The low boiling alkane must be heated to maintain a relatively high vapor pressure for the extraction process. For the

Figure 1. A continuous extraction apparatus first designed by Liken and Nickerson (1964) for the extraction of volatiles with a comparatively small amount of solvent. Some discussed modifications are presented. (Lester,1981)



process to work, sufficient steam must be provided to flow through the slurry and on to the condenser; consequently, without reduced pressure, the carrot slurry would maintain a constant temperature of 100C. Furthermore, using hexane as the solvent would require maintaining the extraction solvent at or near 68C or in the case of heptane, 98C and pentane, 36C. Major components identified in this analysis were terpinolene, alpha-bisabolene, gamma-terpinene, carophylene, sabinene, and eight other less prominent terpenoid hydrocarbons. A number of oxygenated compounds were also identified: falcarinol, terpinene-4-ol, bornyl acetate, alpha-terpinol, myristicin, 2-nonenal, octanol, and eight other less prominent oxygenated compounds (Table A1 in Appendix A). Buttery et al. noted that the distillation extraction at atmospheric pressure resulted in an aroma of cooked carrots and that under reduced pressure at 40 to 45C the extraction had an odor somewhat similar to raw carrots.

In 1971, Heatherbell et al. characterized the effects of canning and freeze drying on carrot volatiles. Differences in volatile composition between canned, freeze-dried and raw carrots were found to be mainly quantitative and not qualitative. Canning resulted in an approximate 50% loss of "higher boiling" compounds; however, it produced an increase in "lower boiling" compounds, particularly methanol, which increased from 0.05 to 60 ppm (Appendix A, Table A2). Freeze drying

resulted in an approximate 75% loss of total volatile content. In a follow up paper, Heatherbell and Wrolstad reported on the influence of variety, maturity, and storage on carrot volatiles as determined by use of an on column trapping system combined with mass spectrascopic analysis. Their results indicated that differences were quantitative rather than qualitative in respect to all three factors (Heatherbell and Wrolstad, 1971a).

Enzymatic regeneration of volatile flavor components in carrots was the subject of a paper published in 1971 (Heatherbell and Wrolstad, 1971b). Limited success was reported; however, their technique provided no reproducible evidence for the enzymatic formation of volatile compounds coinciding with the enzymatic regeneration of raw carrot aroma.

In the late sixties, porous polymer chromatographic adsorbents were developed with the ability to efficiently and selectively retain organic molecules yet display a low affinity for water and other low molecular weight alcohols frequently encountered in food systems (Withycombe et al., 1978). The techniques of porous polymer headspace collection are as diverse and numerous as the number of scientists collecting headspace volatiles. The technique in general, consists of four essential components (1) a high purity purge gas at constant flowrate, (2) a sample container, (3) an adsorbent trap, and (4) a constant-condition desorption process.

Utilizing the porous polymer techniques of head-space analysis in a survey of the occurrence of 3-isopropyl-, 3-sec-butyl, and 3-isobutyl-2-methoxypyrazines found in raw vegetables, Murray and Whitfield (1975), reported that raw carrots contain amounts of less than 10ng of 3-isopropyl-2-methoxypyrazine, a compound found in greater amounts in asparagus, beans, beet roots, cucumbers, lettuce and peppers. They also reported the occurrence of 3-sec-butyl-2-methoxypyrazine in raw carrots at the level of 250ng, as well as in greater amounts, in beetroots, sweet peppers, and parsnips (Appendix A, Table A3). The raw vegetables in this study were put through a screw type extractor with added sodium chloride (NaCl) and the filtered juice was maintained in a saturated salt condition thereafter. Collection of volatiles utilized Chromosorb 105 as the porous polymer trap material and the sample flask was maintained at 28C. Trapped volatiles were subsequently eluted and gas chromatographed on a capillary Carbowax 20M column. Murray and Whitfield surmise that these 3-alkyl-2-methoxypyrazine compounds may play a significant role in the cooked or processed product. In odor character the sec-butyl compound more closely resembles the isopropyl than the isobutyl compound but has a less harsh quality. The compound, 3-sec-butyl-2-methoxypyrazine has been likened to peas and pea shells, but workers familiar with the aroma of galbanum have suggested that the two have qualities in common also (Murray and Whitfield, 1975).

In 1976, Cronin and Stanton (1976) reported that 3-sec-butyl-2-methoxypyrazine appeared to be an important contributor to carrot aroma (Appendix A, Table A4). Their

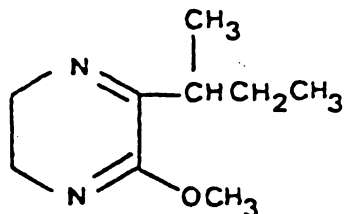


Figure 2. 3-sec-butyl-2-methoxypyrazine

work was based upon a steam distillation-extraction method with reintroduction of specific peaks using porous layered open tubular (PLOT) capillary traps (Clark and Cronin, 1975).

A characterization of some previously unidentified sesquiterpenes in the steam volatile oil of carrot roots was made by Siefert and Buttery (1978). (Appendix A, Table A1). Alpha-humulene and beta-farnesene were newly found volatiles and the previously identified beta- and gamma-bisabolene were confirmed to be actually both geometric isomers of gamma-bisabolene.

Seven new monocarbonyl compounds: undecanal, buten-2-al, methylbutenal, pentan-2-one, 6-methyl-5-hepten-2-one and 5-methylfurfural were reported using a distillation under reduced pressure at 30C (Linko et al., 1978). (Appendix A, Table A5).

In 1979, additional volatile constituents of carrot roots separated from a steam volatile oil, were identified. They included geranyl 2-methylbutyrate, geranyl isobutyrate, beta-ionone, geranylacetone, p-cymen-8-ol, elemicin, eugenol, p-vinylguaiaicol, and 4-methylisopropenylbenzene (Buttery et al., 1979). (Appendix A, Table A1.).

Simon et al. (1980a) investigated the genetic and environmental influences on carrot flavor. Gas liquid chromatography analysis utilizing the porous polymer trap technology yielded results similar to previous researchers. (See Appendix A, Table A6.) Sensory evaluation consisted of panelists judging the raw carrot slices on the following parameters: intensity difference, harsh biting flavor, sweetness, overall carrot flavor, and degree of preference. Their results indicated that carrot flavor attributes were influenced by genetic and environmental variation. Further work by the same authors (Simon et al., 1980b) indicated correlations between the above mentioned taste parameters and objective measurements including sugars, carotenoids and volatile components measured using porous polymer traps packed with Tenax GC (Simon et al., 1980c).

B. Carrot Taste

Carlton and Peterson (1963) evaluated the possibility of breeding carrots for sugar and dry matter content. Their results indicated that it is feasible to

select and inbreed to establish lines higher or lower and more uniform in sugar and dry matter than the varieties from which they were derived. Lester (1980) confirmed that specific parental lines and cultivars exhibit significantly higher concentrations for either reducing or non-reducing sugars and that breeding for reducing and non-reducing sugar content should be feasible. The free sugars that have been identified in carrots are fructose, glucose, sucrose and maltose (Rygg, 1945; Otsuka and Take, 1969; Alabran and Mabrouk, 1973; Phan et al., 1973; Lester, 1980).

The sapid components in carrots were studied to determine the importance of various components. The research indicated that the sweetness of the carrot was due to the presence of sucrose, maltose, and glucose and the taste of carrots was reported to be due mainly to the presence of glutamic acid and the buffering action of various amino acids (Otsuka and Take, 1969).

Alabran and Mabrouk (1973) indicate that aspartic acid, alpha-alanine, serine, and glutamic acid in the free form are abundant in fresh carrots and account for about 68% of the free nitrogenous compounds. Additionally the authors state that, due to the delicate flavor of carrots, the contribution of essential oils may be small in comparison with that of the non-volatile, taste-bearing components.

A study involving the feasibility of improving

eating quality of table carrots by selecting for total soluble solids tends to support the fact that consumers show a slight preference for eating carrots from a high soluble solids selection (Scheerens and Hosfield, 1976). The authors indicate that background constituents of carrot flavor may play an important role in the perception of sweetness at all levels of soluble solids.

Some of the original studies on carrot roots dealt with the determination of sugars; however, much concern over the storage quality of carrots led to the investigation of a bitter component recognized in carrots especially found during certain storage conditions (Sondheimer et al., 1955; Sell, 1956; Carolus and Ellis, 1957). The isolation and identification of 3-methyl-6-methoxy-8-hydroxy-3,4-dihydroisocoumarin (Figure 3) from carrots was the first characterization of this bitter component (Sondheimer, 1956; Sondheimer, 1957).

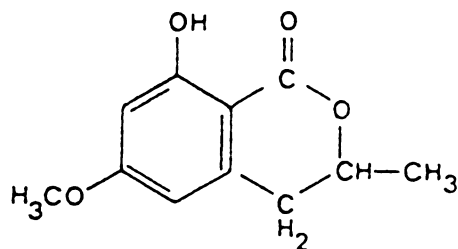


Figure 3. 3-Methyl-6-methoxy-8-hydroxy-3,4-dihydroisocoumarin

Further work accounted for the effect of ethylene on stimulation and/or catalysis of formation of the

isocoumarin compound responsible for the bitter taste in some carrots (Carlton et al., 1961; Condon and Draudt, 1963; Chalutz et al., 1969; Sarkar and Phan, 1979).

C. Carrot Storage

Researchers have investigated the optimum conditions for storage of carrots (Berg and Lentz, 1966; Berg and Lentz, 1973; Phan et al, 1973). Those conditions appear to consist of two major factors: (1) Optimum temperature between 0-2C. (2) Optimum relative humidity between 98-100%. In 1977, Weichmann (1977) reported on the response of carrots to controlled atmosphere storage. He concluded that controlled atmosphere storage was not significantly advantageous over the previous recommendations of 0-2C and 98-100% RH.

D. Sensory descriptors of carrot flavor

Buttery et al.(1968) reported that sabinene and myrcene in dilute water solutions gave odors somewhat similar to the green tops of carrots. Heatherbell et al. (1971) described the raw carrot aroma as predominantly a "strong"(green-earthy) "carrot tops" note with varying degrees of "soft","sweet","pumpkin-like" and "perfumy" notes. The authors indicated that acetaldehyde appeared to lend a "soft","sweet" note and that sabinene and particularly myrcene contributed to the "green", "earthy" carrot top notes.

Cronin and Stanton(1976) suggest that although these individual compounds and notes affect the overall aroma they each alone or together do not represent the full story. The authors suggest that the "perfumy" character may be tied to terpinolene; however, they also report that 2-methoxy-3-sec-butylpyrazine makes a significant contribution to the overall aroma by imparting the slightly "sharp", "raw", "earthy", "rooty" character. The authors contend that this aroma complements the sweeter, oily, perfumy contributions made by the major terpinoid components.

Alabran et al.(1975) studied a dimensional characterization of the aroma from carrot-root oil and found that the descriptors for the carrot concept chosen by the panelists as most preferred were: "aromatic, light, fragrant, sweet, soft, green, warm".

Sweetness, bitterness, carrot flavor intensity, and carrot flavor type were sensory descriptors used in a taste panel involved in evaluating the feasibility of improving eating quality of table carrots by selecting for total soluble solids (Scheerens and Hosfield, 1976).

Martens et al.(1979) found that the most salient features of carrots from a sensory point of view were the following factors: "sharp, bitter, aftertaste, green grass, fruity, sweet, juciness, crisp, and hard resistance to chewing". They also reported that correlations, conical and others, between chemical and physical

variables on one side and sensory ones on the other, were low, but some were significant and meaningful.

Simon et al. (1980) used five flavor descriptors in their sensory analysis of carrots :
"intensity of difference, harsh biting flavor, sweetness, overall carrot aroma, and overall degree of preference".

E. Computer Interfacing to Sensory Measurement

Computers have enabled the researcher to manage, manipulate, and analyze data from all phases of science. In the area of sensory evaluation, many researchers are using computers for data analysis; however, few have published methods involving the computers in the actual data collection phase of sensory analysis. Gipps and Casimir (1973) described procedures by which panelists, at their laboratory, recorded scores directly on computer cards using the IBM Port-a-Punch system. This approach enabled checking, tabulation, and analyses to be carried out by the computer with minimal manual involvement.

Warner et al., 1974 reported on a system designed to assist taste panel managers doing manual calculations, as well as others who might expand their computer data handling systems. Their system included a score card designed for easy keypunching where each box on the card represented a column on an 80 column computer card. Once the data were keypunched; it was stored on disk for later analysis and breakdown.

MATERIALS AND METHODS

A. Selection of Raw Carrots for Study

All carrots used in this study were grown near Bath, MI. during 1978-1980 using standard cultural practices for organic soils (Anonymous, 1970).

In 1978, a review was made of previous years field trial books on carrot breeding at Michigan State University (MSU). Under a section reserved for the breeder's comments, mention was sometimes made of the flavor attributes for a particular breeding line or cultivar. Breeding lines and cultivars were noted for use in the aroma study if flavor comments were similar in any sequential double-year notation. Specific additional breeding lines were included in the study on the recommendation of the carrot breeding program. Also, specific cultivars were included because of their common use in the fresh market and processing industry.

In 1979, chosen breeding lines and cultivars for the aroma study were planted for a preliminary re-evaluation and use in establishing the environmental storage chamber.

Breeding lines and cultivars for use in the sensory and analytical study were planted May 28, 1980 and

harvested on September 27, 1980.

Of the carrots planted, 10 breeding lines and cultivars were chosen for use in the study (Table 1).

Table 1. -- Carrot lines and cultivars utilized in the analysis of raw carrot volatiles and for sensory evaluation of aroma attributes.
(Taken from MSU carrot breeding records)

=====

Breeding Line No./ Cultivar	Line No./ Pedigree	Field Trial Comment (if any)
<u>Parent</u>		
1413	MSU 1413	Bitter
1385	MSU 1385	Bitter - harsh
1383	MSU 1383	Perfumy - bland
5987	MSU 5987	Piney
107	MSU 107	Perfumy
6000	MSU 6000	High Sugar
 <u>Cultivars</u>		
Spartansweet	MSU 5931 x 6000	Commercial
Spartan Fancy 80	MSU (5931 x 6000) 1302	Commercial
Goldpak	Open-pollinated	Commercial
Gosinoostrovakaja 13	-	USSR - Low Sugar

B. Environmental Storage Chamber.

Carrot roots were stored under controlled conditions in an environmental storage cubicle. Temperature was maintained at $0 \pm 2^{\circ}\text{C}$. using a freon refrigeration system. Carrot greens were removed and carrots were washed prior to storage in wooden crates in the chamber. Relative humidity was maintained in the range of 95 to 99 % RH by an atomizer cycling on and off every two hours. Water flow was maintained to the atomizer by a small reservoir which was continuously monitored and refilled automatically by a pump connected to a 55 gallon distilled water supply tank. The supply tank needed refilling an average of once every month. (See Appendix B, Figure B1).

C. Porous Polymer Trap Preparation.

A modified version of the porous polymer trap system described by Simon et al(1980) was used in this study. Disposable pipets (Scientific Products Inc. McGaw Park, Il., P5211-2) were prepared for building of the traps by shortening the barrel on the large end to within one inch of the transition section of the pipet. A very fine copper wire was used to coax a light plug of glass wool down to the fine tip of the trap. Precisely 0.01g of Tenax GC (Applied Science Laboratories, State College, PA., Tenax GC 80/100 mesh) was funneled into the plugged trap. An additional plug of glass wool was placed on top of the column of Tenax GC and tamped lightly. The trap

was labeled and flushed with at least 1ml of ethyl ether anhydrous (Mallinckrodt, St.Louis, Mi). All traps were stored in a clean dry glass container with a fritted glass stopper.

D. Sampling and Volatile Collection.

Enough carrot roots were randomly selected from a breeding line or cultivar so that after trimming the carrot tissue would weigh approximately 1000 grams. An equal weight of distilled water was added to the remaining tissue that was sliced after trimming. Salt (NaCl) was added to the mixture at the level of 12% to reduce enzymatic oxidation. The complete mixture was put into a 4 liter Waring Blender and blended at low speed for 90 seconds.

Three 100 gram sub-samples of the blended mixture were each placed in a 500 ml round bottom boiling flask. Each of the flasks were placed in a water bath at 30C. with nitrogen from a controlled source bubbled through the sample at a rate of 15 ml/min.

The nitrogen-swept volatiles were carried through clear tubing (Fisher Scientific, Tygon R-3603) to the porous polymer traps. Flow from the traps was monitored via a bubble flow meter located at the end of the trap. Nitrogen flow was maintained through the sample for 1 hour and then each trap was dried using a flow of nitrogen, bypassing the blended carrot sample, for two minutes

(Appendix C, Figure C1). Traps were then removed, sealed with parafilm, (American Can Co., Greenwich, CT.) and stored at -23C until analysis.

E. Trap Elution.

Sample receptacles were made for use in the sample elution by shortening a disposable pipet (Scientific Products, McGaw Park, IL., P5211-1) to within one inch of the transition section. The thin end was then fired in a bunsen burner and rotated continuously until the glass formed a ball approximately 2-3 mm in diameter. This short thin cup was used to hold the eluted volatiles.

The porous polymer traps were readied for elution by removing the parafilm seals from both ends and placing approximately one ml of ethyl ether in the top of the trap. The trap was then inserted into a plastic manifold attached to a 5 cc B-D Cornwall glass syringe (Becton, Dickinson & Co.), (See Appendix D, Figure D1). The special sample receptacle was put under the trap and a slight pressure applied to the syringe plunger to effect the solvent flow. The first three drops, approximately 50ul, were collected from each trap and a 5ul sample was immediately injected into the gas chromatograph.

F. Gas Chromatography.

Gas - liquid chromatography was used to separate the various volatile constituents in raw carrot aroma.

Chromatographic conditions were as follows (See Appendix E for calculations):

Instrument : Hewlett Packard Model 5840A Research Gas Chromatograph equipped with microprocessor control and integration.

Detector : Flame Ionization.

* Peak Area = K * Mass

* Integrating Mass Flow Rate Detector.

Column : 25 meter Carbowax 20M Fused Silica Capillary Column (Carbowax 20M deactivated)

* Inside diameter = 0.20 - 0.21 mm

* Void volume (installed) = 785.3 cu.mm.

* HETP = approx. 4000

Carrier Gas : Nitrogen

Flow rates : Nitrogen = .52 ml/min.

Split Ratio = 1/121

Nitrogen make-up = 12 ml/min

Hydrogen = 35 ml/ min.

Air = 240 ml/ min.

Split Vent Flow = 60 ml/ min.

Temperature - Time Microprocessor Functions :

Temperature 1 = -30.00C.

* cooled using solid CO

Time 1 = 2.00 min.

2

Initial Linear Program Rate = 7.00 .

Temperature 2 = 130.00C.

Time 2 = 5.00 min.

Injection Temperature = 195.00C.

Flame Ionization Temperature = 130.00C.

Chart Speed = 0.75 cm/min.

Attenuation = 6.0

Slope Sensitivity = 0.05

Area Reject = 99980000000

Time 2.50 => Area Reject to 5

Time 6.00 => Attenuation to 1

Time 10.00 => Rate to 0.01

Time 14.00 => Rate to 30.00

Quantitative results for the purpose of comparisons between various carrot sample were based on reported peak area. Comparisons were considered valid as carrot samples were treated identically.

Five standards were purchased (K&K Fine and Rare Chemicals, Plainview NJ.) for use in the identification of some of the chromatographed volatiles : alpha-D-Pinene 95% (Lot-38117A), Myrcene Techn. (Lot-31123-A), DL-Limonene (Lot-31123-A), Isobornyl Acetate (Lot-32075-A), and Beta-Carophylene Techn. (Lot-34249-A).

G. Mass Spectrometry.

Fifteen traps were collected of a carrot selection mixture that would provide most of the compounds for high resolution mass spectrometer analysis. The eluted compounds were concentrated approximately 20 fold through a an endothermic nitrogen evaporation process. The resultant

concentrate was used in the HP 5989 GC-mass spectrometer system. The column used in the GC/MS system was a six foot glass column of 4mm id and packed with 5% Carbowax 20M. The following conditions were maintained by the gas chromatograph for the packed column:

Detector : Total ion

Carrier Gas : Helium = 40 ml/min.

Temperature - Time Microprocessor Functions:

Temperature 1 = 30C

Time 1 = 4.0 minutes

Rate = 4.0C/minute

Temperature 2 = 170C

Time 2 = 10 minutes

Injection temperature = 150C

Chart speed = 0.75 cm/min.

Attenuation = 10

Area reject = (-)

Time 4.5 => Attenuation to 6

Time 5.0 => Area reject to 1

Time 12.0 => Rate to 6C/min

The mass spectrometer was set up for a run time of 40 minutes. Start - Stop masses were 40 and 400 m/e respectively. Analog to digital conversion was on the order of 3 measurements per minute. The scan start was set to a 30 second delay with a threshold of 5.0, the most sensitive setting possible in relation to signal to noise ratios. The ion source temperature was set for 200C. The electron

multiplier was adjusted for 2200 electron volts and the ion source emitted 70 electron volts for standard ionization.

H. Sensory Evaluation - Open Discussion Profile Panel.

Prior to panel testing and sample evaluation an open discussion panel was convened for the purpose of developing proper descriptors for raw carrot aroma. Two sessions were run where each of seven judges was given two sets of five samples labeled A through E and F through J. The profile panel consisted of three stages : (1) initial discussion, (2) private evaluation and (3) open discussion. Each set of samples was presented to the panelists with a general discussion of the raw carrot puree. Panelists were asked to privately characterize the aroma by writing down appropriate descriptors. Open discussion of each sample was subsequently encouraged to exchange ideas and impressions. Judges were allowed to add to their list of descriptors during the discussion. Finally, each judge was asked to rank the five samples in order of preference based upon aroma. This process was repeated for the second set of samples and again for the two sets of samples in the second panel.

I. Sensory evaluation - Discrimination / Intensity Testing and Training.

All panelists were introduced to nine standards (Appendix F, Table F1) representing each of the classes of

smells identified by the flavor profile panel. No attempt was made to exactly duplicate any one odorant identified in carrots but rather the classes of odorants were represented. All samples were placed in plastic containers covered on the outside so that nothing inside could be seen and the sample was also covered on the inside with a 4 cm thick pad of tight fitting Dacron Fiber Fill II. All sample cups remained covered with lids until uncovered by the panelists. The panelists had a list of aroma definitions before them at all times during the sniffing (Appendix F, Table F2.).

After the introduction session, three testing sessions were run where each panelist was required to properly identify the nine standards. A data base was maintained on a TRS-80 Model II microcomputer (Tandy Corp., TRS-80 Model II , Appendix G, hereafter simply noted as "the microcomputer") for each panelist containing their scores on the testing/training phase. Each panelist was given a personalized ballot (Appendix H, Figure H1) containing not only the questions but also that panelist's previous results. The test sessions were started two days after the introduction session and ran for the next two days with the third panel following two days after the end of the first two test days. Panelists were allowed to get one answer wrong on the first test panel; however, thereafter all panel tests had to be completely correct.

Panelists correctly completing all requirements

were used in the sensory analysis of the raw carrot samples.

J. Sensory Evaluation - Raw Carrot Sample Analysis.

Carrots were prepared as explained in preparation of raw carrots for volatile analysis. A covered plastic cup was prepared for each sample, for each panelist. Approximately 50 ml of carrot puree were put in each cup and covered with a tight fitting cap until opened by the panelist.

Sensory analysis of carrot samples was performed using the microcomputer as the medium of interaction and data acquisition with the panelists. The panel booth was constructed around the microcomputer so that the integration of the two was uniform and non-distracting (Appendix G, Figure G1.). All questions asked of the panelists were presented on the video screen of the microcomputer through the use of a specially designed program writtern in BASIC (An acronym for Beginners All-purpose Symbolic Instruction Code) for the microcomputer (See Appendix I, Figure I1). Panelists initiated the session by typing in their last name on the microcomputer console keyboard. Once initiation of the panelist was completed for that session, a specially constructed mask was placed over the keyboard which only enabled access to the ">", "<", "?" and "space bar" keys. These keys represented all that was required to complete any acceptable response from the

panelists. Although each session consisted of 3-4 samples, the order of sampling was randomized by the computer and this order of sniffing was relayed to the panelists via messages on the video screen. Responses were automatically measured, interpreted, coded and stored for later use in statistical analysis.

K. Statistical Analysis.

In the open discussion profile panel the frequency of all responses were measured. An arbitrary inclusion point was chosen to be a frequency of 50% of the participating judges, hence an characteristic having a recorded frequency over 6 was considered for use in the study.

The ranking that was done for the two sets of samples in the profile panel was analyzed using two methods of analysis. To determine if there was a significant agreement between rankings assigned to the samples by the judges; an analysis of variance technique was applied using a special statistic W, the coefficient of concordance (Kendall, 1948). To determine if a sample was significantly different from others in the group of similar samples on the basis of ranking, Kramer's Rank Sum Method was used (Kramer, 1960).

Variation between carrot samples for peak areas was analyzed using an analysis of variance by peak for all carrot samples.

Variation between carrot samples for sensory eval-

uation parameters was analyzed using an analysis of variance by sensory parameter for all carrot samples.

To evaluate the existence of some underlying pattern of relationships in the sensory evaluation data a factor analysis was implemented. The factor analysis evaluated the pattern of relationships to identify and interpolate a set of source variables accounting for observed interrelations in the data.

A calculation of new source variables was made with the data to enable the application of a second factor analysis including peak area data for the evaluation of underlying relationships. These relationships were tested for levels of significance using multiple regression analysis.

RESULTS AND DISCUSSION

Experimental Design.

The carrot selections were chosen on the basis of a carrot breeders' written comments in field trial records. The selection process strived to produce as widely varied a sample as possible. The more the variance on this level the greater the power of study in determination of differences later.

Carrot seed for this study were planted on muck soil in a completely randomized block design with duplicate rows per selection.

Sample preparation for gas chromatography was designed to eliminate intra-varietal differences of aroma volatiles. Fifteen to twenty roots of each selection were trimmed, sliced and a 1000g sample was blended for use in trappings and aroma panel studies. Collection and trapping for gas chromatography samples included three subsamples of 100g each, connected to a porous polymer traps.

Two open discussion panels were run in order to generate proper descriptors for use in the characterization of the raw carrot aroma. Panelists were directed to select and list privately chosen descriptors. Following

the private evaluation, an open discussion was promoted where panelists were encouraged to discuss each carrot selection and to develop a uniform description of the aromas. Panelists were encouraged to include descriptors from the discussion in their listings where appropriate. This method differs from the classical approach to discussion profile panels (Amerine et al., 1965) where only the descriptors from the open discussion section are included in the analysis. In the approach used in this study, the results include not only open discussion descriptors but also the individual descriptors. As a final step the descriptors totaling to 50% of the total number of panelists were included in the final list of descriptors. This approach ensures, the collection of descriptors not discussed, yet written frequently, as well as those descriptors that were discussed openly by the panel.

The testing-training phase of the study was designed to accomplish the task of preparing panelists for separating and identifying classes of compounds in raw carrot aroma. It also served to eliminate panelists, based on their performance in the areas of sensitivity, separation of odor character, and consistancy.

The Qualitative Descriptive Analysis was designed as a completely randomized block with duplicates.

The factor analysis was included in the design to accomplish an evaluation of underlying trends and reduction of sensory data into orthogonal parts. The results

of this first analysis were used for calculation of new factor variables for inclusion in a second factor analysis; which included both new factor variables and peak area data.

The approach chosen in the design of this study is somewhat different from previous studies. It is realized from previous contributions to the literature that the levels of sweetness (soluble solids, sugars), bitterness (isocoumarin), and dry matter are of critical importance in the acceptance or rejection of carrots (Scheerens and Hosfield, 1976.; Carolus and Ells, 1957.; Carlton and Peterson, 1963.). It was not the intent of this study to reaffirm the well supported findings concerning these attributes but rather break away from the repeated study of taste-flavor, the two not necessarily separable in this case, and initiate a study of the aroma of raw carrots. In this study, the word aroma is taken to mean smells detected by the nose without interference of taste stimuli. The raw carrot aroma is the smell of carrots in their raw state with no off odor due to heating. When eating raw carrots, the temperature at which the raw carrot aroma is smelled is no higher than body temperature; hence the temperature for collection of headspace volatiles was set no higher than 30C.

Controlled Environment Chamber

The controlled environment chamber was set up to accommodate crates of carrots. Air flow was maintained at all times with a built-in circulating fan and moisture was introduced using the system described in the methods section. Relative Humidity was maintained between 95% and 99% . The electrical float control on the atomizer unit was found to develop corrosion problems after a year in operation. Repetitive cleaning of contacts remedied the situation; however, a replacement part where contacts were fully weatherized would be highly recommended. Although the control function in this system was simply a clock cycle gauged to the static environmental conditions of the chamber; an alternative system could be suggested where the control system included a Dunmore type hygrometer cell. In this system resistance of a sensing element varies with percent relative humidity (Ross, I.J., 1975).

Selection of Carrots Based on Breeder's Comments.

Previous year's field trial records for all carrot selections in the Michigan State University Carrot Breeding Program were evaluated for possible inclusion in the aroma quality study. The decision of whether or not to include a selection was made on a basis of the breeder's comment as to the eating quality of the carrot. It was realized that many of the descriptions and opinions were probably biased, however, they provided a base to start

from. Some of the descriptions recorded in the field trial records were : bitter, sweet, sweet pleasant smell, oily, carrotty, strong, bland, perfumy, piney, and pleasant. Along with the selections chosen from the field trial books, several commercial varieties were also evaluated.

Porous Polymer Traps and Collection System.

The collection system used in this study was a modified version of that described by Simon et al., (1980a). The packing weight was approximately the same as that used by Simon although the reported amount was some ten times greater than what was used in this study (Simon, 1981).

The study of headspace volatiles offers several advantages to the aroma chemist:

- (a) A relatively small sample of food is required.
- (b) Very little sample preparation is required, therefore artifacts are kept to a minimum.
- (c) Compounds in the headspace are representative of what one actually smells.

A limited concentration process will bring the headspace volatiles into the range of many analytical techniques (Teranishi et al., 1971). Of concern in this study was the possible development of the familiar off odor of cooked carrots, since the purpose of the study was to deal with the raw carrot aroma. In the determination of

collection conditions for this study, it was felt that even a holding temperature of 60C was too harsh because of the distinct off odor developed. It was concluded that after an hour of holding at 30C, the collection temperature of this study, no noticable off odor (cooked aroma) was detected.

Gas Chromatography

The elution time of volatiles off the porous polymer trap was quite fast, due to the use of a plastic manifold adapted to a syringe, which enabled moderate pressure to be applied to the solvent placed on the top of the trap.

The chromatogram of the compounds eluted from the porous polymer trap was somewhat different from previous results (Simon et al., 1980a) because the collection conditions promoted a shift in the total peak area to the more volatile early eluting compounds. These included peaks 1 through 13 as indicated in a table of average peak areas (Table E1, Appendix E). In most previous works relatively moderate heating conditions were maintained which drove off the more stable higher boiling compounds. However, in this study particular care was taken to avoid any possible artifact formation or odor character degradation.

In Figure 4 a representative chromatogram of MSU-1413 is shown. The majority of the peak area is taken up by peaks 1 through 12 with peaks 1,4, and 5 being very

Figure 4. -- Gas chromatogram of carrot selection
MSU-1413 in the raw carrot aroma
study.

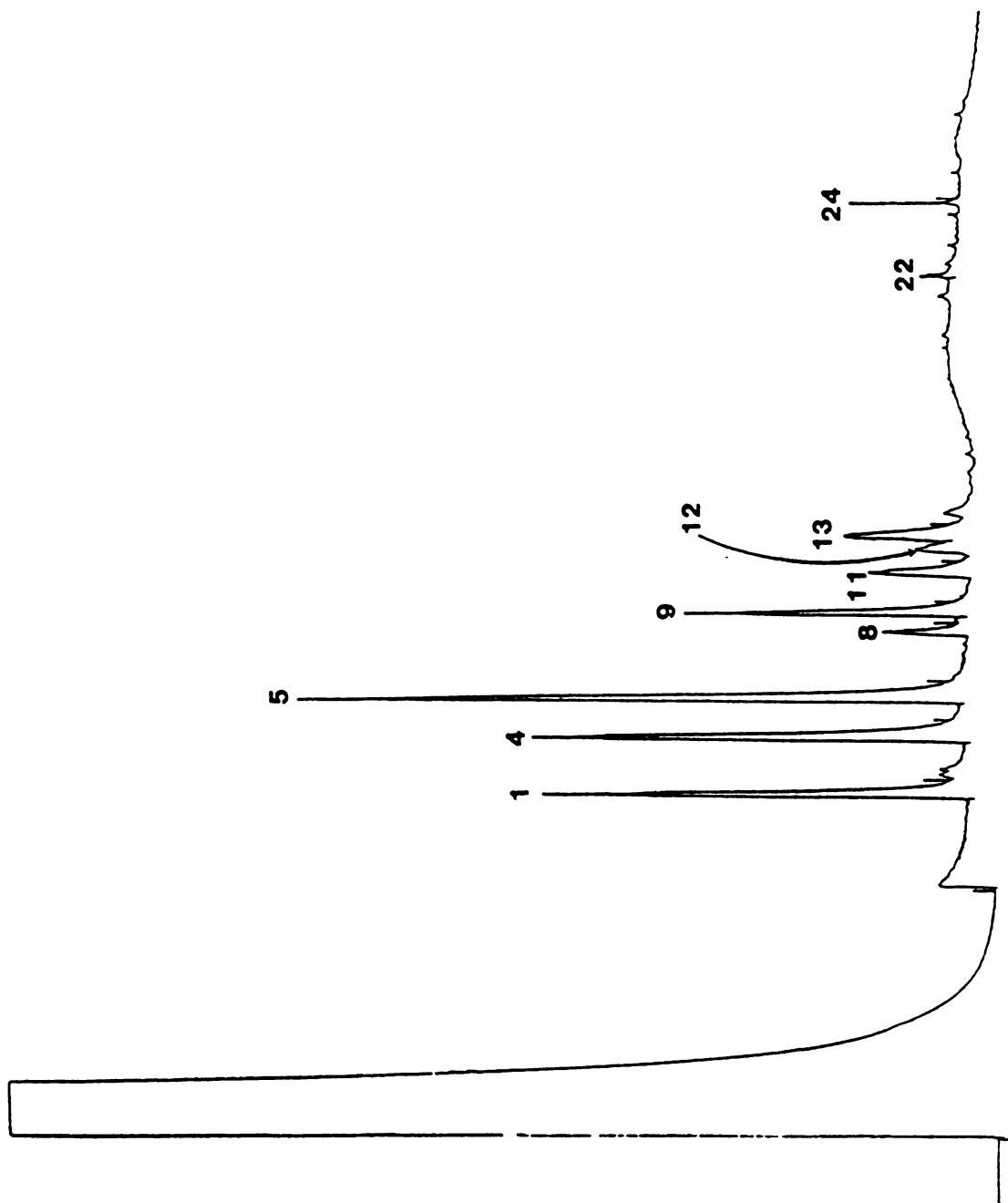


Table 2. -- Gas chromatographic data for aroma volatiles eluted from a porous polymer trap for carrot selection MSU-1413.

Peak No.	Retention Index tr/tr (a)	Peak Area	Percent Total Area (b)
1	0.83	604	17.517
4	0.92	765	22.187
5	1.00	1139	33.034
8	1.13	111	3.219
9	1.16	355	10.296
11	1.24	170	4.930
12	1.29	65	1.885
13	1.31	196	5.684
22	1.83	10	0.290
23	1.97	33	0.957

(a)

(b) Based upon Sabinene

Excluding solvent peak

prominent. Table 2 is a breakdown of the gas chromatography data. In this table, a retention index is used for comparison of all peak retention times to a standard (Heatherbell et al., 1971). Sabinene, which is peak 5, was chosen as a standard because it appears in each of the traps evaluated and falls towards the middle of the chromatogram.

MSU-1385 is shown in Figure 5. Peak areas are quite high with over 59% of the total volatiles consisting of peaks 1,4, and 5 (Table 3).

The carrot line MSU-1383 drops in amount of total volatiles overall but maintains the presence of some of the higher boiling compounds (Figure 6.). This would tend to indicate a higher ratio of high boiling compounds to low boiling compounds, otherwise one would expect a lower peak area for both high and low boiling compounds (Table 4).

MSU-5987 is shown in Figure 7. A large amount of total volatiles are present with five peaks registering with longer retention times than beyond peak 13 although peaks 1,9, and 13 constitute the majority of the volatiles (Table 5.).

In comparison, MSU-107, is quite low in total volatiles (Figure 8) with only five peaks registering on the integrator (Table 6). Peaks 1,4, and 5 constituted the majority of the total volatiles.

Figure 9 shows the commercial variety, Spartan Sweet, a fresh market product. Note that total volatiles

Figure 5. -- Gas chromatogram of carrot selection
MSU-1385 in the raw carrot aroma
study.

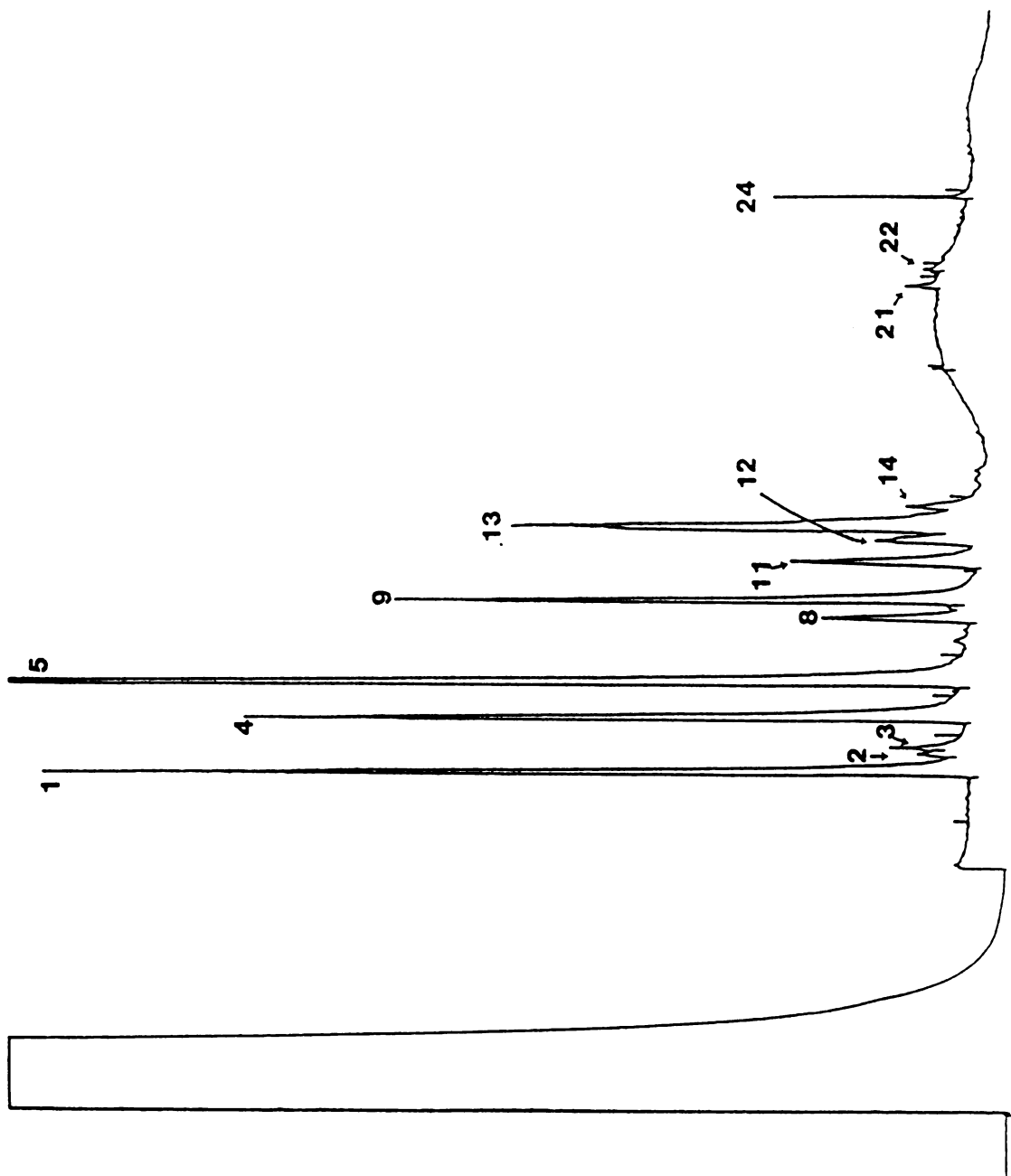


Table 3. -- Gas chromatographic data for aroma volatiles eluted from a porous polymer trap for carrot selection MSU-1385.

Peak No.	Retention Index tr/tr (a)	Peak Area	Percent Total Area (b)
1	0.82	1292	16.346
2	0.85	70	0.885
3	0.87	99	1.252
4	0.93	1185	14.992
5	1.00	2341	29.617
8	1.13	211	2.660
9	1.16	908	11.487
11	1.24	331	4.187
12	1.28	190	2.403
13	1.31	1054	13.33
14	1.35	119	1.505
21	1.79	20	0.253
22	1.83	10	0.126
24	1.97	74	0.936

(a)

(b) Based upon Sabinene

Excluding solvent peak

Figure 6. -- Gas chromatogram of carrot selection
MSU-1383 in the raw carrot aroma
study.

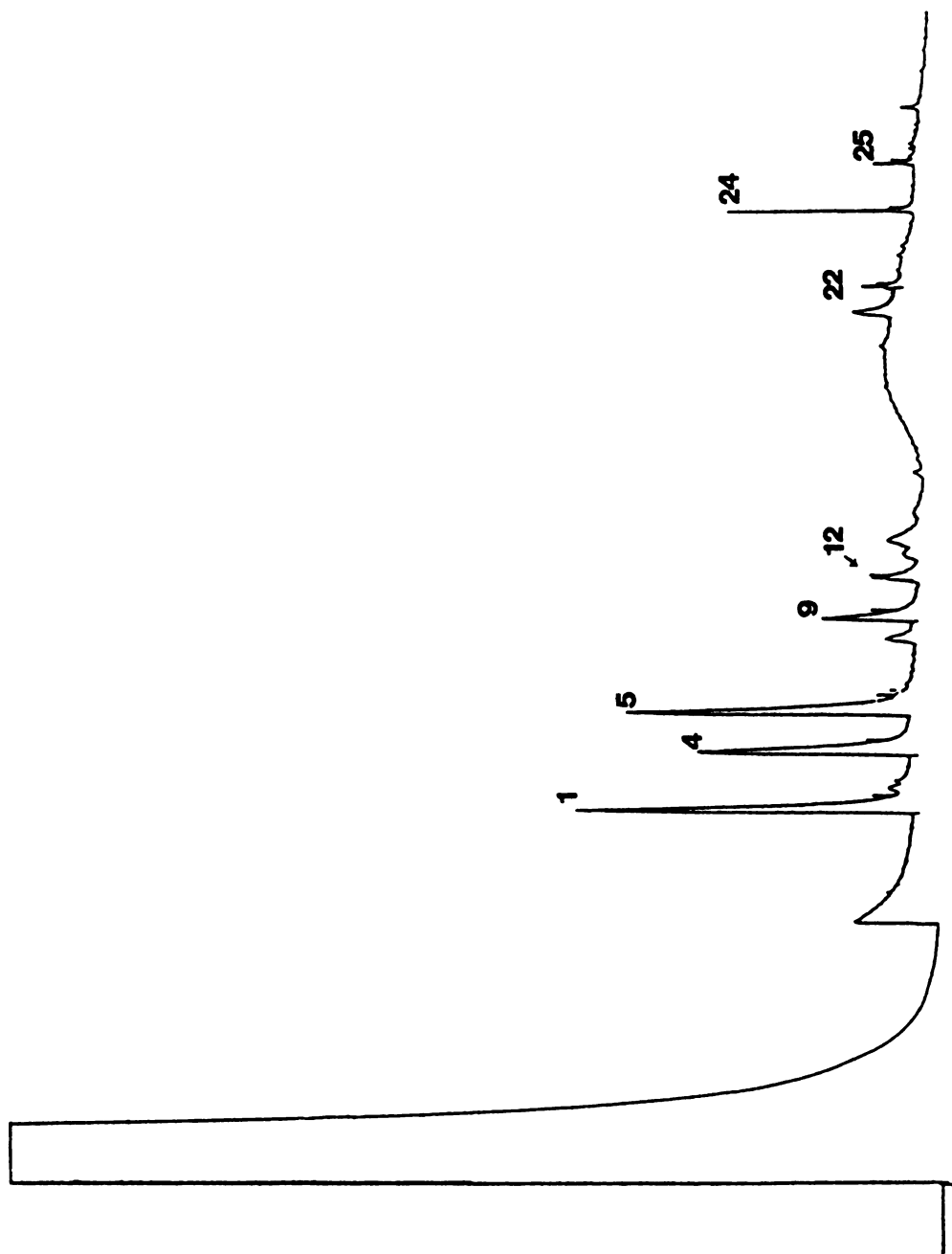


Table 4. -- Gas chromatographic data for aroma volatiles
eluted from a porous polymer trap for carrot
selection MSU-1383.

Peak No.	Retention Index tr/tr (a)	Peak Area	Percent Total Area (b)
1	0.81	495	33.559
4	0.92	337	22.848
5	1.00	448	30.373
9	1.17	97	6.576
12	1.24	14	0.949
22	1.78	11	0.746
24	1.92	61	4.136
25	2.01	12	0.814

(a)

(b) Based upon Sabinene

Excluding solvent peak

Figure 7. -- Gas chromatogram of carrot selection
MSU-5987 in the raw carrot aroma
study.

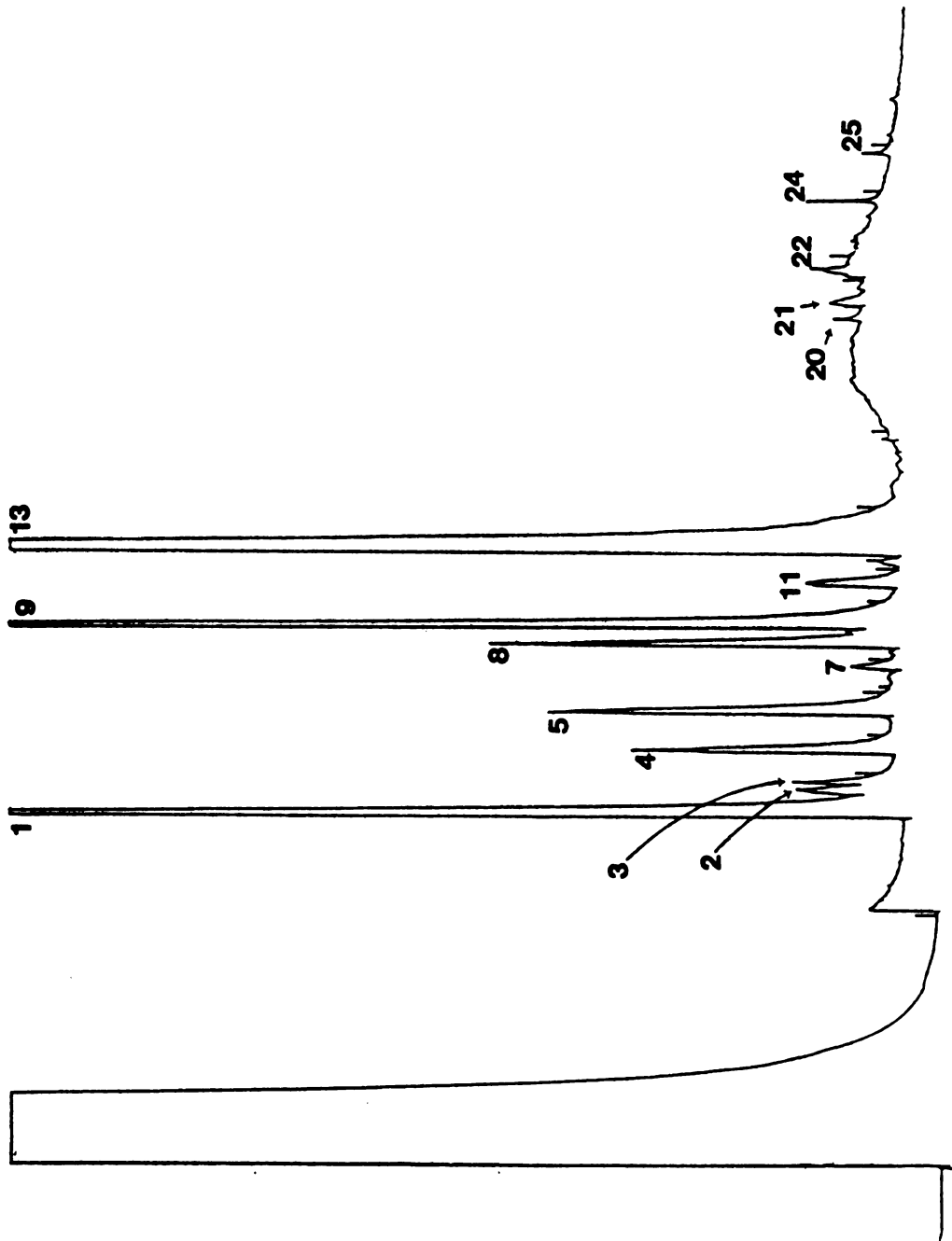


Table 5. -- Gas chromatographic data for aroma volatiles eluted from a porous polymer trap for carrot selection MSU-5987.

Peak No.	Retention Index tr/tr (a)	Peak Area	Percent Total Area (b)
1	0.80	2444	18.871
2	0.85	165	1.274
3	0.86	120	0.927
4	0.92	446	3.444
5	1.00	586	4.525
7	1.08	48	0.371
8	1.12	668	5.158
9	1.16	2027	15.651
11	1.24	152	1.174
13	1.31	6088	47.008
20	1.74	25	0.193
21	1.77	53	0.409
22	1.83	78	0.602
24	1.96	30	0.232
25	2.05	21	0.162

(a)

(b) Based upon Sabinene

Excluding solvent peak

Figure 8. -- Gas chromatogram of carrot selection
MSU-107 in the raw carrot aroma study.

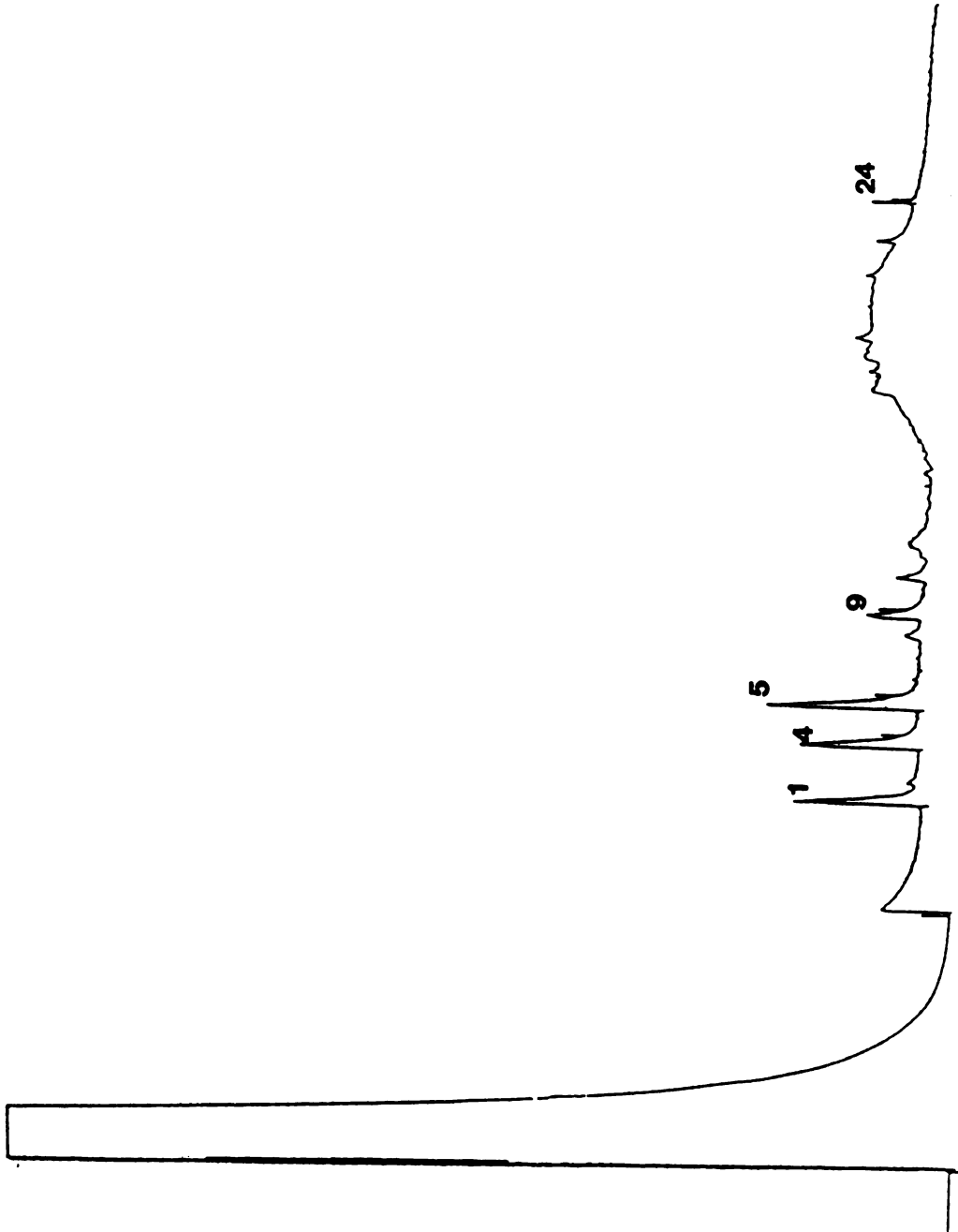


Figure 9. -- Gas chromatogram of carrot selection Spartansweet in the raw carrot aroma study.

Table 6. -- Gas chromatographic data for aroma volatiles eluted from a porous polymer trap for carrot selection MSU-107.

Peak No.	Retention Index tr/tr (a)	Peak Area	Percent Total Area (b)
1	0.81	126	21.687
4	0.92	169	29.088
5	1.00	220	37.866
9	1.16	57	9.811
24	1.93	9	1.549

(a)

(b) Based upon Sabinene
Excluding solvent peak

Table 7. -- Gas chromatographic data for aroma volatiles eluted from a porous polymer trap for carrot selection Spartansweet.

Peak No.	Retention Index tr/tr (a)	Peak Area	Percent Total Area (b)
1	0.81	1104	43.706
4	0.92	487	19.280
5	1.00	666	26.366
8	1.13	37	1.465
9	1.17	204	8.076
24	1.93	38	1.108

(a)

(b) Based upon Sabinene
Excluding solvent peak

appear low as compared to some of the previous lines shown (Table 7); however, as with virtually all of the previous selections, the majority of the total volatiles, over 80%, are found in peaks 1,4, and 5.

Spartan Fancy is also a commercial variety used for fresh market produce. It is interesting to note that Spartan Fancy, although a named variety, has very low total volatiles in comparison to previously mentioned breeding lines (Figure 10). The digital integrator interpreted only three peaks for integration and they were peaks 1,4,and 5 (Table 8).

The commercially grown U.S. variety, Goldpak, was included in the study. A representative chromatogram shown in Figure 11 indicates a majority of the volatiles were included in the three peaks 1,4, and 5 (Table 9).

In 1980, a study concluded that some breeding lines and cultivars had significantly higher levels of reducing sugars and non reducing sugars (Lester, 1980). Two breeding line from that study were included in this study of raw carrot aroma. They were MSU-6000, reportedly a high sugar line, and Gosinoostrovakaja-13, reportedly a low sugar line. MSU-6000 is shown in Figure 12 with supporting data in Table 10. MSU-6000 was quite interesting because total volatiles were low, but numerous high boiling compounds showed up in the chromatogram. Gosinoostrovakaja-13, the low sugar line, appeared to be similar to MSU 6000 but with less high boiling compounds (Figure 13, Table 11).

Figure 10. -- Gas chromatogram of carrot selection
Spartan Fancy in the raw carrot aroma
study.

Table 8. -- Gas chromatographic data for aroma volatiles
eluted from a porous polymer trap for carrot
selection Spartan Fancy.

Peak No.	Retention Index tr/tr (a)	Peak Area	Percent Total Area (b)
1	0.81	449	43.677
4	0.92	323	31.420
5	1.00	256	24.903

(a)

(b) Based upon Sabinene

Excluding solvent peak

Figure 11. -- Gas chromatogram of carrot selection
GoldPak in the raw carrot aroma
study.

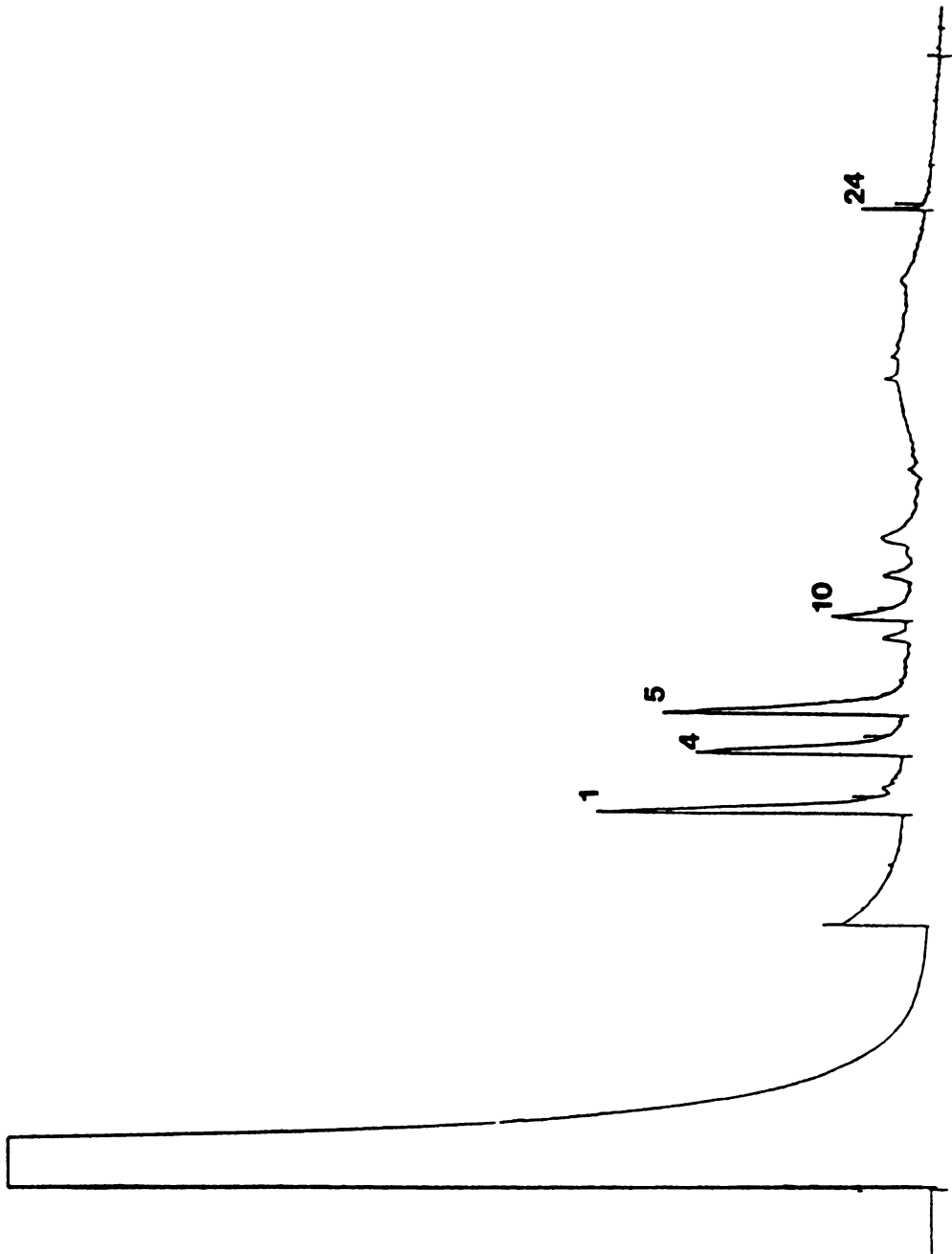


Figure 12. -- Gas chromatogram of carrot selection
MSU-6000 in the raw carrot aroma
study.

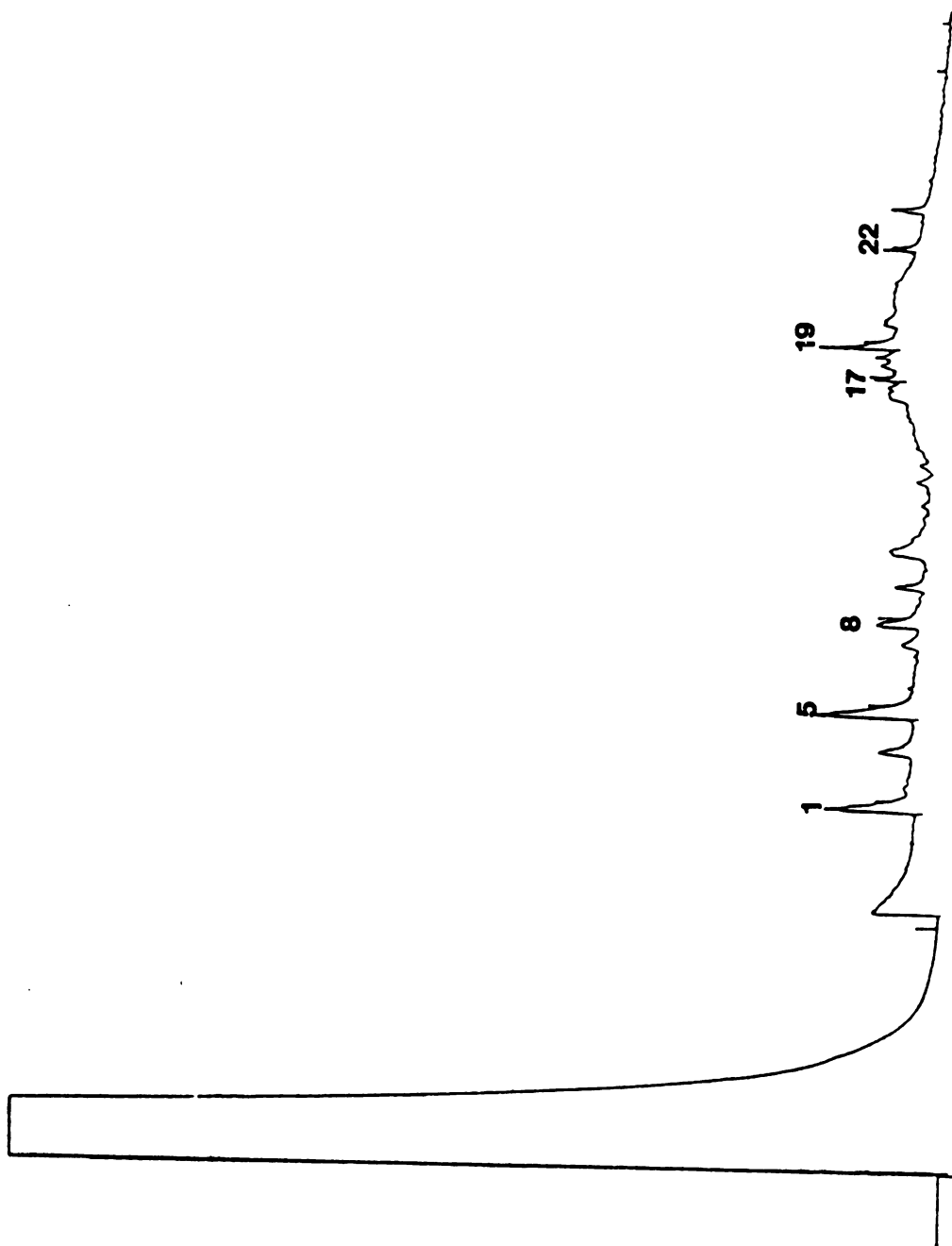


Table 9. -- Gas chromatographic data for aroma volatiles eluted from a porous polymer trap for carrot selection GoldPak.

Peak No.	Retention Index tr/tr (a)	Peak Area	Percent Total Area (b)
1	0.82	511	34.786
4	0.92	387	26.345
5	1.00	455	30.974
10	1.17	94	6.399
24	1.91	22	1.498

(a)

(b) Based upon Sabinene

Excluding solvent peak

Table 10. -- Gas chromatographic data for aroma volatiles eluted from a porous polymer trap for carrot selection MSU-6000.

Peak No.	Retention Index tr/tr (a)	Peak Area	Percent Total Area (b)
1	0.82	110	30.812
5	1.00	132	36.975
8	1.17	44	12.325
17	1.63	9	2.521
19	1.69	52	14.566
23	1.88	10	2.801

(a)

(b) Based upon Sabinene

Excluding solvent peak

Figure 13. -- Gas chromatogram of carrot selection
Gosinoostrovakaja-13 in the raw carrot
aroma study.

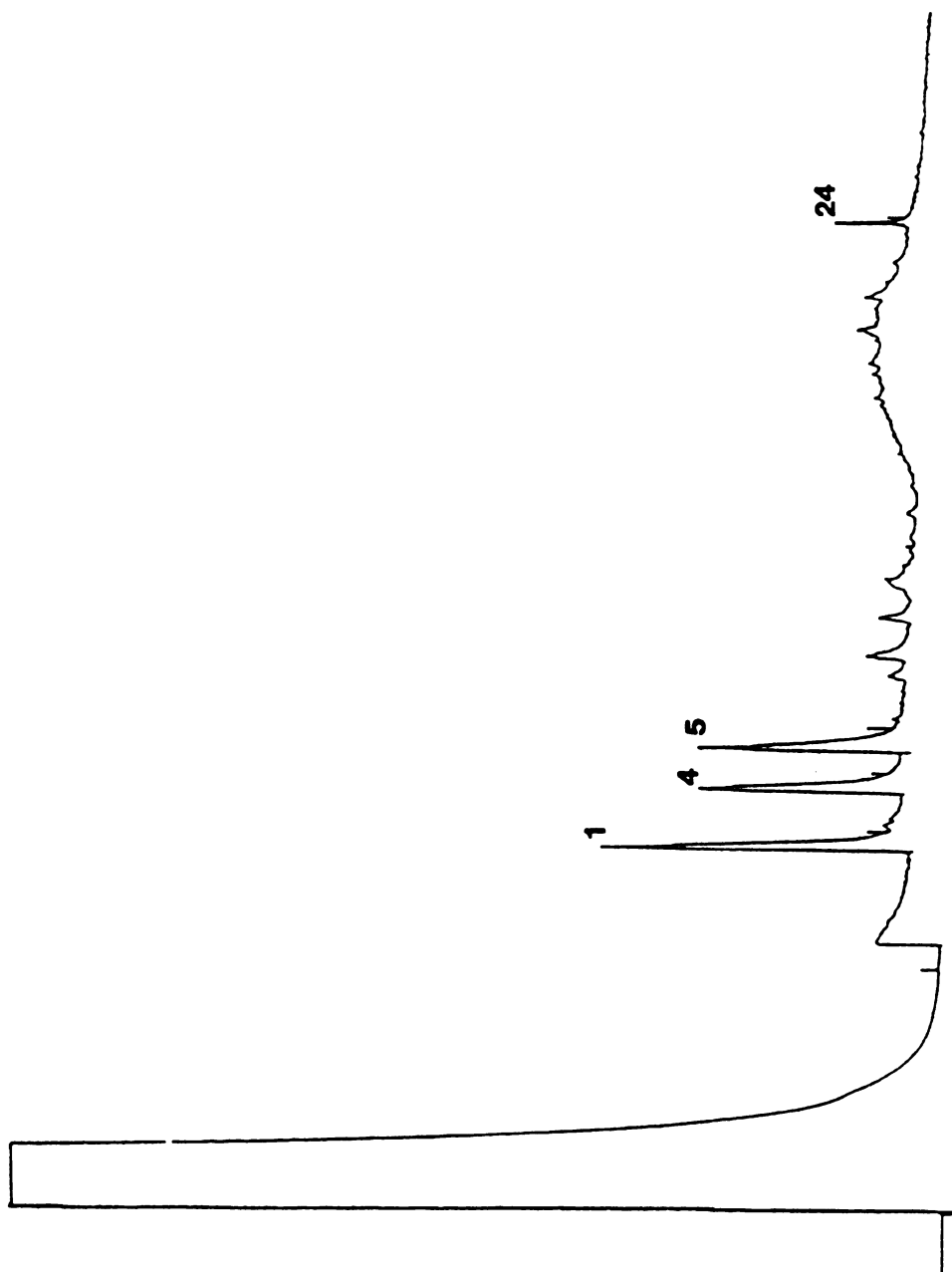


Table 11. -- Gas chromatographic data for aroma volatiles
eluted from a porous polymer trap for carrot
selection Gosinoostovakja.

Peak No.	Retention Index tr/tr (a)	Peak Area	Percent Total Area (b)
1	0.81	487	39.085
4	0.92	365	29.294
5	1.00	371	29.775
24	1.97	23	1.846

(a)

(b) Based upon Sabinene

Excluding solvent peak

Withycombe et al. (1978) were evaluating trace volatile constituents of hydrolyzed vegetable protein when they found that of a number of polymers tested, Tenax-GC produced the most organoleptically characteristic isolate. The Tenax-GC was compared to Chromosorb 105 and Porapak Q. Boyko et al. (1978) reported that retention times of trapped compounds were shorter on the the Tenax-GC and found that during a twenty minute water removal step, losses of low boiling compounds would occur. Simon et al. (1980a) used Tenax-GC for the collection of carrot volatiles and reported an increasing variability in peak areas with the more volatile, low boiling compounds. Variability was found to be quite high in the present study, although measures were taken to minimize it. Water elimination was kept to a maximum of two minutes by nitrogen flush and all traps were capped with parafilm then held at -23C until elution. The variability problem was accentuated by the number of trace level components found in the samples (Table 12).

(a)

Table 12. -- List of trace level peaks detected in the porous polymer trappings of the raw carrot headspace. (See Peak Identification p.75)

Peak Number - Identity		Peak Number - Identity	
Peak 6	- unknown	Peak 7	- unknown
Peak 14	- unknown	Peak 15	- unknown
Peak 16	- unknown	Peak 17	- unknown
Peak 18	- unknown	Peak 19	- unknown
Peak 20	- unknown	Peak 21	- isobornyl acetate
Peak 22	- beta-carophylene	Peak 23	- unknown
Peak 25	- unknown	Peak 26	- unknown

(a)

less than an area of 15 on the digital integrator.

The term trace level volatiles was used to describe compounds not averaging over three times the integrator minimum peak height which was set at a peak area level of 5. Therefore, peaks averaging less than a peak area of 15 were considered trace level. In previous works on the volatile constituents of carrots, many compounds were found in large quantity but the conditions by which these compounds were collected could not be assumed to represent the raw carrot aroma. In this study, some compounds of the high concentration which previous researchers had driven out of the carrot puree by moderate to harsh holding conditions showed up as only trace quantities.

A one-way analysis of variance was applied to the peak data to distinguish peaks which varied at a statistically significant level over the various carrot selections. Mean square values and degrees of freedom for each are shown in Table 13. As noted, four peaks were significantly different: peaks 7, 13, 21, and 25. Simon et al. (1980) indicated that only three of the volatiles measured in their study were significantly different between carrot selections. They were alpha-phellanderene, limonene, and terpinolene.

Of the four peaks which varied significantly between carrot selections, peak 7 is unknown, peak 13 is gamma-terpinene, peak 21 is isobornyl acetate, and peak 25 is unknown. Testing of differences between means for the compounds was performed using Tukey's "Honestly

Table 13. -- Mean Squares and degrees of freedom as analyzed using One Way Analysis of Variance.

Analysis of Variance for Peak Area Data				
Variable	Between Groups		Within Groups	
	D.F.	M.S.	D.F.	M.S.
P01 - alpha-Pinene	9	637641.7926	20	358753.6667
P02 - Camphene	9	964.2370	20	1082.8667
P03 - unknown	9	699.5889	20	820.0333
P04 - beta-Pinene	9	105914.5037	20	109989.7333
P05 - Sabinene	9	388784.4296	20	501897.8667
P06 - unknown	9	1.6333	20	1.6333
P07 - unknown	9	388.8000	20	388.8000*
P08 - unknown	9	54550.2259	20	26127.1667
P09 - Myrecene	9	543156.0037	20	269518.9333
P10 - unknown	9	3511.4407	20	3210.7000
P11 - Limonene	9	9522.3000	20	4059.3333
P12 - unknown	9	26829.8667	20	29956.3333
P13 - gamma-Terpinene	9	5515742.5519	20	1382385.5000*
P14 - unknown	9	466.8000	20	474.7333
P15 - unknown	9	13.3333	20	13.3333
P16 - unknown	9	108.1630	20	120.8667
P17 - unknown	9	28.6852	20	14.5667
P18 - unknown	9	32.0333	20	32.0333

(continued)

Table 13. -- Mean Squares and degrees of freedom as analyzed
using One Way Analysis of Variance. (Cont.)

Analysis of Variance Peak Area Data Cont'd.				
Variable	Between Groups		Within Groups	
	D.F.	M.S.	D.F.	M.S.
P19 - unknown	9	1303.6444	20	648.7333
P20 - unknown	9	154.6519	20	197.2000
P21 - Isobornyl Acetate	9	602.0185	20	192.6667*
P22 - beta-Carophylene	9	245.3370	20	192.8667
P23 - unknown	9	49.0704	20	24.1667
P24 - unknown	9	1361.2185	20	1258.7667
P25 - unknown	9	57.1889	20	18.8333*
P26 - unknown	9	13.3333	20	13.3333

*

95% Significance Level

Significant Difference" test which utilizes a t-like statistic based on the distribution of the Studentized Range (Tukey, 1953). The test statistic used was:

$$\left(\bar{y}_i - \bar{y}_{i'} \right) \sqrt{\frac{ms_E}{r}}$$

with the critical value of $\underline{q}_{\alpha, t, n-t}$ equal to 5.008 for $\alpha = 0.05$, $t = 10$, and $t-n = 20$.

In Figure 14, the means for the ten carrot selections are shown for peak #7. The breeding line MSU-5987 is significantly different from MSU-1385, MSU-1383, MSU-107, Spartansweet, Spartan Fancy, GoldPak, MSU-6000, and Gosinoostrovaka-13. MSU-5987 is not significantly different from MSU-1413 for peak #7.

Figure 15. shows the differences among carrot selection for peak #13, gamma-terpinene. MSU-5987 is significantly higher in gamma-terpinene than any other selection studied.

Isobornyl acetate is peak # 21 and comparisons between carrot selections are shown in Figure 16. MSU-5987 is higher in isobornyl acetate than any other selection studied.

Peak #25 is compared between all of the carrot selections in Figure 17. MSU-5987 is shown to be significantly higher in this unknown compound than any other selection.

Figure 14. -- Graphic presentation of the means for peak #7 for all the carrot selections included in the study.

Figure 15. -- Graphic presentation of the means for peak #13, gamma-terpinene for all the carrot selections included in the study.

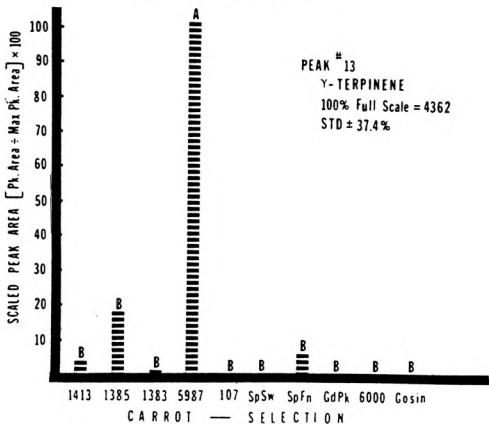
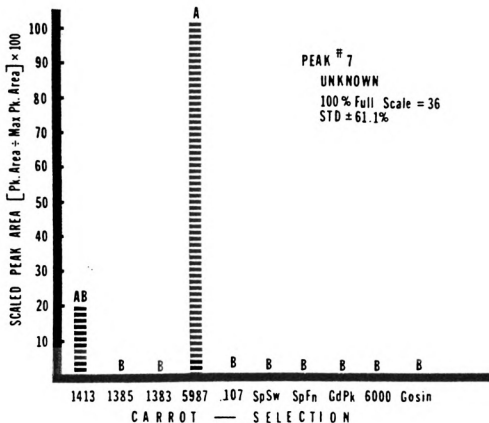
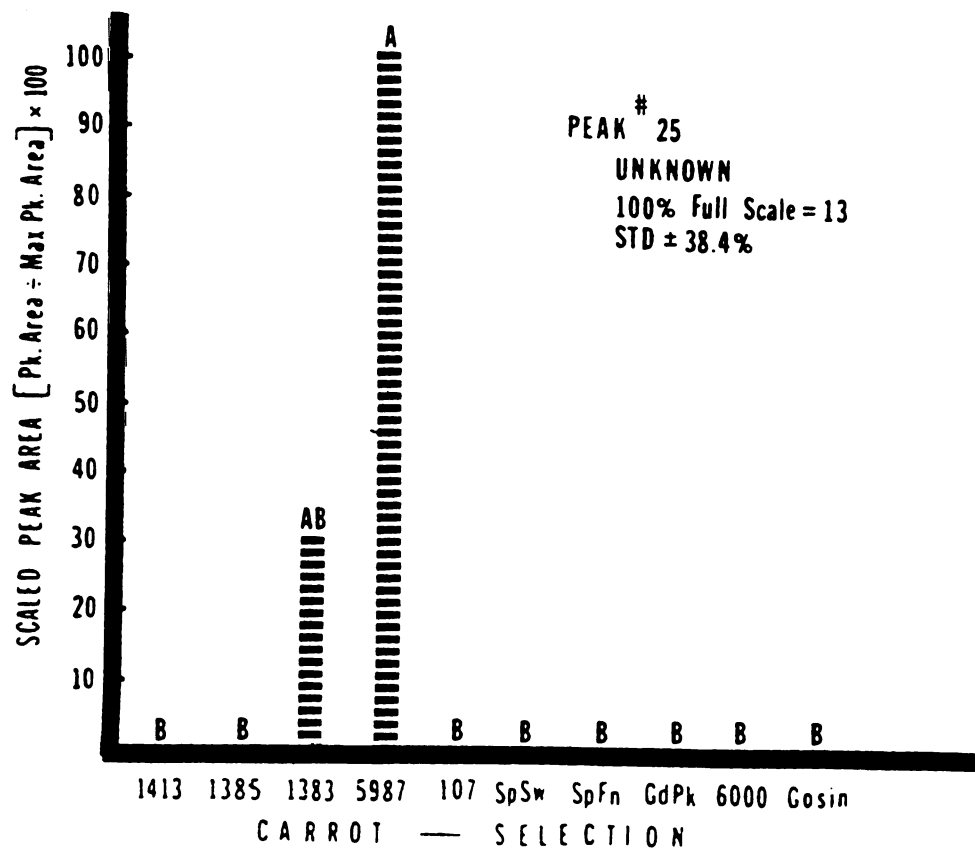
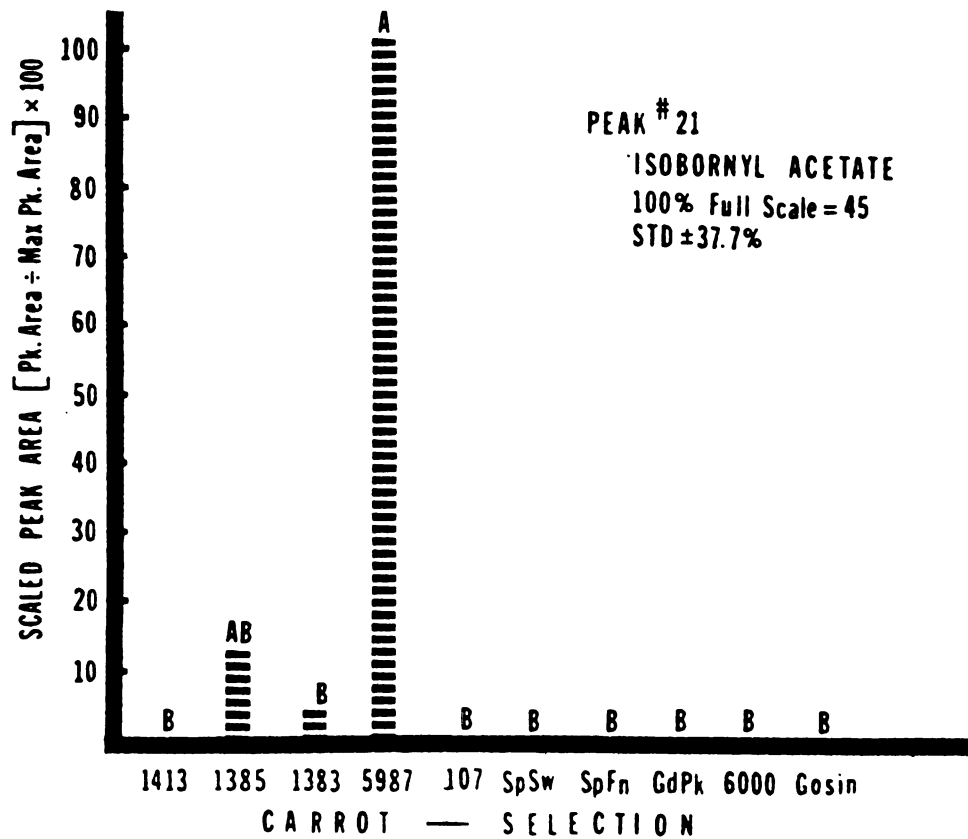


Figure 16. -- Graphic presentation of the means for peak #21, isobornyl acetate for all the carrot selections included in the study.

Figure 17. -- Graphic presentation of the means for peak #25 for all the carrot selections included in the study.



Peak Identification.

Identification of peaks was facilitated by the use of mass spectrometry, literature references, and standards, where available. In Table 14, a listing of those peaks identified is given with reference to method of identification and confirmation.

The compound indicated as peak #1 eluted on the capillary column at 7.80 minutes and on the packed column at 7.95 minutes. These are both very close to alpha-pinene's elution time of 7.82 minutes for the capillary and 7.96 minutes for the packed column. This alpha-pinene standard was 95% pure with a second peak at 9.00 minutes which constituted the other 5%, most probably in the form of beta-pinene. The mass spectral scan over peak #1 (Appendix K, Figure K1) was very similar to that reported by Buttery et al. (1968) and Ryhage and Von Sydow (1963) for alpha-pinene. The molecular ion was weak at 136 m/e. The first five major ions in descending order were: 93, 91, 92, 77, and 79 m/e. The M-43 ion is 93 m/e and is characteristic of the loss of an isopropyl group. Further transformation yields the 92 m/e and 91 m/e ions.

The compound indicated as peak #2 eluted at 8.17 minutes for the capillary column and 9.40 minutes for the packed column. The mass spectral scan over peak #2 is shown in Appendix K, Figure K2. The molecular ion is not intense enough to show up in this scan, however, the base peak is 121 m/e. Other researchers looking at total

Table 14. -- Compounds identified through the use of Gas Chromatography and Mass Spectrometry of the volatile constituents trapped on the porous polymer, Tenax-GC.

Peak No.	Compound	GC Stds.	MS confirmation
1	alpha-Pinene	+	Buttery et.al.(1968) Ryhage/Sydow (1963)
2	Camphene		"
4	beta-Pinene	+	"
5	Sabinene		"
9	Myrecene	+	"
11	Limonene	+	"
13	gamma-Terpinene		"
21	Isobornyl-acetate	+	
22	beta-Carophylene	+	

volatile components of carrots have indicated that camphene might be a likely candidate for this position in the chromatogram. camphene, like some of the other terpenes, could very easily lose a methyl group from its structure during ionization in the mass spectrometer. This information, in conjunction with the base peak, might suggest a molecular ion = 136 m/e, which corresponds with the molecular ion of camphene as well as other terpinenes. The first five major ions found in the spectrum of peak #2 were: 121, 67, 95, 68, and 71 m/e. Ryhage and Von Sydow (1963) indicate a base peak of 93 m/e for camphene and Buttery et al. (1968) support this finding. The major ions reported, other than the base peak, were 121, 79, and 67 m/e. The fact that the 93 m/e and 79 m/e ions were missing from the spectrum of peak #2 indicates some question as to its being camphene. However, the remainder of the spectrum does look quite close to the rest of the reported spectrum for camphene.

Eluting at 8.87 minutes on the capillary column was the compound indicated by peak #4. The same peak eluted at 10.95 minutes on the packed column. The elution times on both packed and capillary columns were similar to the 5% peak eluted during the injection of the 95% alpha-pinene standard. This second peak in the alpha-pinene standard was probably beta-pinene. Figure K3, Appendix K, is the mass spectral scan of peak #4. The molecular ion was 136 m/e and the first five major ions were: 93, (40,

41,) 91, 69, 77, and 79 m/e. The ions 40 m/e and 41 m/e are placed in parentheses due to significant contributions to these peaks from the background noise. In referring to Ryhage and Von Sydow (1963), the strong ion at 41 m/e is typical of the beta-pinene spectrum. Buttery et al. (1968) makes no mention of this ion. The rest of the spectrum leaves no reasonable doubt as to its being beta-pinene since the pattern of ions are virtually identical in terms of the probability of intensity as that reported for beta-Pinene previously (Ryhage and Sydow, 1963).

The compound indicated by peak #5 had an elution time of 9.53 minutes on the capillary column and 11.36 minutes on the packed column. Two mass spectral scans were run to either side of this peak to verify it's purity. Both scans were nearly identical and one is shown in Appendix K, Figure K4. The molecular ion was somewhat weak at 136 m/e and the first five major ions were: 93, 91, 77, 79, 136, and 94 m/e. The position of peak #5 in the chromatogram suggested Sabinene as the compound when compared to other chromatograms in the literature. Buttery et al (1968) reported a mass spectrum for sabinene that was very close to the findings reported here, and the published spectrum by Ryhage and Von Sydow (1963) was virtually identical.

The compound indicated as peak #9 had an elution time of 11.13 minutes on the capillary column and 14.04 minutes on the packed column. These retentions times were quite similar to those obtained for an injection of

myrcene. The retention times for myrcene were 11.23 minutes on the capillary column and 14.09 minutes on the packed column. A mass spectrum scan of peak #9, shown in Appendix K, Figure K5, is very close to that of myrcene as indicated by Buttery et al. (1968) and also by Ryhage and Von Sydow (1963). The molecular ion was weak at 136 m/e and the first five major ions were 93, 69, 41, 91 and 77 m/e. The compound is very easily decomposed, as indicated by the very strong ions of 69 m/e and 41 m/e.

The retention time of the compound indicated as peak #11 was 11.88 minutes on the capillary column and 15.11 minutes on the packed column. These retention times were quite similar to those of limonene when injected on the same columns. The retention times for limonene was 12.08 minutes on the capillary column and 15.17 minutes on the packed column. In Appendix K, Figure K6, is shown the mass spectral scan of peak #11. The molecular ion was 136 m/e and the first five major ions were: 68, 67, 93, 79, and 94 m/e. This corresponds very nicely with the spectrum published by Ryhage and Von Sydow (1963) and closely matches the major ions listed by Buttery et al. (1968) for limonene.

The compound indicated as peak #13 had a retention time of 12.54 minutes on the capillary column and 18.03 minutes on the packed column. The relative position and time of retention in the chromatogram suggests that the peak could possibly be gamma-terpinene. A mass spectral

scan of peak #13 is shown in Appendix K, Figure K7. The molecular ion was 136 m/e and the first five major ions were: 93, 121, 136, 91, and 77 m/e. This mass spectrum agrees very closely with what Ryhage and Von Sydow (1963) published for gamma-terpinene. Buttery et al. (1968) also published the identical list of major ions shown here for gamma-terpinene. The distinction between alpha-terpinene and gamma-terpinene is a very slight one in terms of mass spectral analysis. The distinguishing factor between the two is the base peak. Alpha-terpinene has a base peak of 121 m/e which is the molecular ion minus a methyl group (M-15) the sequence then follows 93 m/e (M-43) and then 136 m/e (M). The mass spectrum for gamma-terpinene on the other hand has a base peak of 93 m/e which is the molecular ion minus an isopropyl group (M-43) the sequence then follows 121 m/e (M-15) and then 136 m/e (M). The difference between the two spectrum is caused by the different positions of the double bonds in the two compounds.

The compounds indicated by peaks #21 and #22 have retention time of 17.14 minutes and 17.45 minutes, respectively, on the capillary column. The same peaks have retention times of 25.08 minutes and 25.87 minutes, respectively, on the packed columns. These retention times are nearly identical to that of isobornyl acetate and beta-carophylene on the same columns. Due to difficulties in background noise separation mass spectral data were not collected for these peaks.

Sensory Evaluation.

Striver (1961) has calculated that as few as eight molecules of a powerful odorant are required for the triggering of one olfactory neuron in man and that as few as 40 molecules can produce an identifiable olfactory sensation. If an assumption is made that only one in 1000 molecules that are inspired ever reaches the olfactory region, then 40,000 molecules or about 10^{-19} moles can, at least theoretically, be detected by the nose. Scientist continue to investigate those odorants within the range of our analytical techniques and utilize methods of aroma enrichment as with the porous polymer trapping technique to produce quantities within range of the analytical techniques.

Few scientists take the time to realize the true complexity of our olfactory system. The Stimulus-Response Circuit diagram in Figure 18 is a breakdown of the signal path for a nerve network. As shown, the raw (true) stimulus is received by the receptor. The receptor passes it's "reading" on to the processing of stimulus section of the central nervous system by way of the afferent nerves. The brain retrieves the processed stimulus message and verifies it. The brain can then evaluate and pass judgement on the stimulus, interpreting it based upon it's inherent information and application of logic (or ill-logic) and with a multitude of inherent biases possibly

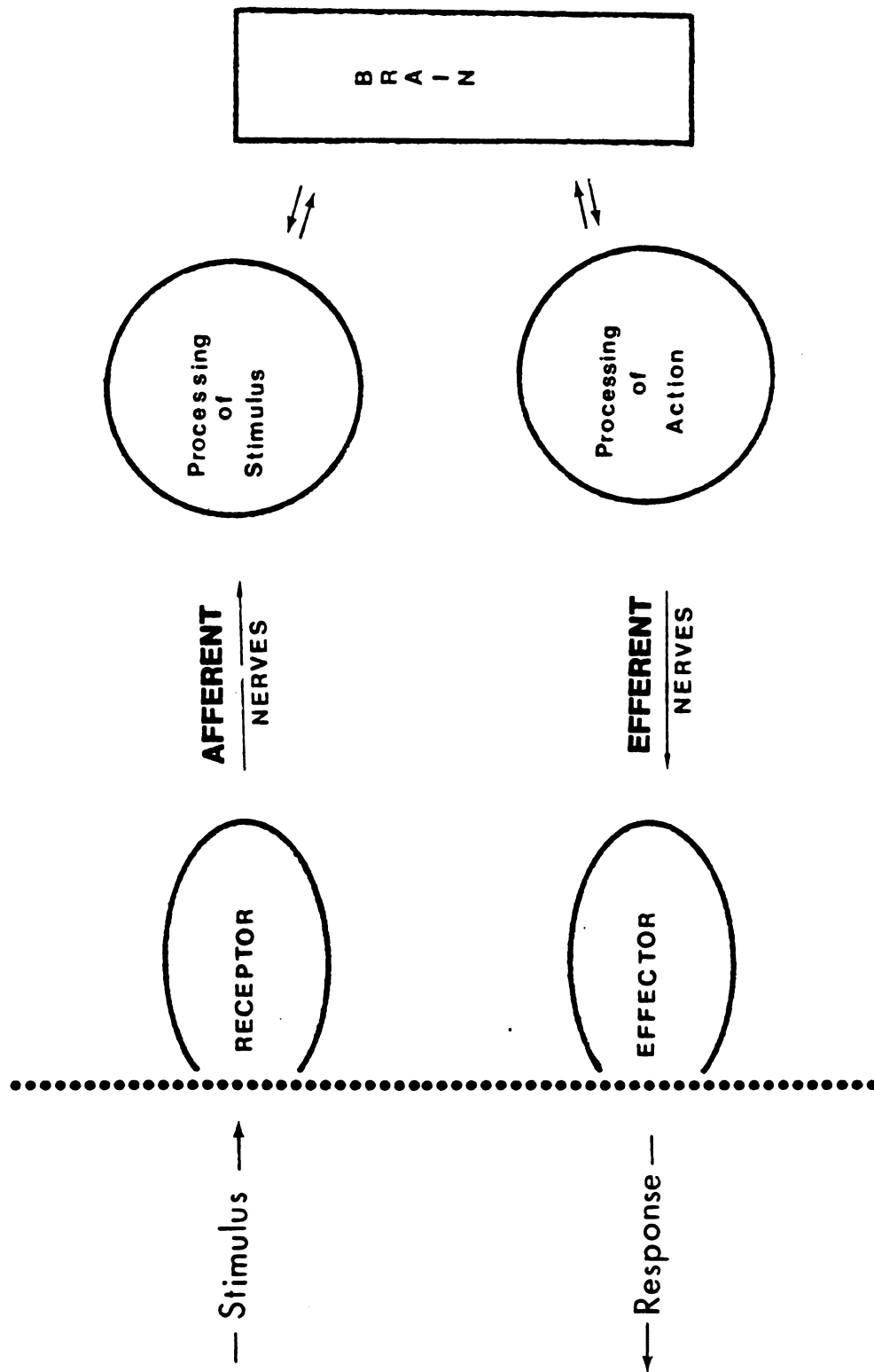


Figure 18. -- Schematic of the Stimulus - Response Circuit typically found in man.

being applied. At this point a proper response is formulated and transferred to a Process of Action section in the central nervous system from the brain. Efferent nerves then carry a message to the effectors which produce the response. There are many places in the circuit where variations can appear and differences manifest themselves. The psychology of the process is very involved and it is of utmost concern that the researcher be very aware of this.

A. Modified Open Discussion Profile Panel.

The modified open discussion panel was designed to not only collect commonly agreed upon and discussed descriptors but also any descriptors not discussed yet commonly noted on the ballots of 50% of the judges. The histogram in Figure 19 shows the various aroma characteristics listed by the judges as possible descriptors for the aroma of raw carrots. Of the total number of descriptors listed, 62% were accepted as viable. Those descriptors that were rejected were: stale, rancid, green, bitter, aromatic, and pungent. It is interesting to note that the "green" descriptor was eliminated from the listing. This descriptor has been implicated in the "green top" notes of the raw carrot (Buttery et al., 1968; Heatherbell et al., 1971; Alabran et al., 1975), especially in reference to the carrot greens. One might suspect that in this case, due to the large number of

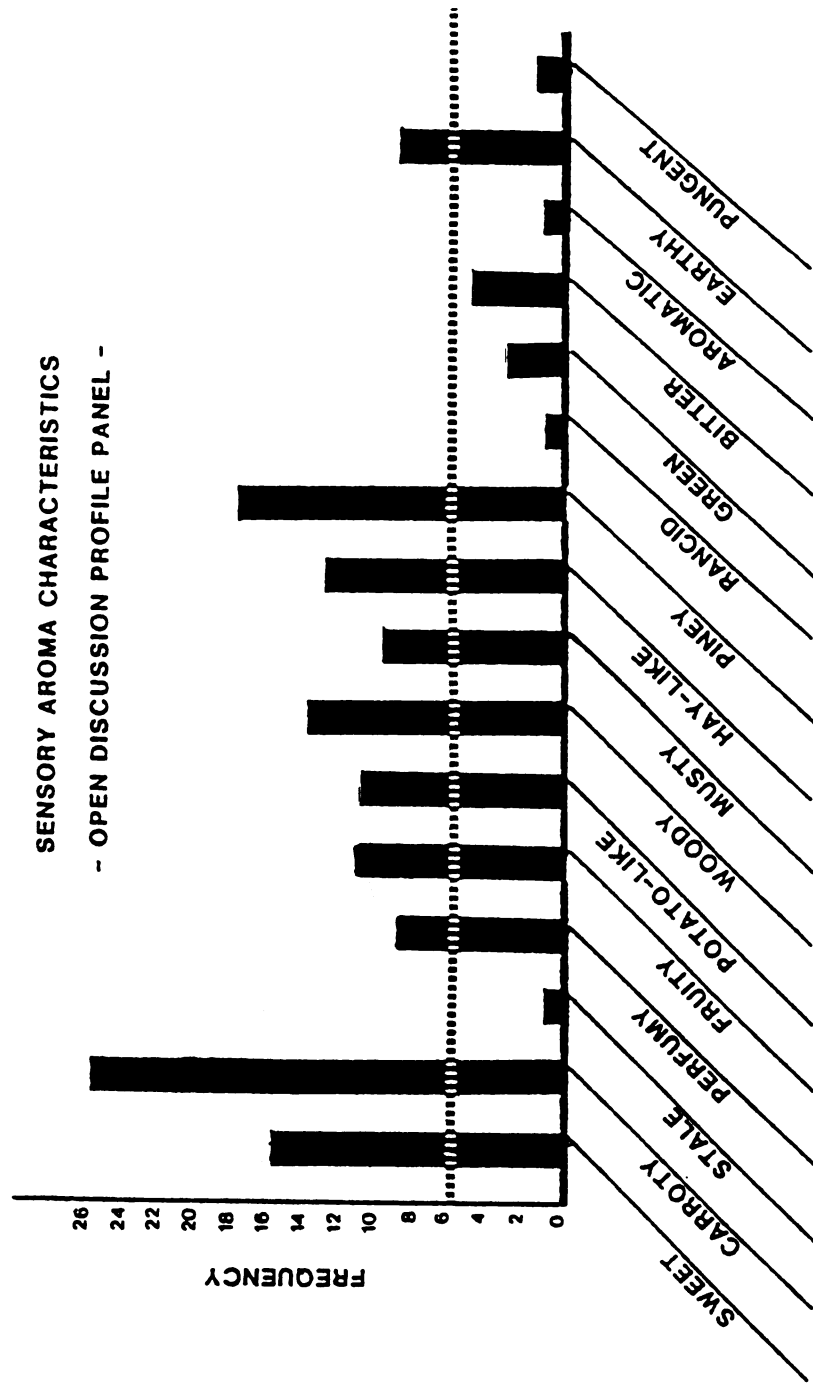


Figure 19. -- Histogram for sensory aroma characteristics generated from the open discussion panel.

descriptors, that other descriptors might adequately explain the aroma characteristic described as "green". Heatherbell et al. (1971) tied the "green" aroma to "earthy" calling it a "strong green-earthy" aroma and the earthy descriptor was included in the listing chosen by the open discussion panel. Martens et al. (1979) tied the "green" aroma to "grass" calling it a "green grass" aroma. This might be similar to the hay-like and/or piney descriptors. The remaining descriptors were: sweet, carrot, perfumy, potato-like, woody, musty, hay-like, piney, and earthy. Of these descriptors, all but one were used in the testing-training phase and the Qualitative Descriptive Analysis. The one descriptor removed was potato-like. This was removed by the analyst because of the existence of reasonable doubt surrounding the validity of this descriptor. The reasonable doubt is based on the fact that just prior to going into storage, other storage chambers located off the same corridor were filled with freshly harvested potatoes. Any exchange of air in the storage cubicles took place between the corridor and the cubicles giving ample opportunity for exchange of volatiles. In this particular wing of the controlled environment facility, six out of the 13 chambers were used for potato storage. One was used for the storage of carrots. On the basis of these conditions the descriptor, potato-like, was removed from the listing of valid descriptors of raw carrot aroma.

In the second portion of the open discussion panel each judge was asked to rank the two sets of carrot selections in order of preference. The results were analyzed in two ways: (1) using Analysis of Variance and the W coefficient (Kendall, 1948) and (2) Kramer's Rank Sum Method (Kramer, 1960). The coefficient of concordance (W) applied to the Analysis of Variance was used to determine if there was significant agreement between rankings made by the judges. No significant agreement was found for either group of samples using the coefficient of concordance method (Appendix L). The Kramer's Rank Sum Method was used to determine if differences existed between samples. Of the first set of five samples, no difference was noted between samples. Of the second set of samples, one was determined to be the worst. The exercise of requesting judges in the open discussion panel to rank samples was simply to evaluate the ability of the judges to rank similarly some quite different samples. The results might suggest that the judges disagree on what constitutes the best raw carrot aroma. This is a desirable attribute in the open discussion panel. Differences can be discussed and opinions can be shared. The differing attitudes can be molded into a reasonable consortium of descriptors capable of embodying many varied opinions. The fact that the judges appeared to disagree on the ranking of the samples also supports the modified method of open discussion panel used in this study. The

possibility exists that certain judges may unduly over-influence the discussion. With the modified method, some degree of protection is applied to the situation.

B. Testing-Training Panels.

Dawson and Harris (1951) stated: "Successful conduct of taste panels is frequently as much a matter of human relations as a scientific problem. Panel members must have a keen interest in their tasting ability and these feelings must be sustained." Success breeds success, may be a common phrase, but how often is it neglected in terms of sensory panelist's performance. Just as valid might be the statement, failure breeds failure. Success develops attitudes of self-confidence and a desire to succeed. These concepts can well be applied to the sensory evaluation studies and for optimization, should be included in the development of procedures designed to promote the panelist, into a mode of achievement for success. Success appears to be dependent on the desire to excel per se and the desire to do better than other subjects. Henderson and Vaisey (1970) found that judges selected on the basis of high scores in need for achievement performed better than low scorers in flavor difference test. They further noted that throughout the test period high achievers showed somewhat better discrimination of moderately difficult comparisons.

Of the 37 original panelists, 5 dropped out of the study, 14 failed to pass the required tests as outlined in the methods section and 18 panelists completed the testing training phase and continued on to the sensory evaluation of actual samples using the Qualitative Descriptive Analysis method.

Motivation of panelists in the raw carrot aroma study was incorporated into the design of the project through the use of devices that developed a sense of achievement, especially for those panelists who passed the testing-training phase and continued on into the Qualitative Descriptive Analysis part of the study. One of these devices (Appendix H, Figure H1) consisted of personalized ballots. The ballots were generated by a computer data base maintained on each of the panelists. The ballots included direct addressing of the panelists and information concerning previous achievements in tests. A newsletter (Appendix M, Figure M1) was generated to keep the participants of the panels in tune with the purpose of the study and the various stages of the study. For those participants making it through this phase of the study, a "diploma" and "union membership card" was generated for each, again to reinforce the motivational factors behind a sense of achievement.

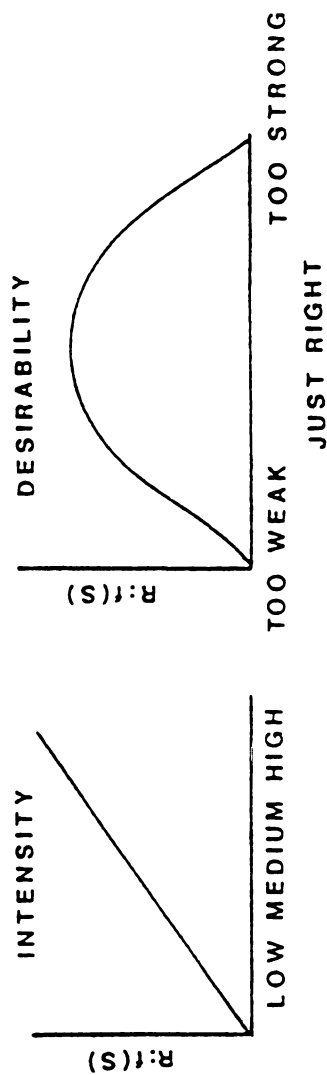
C. Qualitative Descriptive Analysis.

In this part of the study two measurements were made for each aroma descriptor (Figure 20.). The measurement for intensity was simply a quantity measurement for the characteristic of interest. The second measurement was more of a subjective measurement as to how the panelist view the previously measured quantity. The second measurement was labeled as Desirablility.

A one way analysis of variance was applied to the Qualitative Data Analysis to investigate the possibility of individual sensory descriptors varying between carrot selections at a statistically significant level. Mean square values and degrees of freedom for each are shown in Table 15. As noted, the panelists were not able to give descriptive profiles of the raw carrot aroma that varied at a significant level between carrot selections.

A summary of the results for the Qualitative Descriptive Analysis study is presented in Figure 21. This figure is a model for the aroma attributes of carrots in general, based upon the mean values for each descriptor. The solid line describes the ratings of intensity. The circle indicates the a value of five on the 0 to 10 scale. The dotted line describes the desirability rating for each descriptor. In general the carrots included in this study had close to a medium level of plain raw carrot aroma and this level was slightly below what is typically believed by the panelists to be optimum. The piney character was somewhat low but considered close

QUALITATIVE DESCRIPTIVE ANALYSIS (QDA)



Aroma Characteristics

CARROTY	FRUITY
PINEY	PERFUMY
SWEET	EARTHY
WOODY	MUSTY
HAY-LIKE	OVERALL-AROMA

Figure 20. --- Summary of the Qualitative Descriptive Analysis.

Table 15. -- Mean Squares and degrees of freedom as analyzed using One Way Analysis of Variance for the Qualitative Descriptive Analysis Data.

Analysis of Variance for Sensory Data				
Variable	Between Groups		Within Groups	
	D.F.	M.S.	D.F.	M.S.
Q01 - Carroty Intensity	9	7.0464	347	5.4418
Q02 - Carroty Desirability	9	3.3779	347	3.0146
Q03 - Piney Intensity	9	6.4668	347	5.7363
Q04 - Piney Desirability	9	1.6363	347	1.1568
Q05 - Sweet Intensity	9	7.0557	347	4.1812
Q06 - Sweet Desirability	9	2.8448	347	2.1366
Q07 - Woody Intensity	9	4.8688	347	6.9132
Q08 - Woody Desirability	9	1.2687	347	1.5463
Q09 - Hay-like Intensity	9	5.2003	347	7.5453
Q10 - Hay-like Desirability	9	3.1466	347	1.9935
Q11 - Fruity Intensity	9	3.4268	347	3.3576
Q12 - Fruity Desirability	9	.9029	347	2.0025
Q13 - Perfumy Intensity	9	3.7574	347	4.0739
Q14 - Perfumy Desirability	9	1.2802	347	1.3445
Q15 - Earthy Intensity	9	1.2029	347	7.9795
Q16 - Earthy Desirability	9	1.4463	347	1.4034
Q17 - Musty Intensity	9	.8298	347	7.1871
Q18 - Musty Desirability	9	1.1046	347	1.2621
Q19 - Overall Intensity	9	4.6894	347	3.7498
Q20 - Overall Desirability	9	1.5416	347	2.4524

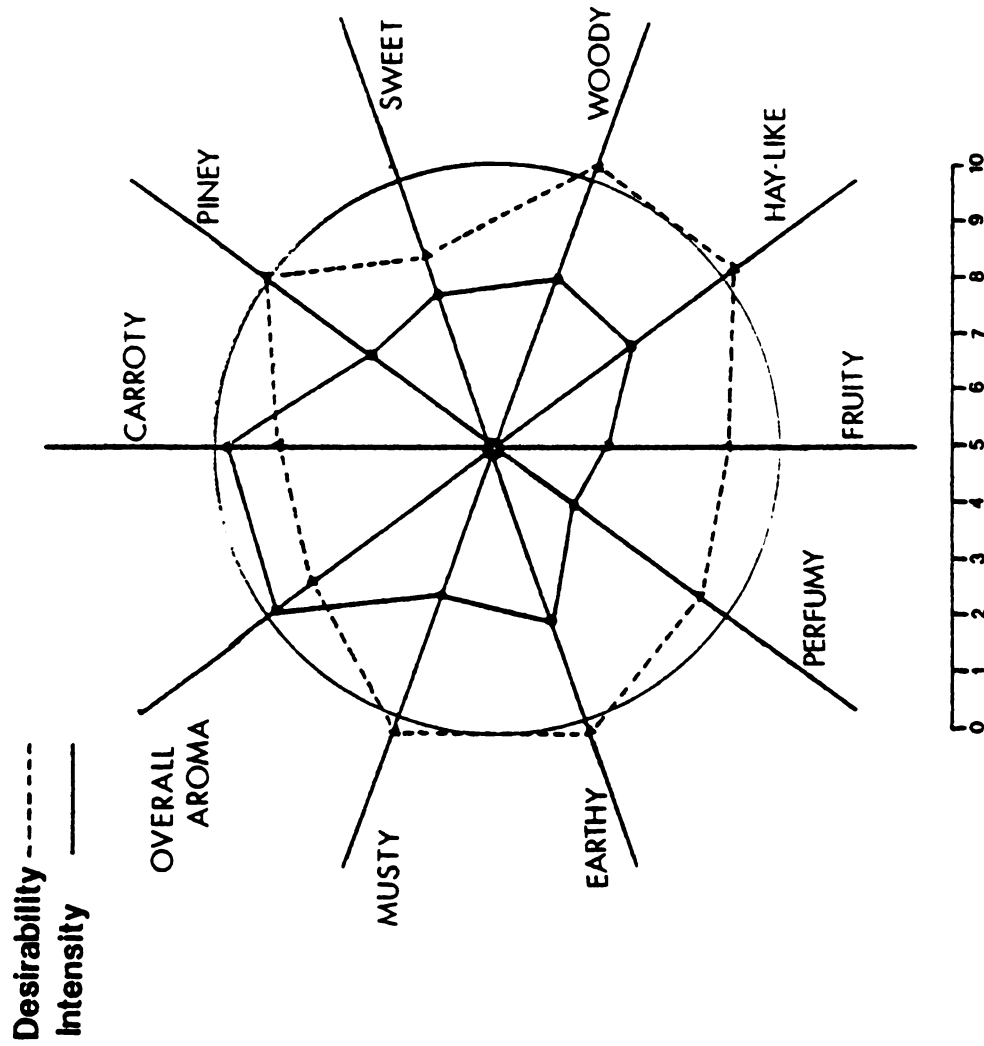


Figure 21. -- Qualitative Descriptive Analysis model for sensory attributes of carrots based upon mean values for each descriptor.

to optimum levels. The sweet aroma in the raw carrot head space was quite low and appeared to be lower than desired by the panelists. The woody aroma was at a similar level of intensity as the sweet aroma but was considered to be close to optimum. This same statement holds true for hay-like, earthy, and musty. The fruity and perfumy aroma characteristics were both rated very low for these carrot selections and yet considered just below an optimum level. The panelists were also required to place an overall rating on the level and desirability of the odorants from the raw carrot. The overall level of intensity was medium and this level was slightly lower than desired.

Factor Analysis.

Factor-analytical techniques enable us to see if some underlying pattern of relationships exist so that data may be rearranged or reduced to a smaller set of components or factors that may be taken as source variables accounting for the observed interrelations in the data.

The study of aroma characteristics is very complex and poses an ideal application of factor analysis. The variability built into the study ranges from that associated with the raw carrot itself to the complexity of the psychological differences among panelists. To some degree there is an attempt to reduce or "commonize" this variability found on the psychological level through the

use of training sessions and/or screening sessions, however, seldom can this goal be achieved completely. In this study, psychological biases are heightened by the use of a deliberate measurement of opinion, the question of desirability for each aroma characteristic. With the intention of using the newly calculated factor variables in multiple regression analysis the question of lost meaningful variation is sometimes raised. Rummel states in his overview of the applications of factor analysis that the composite variables may be used in the regression analysis in place of the original variables with the knowledge that the meaningful variation in the original data has not been lost (Rummel, 1967).

Data or facts are meaningless in and of themselves. It is only when we apply theory to them that we approach the aim of science. Once linked through propositions, an interpretation or meaning can be conferred upon the assembled data. This is the role of factor analytical techniques, that is, to expose and determine these linkages and define them so that the researcher might interpret them.

The factor model represents a mathematical formalism departing from the calculus functions of classical physics. The analytic part of the factor model, that part involved in the separation of the whole into the component parts, is akin to that of quantum theory.

An understanding of the patterns defined by factor

analysis can be enhanced through a geometric interpretation. Each of the carrot selections in this study can be thought of as defining a coordinate axis of a geometric space. Although a pictorial presentation of this model is limited to three dimensions; the space defined above would have a total of 10 dimensions, one for each of the carrot selections included in the study.

In the space defined by the 10 dimensions each sensory characteristic can be considered a point located according to its value for each carrot selection. For each point a line can be drawn from the origin to that point for a vector presentation of the data. The twenty vectors, each representating a sensory characteristic variables (10 related to Intensity measurements of the descriptors and 10 related to Desirability measurements), would then describe a vector space. The angle between any two of these vectors is a measure of the relationship between the two sensory characteristics for the ten carrot selections. The closer the angle to 90 degrees the less the relationship. The closer the angle to zero degrees the stronger the relationship. Obtuse angles indicate a negative relationship and at the extreme, an angle of 180 degrees between two vectors means the two characteristics are inversely related. The cosine of the angle between vectors is, with minor qualifications, equal to the product moment correlation coefficient between the sensory characteristics represented by the vectors.

With the vectors describing a space, their configuration then reflects the data interrelationships. Sensory characteristics that are highly interrelated will cluster together; characteristics that are unrelated will be closer to right angles. Any clusters that are found, index patterns of relationships in the data: each cluster is a pattern. What factor analysis does geometrically is enable the clusters of vectors to be defined when the number of cases (dimensions i.e. carrot selections) exceeds our graphical limit of three. As a result, each factor delineated by factor analysis defines a distinct cluster of vectors.

Factor analysis mathematically lays out a vector space and then projects an axis through each cluster. This is analogous to giving each vector one unit of mass and then allowing the center of gravity to define factor axes. The projection of each vector, in this case a sensory characteristic, on the factor axes defines the clusters. The projections are called loadings and the factor axes are termed factors or dimensions.

The algebraic factor model can be described by the following equation:

$$Y_n = a_{n1} F_1 + a_{n2} F_2 + \dots + a_{nm} F_m$$

where: Y = a variable (sensory characteristic)
with known data.

a = a constant (factor loadings).

F = a function, f(), of an unknown
variable. (A factor or dimension)

The F stands for a function of variables and not a true variable. The unknown variables entering into each function, F, are related in unknown ways, although the equations themselves are linear. From the application of factor analysis the unknown functions are defined. The loadings calculated from the analysis are the "a" constants. The factors are the F functions and the size of each loading for each factor measures how much that specific function (factor) is related to Y (a measured variable).

The sensory evaluation data were submitted for analysis using factor analytical techniques. The correlation matrix is shown in Table N1 of Appendix N. In this 20 by 20 matrix, coefficients of correlation express the degree of linear relationship between the row and column variables of the matrix. The principal diagonal and the upper half of the matrix has been deleted for conciseness of presentation. The principal diagonal consisted of all one's and the upper half was the mirror image of the lower half which is shown.

Initial factoring, using Alpha Factoring, produced the Unrotated Factor Table shown in Table N2 of Appendix N. In Alpha Factoring, variables included in the factor analysis, are considered a sample from the universe of variables. In the Unrotated Factor Table, the columns define the factors, the rows pertain to the variables, and each intersection of row and column is the loading for the

particular row variable on the column factor. Five distinct patterns (factors) are observed in the sensory evaluation data. The first factor accounts for the greatest regularity in the data and each successive factor has been fitted to best determine the remaining regularity. At this point, the patterns in the data have been accounted for but the distinction of clusters have not. This is why the application of factor rotation is commonly the next step.

The rotation of factors was performed using the Varimax criteria system which strives to maximize and minimize loadings for ease of understanding and interpretation. The Varimax criteria system does maintain orthogonality such that factors defined, as independent through alpha factoring and then rotated using Varimax are maintained orthogonal. This is important as mentioned before for application of multiple regression analysis, the final step in this study.

In Table 16, the variation characteristics of each factor are shown. Eigenvalue is a method of expressing the amount of variation accounted for by a factor. As can be seen from the table, the factors are ordered in terms of decreasing accounted variation.

The rotated factors are shown in Table 17. The odd numbered "Q" variables relate to the respective aroma intensity and the following even numbered "Q" variables relate to the respective aroma desirability.

Table 16. -- Summary of data variation explained in the factoring of the sensory evaluation.

Factor	Eigenvalue	% Variance (based on Tot.)	Cum. % (Total)	Cum. % (based on 5) Factors
1	5.22118	26.1	26.1	40.5
2	3.64246	18.2	44.3	67.9
3	2.11467	10.6	54.9	83.2
4	1.67455	8.4	63.3	93.2
5	1.19096	6.0	69.2	100.0

Table 17. -- The rotated factors for the factor analysis of the sensory evaluation data using the Varimax Criteria system of rotation.

Var.	Fact(1)	Fact(2)	Fact(3)	Fact(4)	Fact(5)
Q01	-.10991	.84602	.06197	-.04853	.00648
Q02	-.08480	.78784	-.04481	-.03524	.02829
Q03	.13644	-.00018	.33630	-.25984	.62041
Q04	.28574	.11693	.06910	.01790	.56863
Q05	-.10143	.44588	.45644	.16541	-.11116
Q06	-.17622	.56557	.00534	.41520	-.17382
Q07	.53794	-.10208	.25962	-.36007	.30383
Q08	.67103	.00321	-.05614	.01811	.30605
Q09	.57868	-.07092	.36490	-.35559	.19665
Q10	.76021	.00457	-.02794	.03288	.28718
Q11	-.03311	.14284	.64538	.03098	.16538
Q12	-.15201	.39105	-.08448	.51985	.02521
Q13	.06778	-.11356	.75381	.05756	.13214
Q14	.14861	-.08968	.22300	.83278	-.13519
Q15	.50830	-.09897	.46912	-.54486	-.03198
Q16	.64461	.04959	-.01158	-.11956	.02758
Q17	.49159	-.07832	.60691	-.36695	-.00796
Q18	.70050	.03160	.09833	.07307	-.04370
Q19	.25791	.73363	.04909	.10460	.12432
Q20	.38569	.65466	-.05054	.03810	.14475

Figure 22 is a summary of the interpretation of this factor analysis. Factor 1, accounting for a majority of the explainable variation is characterized by the term: "Earthy - Organic Aroma". It included both intensity and desirability characteristic for the sensory attributes measured with the descriptors: Woody, Hay-like, Earthy, and Musty. These were all, including both the intensity and desirability questions for each, loading on this first factor positively. It is somewhat unexpected that this factor would account for more variation than that of the second factor, termed: "Basic Raw Carrot Aroma".

This second factor consisted of the following aroma variables: Carroty, Sweet, and Overall. These were also positively loading on this second factor including both intensity and desirability questions for each.

The third factor, for lack of a better name was termed: "Intensity of Aromatics Other Than Carrot". This describes a measured variation defined by the intensity rating of the following aroma variables: Fruity, Perfumy, Musty, Earthy, and Sweet. Although the Sweet aroma is connected to the Basic Raw Carrot Aroma it is just slightly within the correlation indices for the acceptance range on this third factor.

The fourth factor is termed: "Desirability of Pleasant Aromatics (Non-Earthy)". The desirability ratings for Sweet, Fruity, and Perfumey load in a positive direction on this factor and the intensity rating of the

FACTOR ANALYSIS OF SENSORY ATTRIBUTES

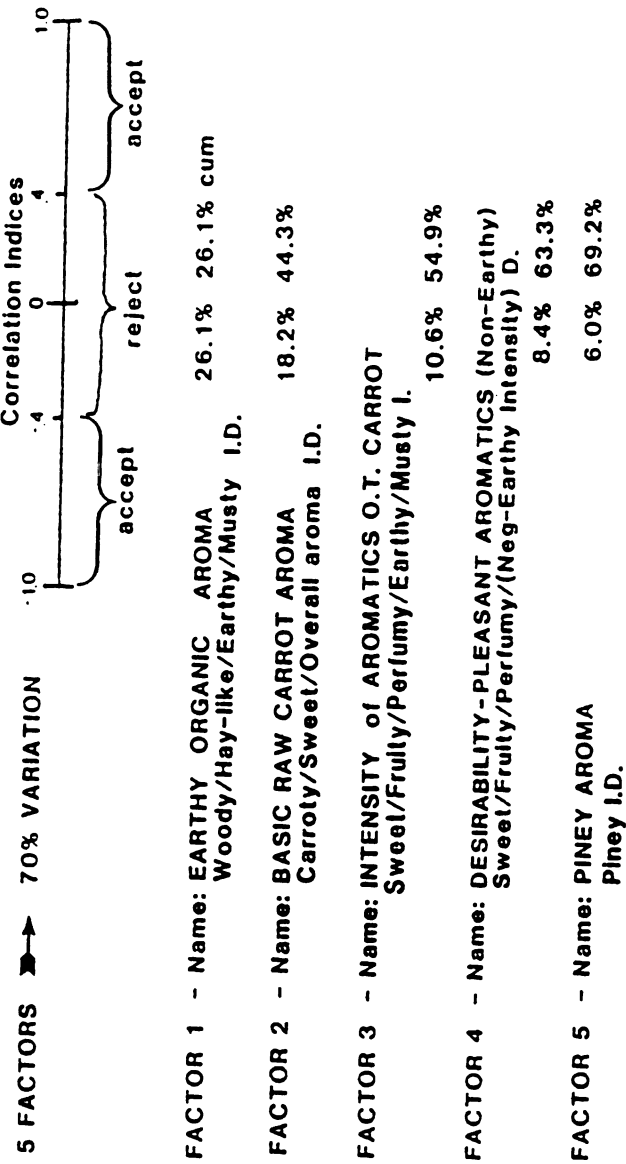


Figure 22. -- Summary of the interpretation of the factor analysis applied to the sensory evaluation data.

Earthy aroma loads negatively on this factor.

The last factor explaining a portion of the variance is termed: "Piney Aroma". It is the only individual aroma variable that was determined to be completely independent, defining it's own factor.

With the first stage of the factor analysis complete, the sensory evaluation data has been interpreted into five definable and completely orthogonal characteristics. These characteristics were then taken as factor variables and calculated on a basis of the equations in Table 18 for all of the sensory evaluation data base.

Table 18. -- Equations used for the calculation of new
Factor Variables
=====

$$\begin{aligned} \text{VB1} = & (.53794 \times \text{Q07}) + (.67103 \times \text{Q08}) + \\ & (.57868 \times \text{Q09}) + (.76021 \times \text{Q10}) + \\ & (.50830 \times \text{Q15}) + (.64461 \times \text{Q16}) + \\ & (.49159 \times \text{Q17}) + (.70050 \times \text{Q18}) \end{aligned}$$

$$\begin{aligned} \text{VB2} = & (.84602 \times \text{Q01}) + (.78784 \times \text{Q02}) + \\ & (.44588 \times \text{Q05}) + (.56557 \times \text{Q06}) + \\ & (.73363 \times \text{Q19}) + (.65466 \times \text{Q20}) \end{aligned}$$

$$\begin{aligned} \text{VB3} = & (.45644 \times \text{Q05}) + (.64538 \times \text{Q11}) + \\ & (.75381 \times \text{Q13}) + (.46912 \times \text{Q15}) + \\ & (.60691 \times \text{Q17}) \end{aligned}$$

$$\begin{aligned} \text{VB4} = & (.41520 \times \text{Q06}) + (.51985 \times \text{Q12}) + \\ & (.83278 \times \text{Q14}) + (-.54486 \times \text{Q15}) \end{aligned}$$

$$\text{VB5} = (.62041 \times \text{Q03}) + (.56863 \times \text{Q04})$$

=====

The equations express the factor variables (mnemonics: VB1, VB2, VB3, VB4 and VB5) in terms of each significant sensory variable with loadings used as coefficients for the variables (Anderson, 1980).

A second factor analysis was performed on the newly calculated factor variables along with the peak area data in order to determine which peaks, if any, should be tested for prediction of factor variables in multiple regression analysis.

In Table N3, Appendix N, is shown the variation accounted for by the nine factors determined for this second factor analysis. The factor matrix was rotated using Varimax criteria. The resultant matrix is shown in Table N4, Appendix N. The first three factors involved only peak area data and thus would not be included in multiple regression analysis. The range for acceptance for inclusion in the multiple regression analysis was extended to the regions of .2 to .1 and -.2 to -.1. This was to ensure that even the variables loading quite low on a factor be tested for possible significance in the regression equation. The fourth factor included four of the factor variables. Factor variables VB1 - Earthy aroma; VB3 - Aromatics O.T. Carrot ; VB5 - Piney Aroma all loaded quite highly on this factor and VB4 - Pleasant aromas, loaded quite highly but negatively. There were three peaks very weakly associated with this fourth factor: P15, unknown; P16, unknown and P24, unknown . All

three peaks varied very little, if at all, between carrot selections and P15 and P16 only showed up in MSU-1413 and MSU-6000 at very low levels. Factor five had two factor variables loading marginally, VB2 - Basic Raw Carrot Aroma and VB5 - Piney Aroma as well as seven peaks including camphene, beta-pinene, sabinene, limonene, and two more unknowns P14 and P24. This is especially interesting in that the Basic Raw Carrot Aroma is slightly associated with compounds classically found in all carrot extractions and volatile analysis. Factor six includes only peak area data. Factor seven had factor variables, VB2 - Basic Raw Carrot Aroma and VB4 - Pleasant Aromatics loading on it with VB2 loading quite strongly. Additionally three peak variables appeared to be associated with the factor, P15 and P16 both unknown and loading negatively, and P17 - unknown, marginally positive. Factor eight involved only peak area data. Factor nine had factor variable VB5 - Piney Aroma and six peaks loading on it, camphene and beta-carophyllene loading positively, and unknown peaks P03, P17, P20, and P24, loading negatively.

The peaks associated with the factor variables were submitted for multiple regression analysis. The prediction equations tested for significance are in Table 19. Of the five equations tested only the equation predicting factor variable VB1 - Earthy Organic Aroma was significant, however, none of the variables in that equation could be shown to be significant.

Table 19. - Multiple Regression Analysis of prediction equations for each factor variable involved in the second factor analysis.

Factor Variable			Peak Variable	
Constant				
VB1 *	=	21.929	+ 0.498	(P15)
			+ 0.145	(P16)
			- 0.047	(P24)
VB2	=	16.084	+ 0.113	(P02)
			+ 0.180	(P15)
			+ 0.893	(P17)
			+ 0.0007	(P24)
			+ 0.057	(P14)
			+ 0.027	(P11)
			- 0.001	(P04)
			- 0.465	(P16)
			- 0.140	(P03)
VB3	=	7.656	+ 0.0930	(P15)
			+ 0.0904	(P16)
			- 0.0241	(P24)
VB4	=	5.44	+ 0.013	(P15)
			+ 0.273	(P17)
			+ 0.012	(P24)
			- 0.173	(P16)
VB5	=	5.121	+ 0.009	(P02)
			+ 0.094	(P15)
			+ 0.044	(P20)
			+ 0.103	(P14)
			+ 0.0008	(P11)
			+ 0.008	(P16)
			+ 0.155	(P22)
			- 0.133	(P17)
			- 0.013	(P24)
			- 0.0002	(P05)
			- 0.001	(P04)
			- 0.113	(P03)

*

Significant at the 95% level

Computer Software for Sensory Analysis.

The use of computers for direct input of data is coming of age. With the sharp decline in cost over the past ten years and the new availability of micro-computers, the computer as a data logging tool is becoming more and more prevalent. In this study we have experimented with direct interfacing of the sensory panelists to the computer via the use of a crt (cathod ray tube) terminal. Special care had to be taken to format an approach that would be simple and easy to understand, yet accomplish the measurement of some sophisticated parameters.

The approach decided upon was to emulate the ballot method of input, which most panelists had previously used for sensory evaluation. The final program is shown in its entirety in Appendix J. The program establishes the conditions of the panel and then enters a mode of self-initiation. Lines 1000 to 1680 in the computer program are where the computer is informed of the panel conditions. Room is cleared for operation in line 1190 and the computer is told whether there is an old file in existence to which the following panel information should be added. The section in lines 1300 to 1400 instruct the computer to read in an old data file if in existence and to re-write the file in ASCII (American Standard Code for Information Interchange) format to a sequential output file. Sequential files were used for storage because of the

convenience of transfer between the TRS-80 microcomputer and the Control Data Computer used for statistical analysis. The sequential files are written to disk in an unabbreviated ASCII format where as a Direct Access file is written in a condensed, abbreviated form. The ASCII format permits the direct transfer of the sequential files to the Control Data Computer without an interpretation in between. This type of application for microcomputers is very popular i.e. working as a mini- "front end computer" to a large "main frame" computer.

Following the reading of old data, the program instructs the computer to load variables with the panelists names, the panel number and the number of samples. Lines 1640 to 1690 describe the instruction for entering the sample number and associated random number in the computer. At this point the computer set up is complete. The computer now waits for a panelist to enter their last name . Upon entry of a name, the computer then randomizes the order of the samples and then checks to make sure that the panelist name is valid. From here, the panelist is personally welcomed and told which of the randomly ordered samples is his/her first one to sniff. The video screen constantly updates the panelist as to which sample he is on and what question he is answering. The qualitative analysis ballot usually involves placing marks on a linear unsegmented scale associated with the sensory characteristic of interest. This is accomplished

through the use of a light bar on the screen. The panelists move an arrow to the appropriate location to place an "X" on the bar. Once the "X" is placed, the computer measures the distance to the "X" and logs this value under the coding for the question number, panelist, sample number, and panel number. Both the intensity and the desirability questions show on the screen together, however, only one aroma characteristic is shown on the screen at one time. Panelists have an option to re-do the responses given for a particular aroma immediately after completing the two questions of intensity and desirability. This operation continues until all twenty responses are collected for the sample. At this point the coded data is then transferred to permanent storage on the floppy disk system to be later transferred to the Control Data Computer for analysis. At the end of the panel when all panelists have finished the analyst enters the name "END" then the computer organizes itself, closing open files and then shuts down.

Care was taken to ensure that each panelist understood exactly how the computer would escort them through the questions. Computer interaction with the panelists was made as personable as possible through the use of a data base which could be called upon by the computer to find out the panelists first name.

Total estimated time saved on the part of the analyst through the use of the computer is approximately

eight hours. This figure is based upon a trial analysis set up for the purpose of testing the amount of time saved. Each ballot took five minutes to measure and code. Assuming a minimum of three samples per panelist per panel this leads to 15 minutes per panelist. If two minutes are added for paper shuffling and rest between every three ballots the total comes to 17 minutes. This times the 18 panelists yields just over five hours. Another three hours could easily be added for the keypunching time. Thus a minimum of eight hours labor per panel of this magnitude can be saved.

CONCLUSIONS

The use of the Tenax-GC as the packing material for the porous polymer trap has positive, as well as negative aspects. The porous polymer afforded an opportunity to collect and concentrate headspace volatiles without many problems commonly associated with the classical methods of headspace analysis. The volume of polymer required in the trap to efficiently collect compounds was very little, in this case 0.01g per trap. Trap regeneration was very efficient, with the passage of approximately 1 ml of ethyl ether sufficient for 100% regeneration. One of the most appreciated aspects of the porous polymer trap techniques is that artifacts are nearly eliminated with the retention of volatile ratios close to that found in the original food stuff.

The porous polymer, Tenax-GC, exhibited high retention time characteristics for the higher boiling compounds with more care required for the collection and concentration of the lower boiling compounds. The drying procedure had to be severely shortened in order to compensate for the possible loss of volatiles. Although the Tenax-GC is reported to be the best polymer in terms of

retaining volatile compositions close to the state of the original food stuff; there might be a possibility of combining some of the newly developed polymers with the Tenax-GC in order to achieve optimum trap characteristics where low and high boiling compounds would both, be highly retained in ratios similar to that found in the original food.

The modified open discussion panel appeared to perform as expected. Assuming a null hypothesis that all descriptors are alike and not significant; the concept behind the modification is akin to protecting against Type II Error in statistics, that is the error of rejecting a descriptor as being invalid when in fact it is a valid descriptor. Although the application of the concept heightens the probability of Type I Error, the error of accepting a descriptor as being valid, when in fact it is not valid; the later application of factor analysis should more than compensate for this by ensuring exposure of indifferent descriptors and formulation of new orthogonal descriptors.

During the testing-training phase of the study, an attempt was made to heighten the sense of achievement of the panelists. It was felt, based on feed back from the panelists, that the achievement factor was entering into how well the panelists were performing the job of identifying classes of aromas in this phase. Seeing their previous scores, panelist commented that they would

attempt to top a previous score or record of high scores. Although the presentation to the panelists of a diploma and union card was taken very light heartly; panelists commented on the sense of belonging and of specialness of the panel.

In the qualitative descriptive analysis study panelists were not able to describe differences between carrot selections. This condition may have arisen from numerous factors. The panelists may well have been able to distinguish differences in the aromas but when requested to elucidate those differences by way of descriptive ratings, they could not. Another possibility is that the training phase of the study did not achieve the uniformity of understandings and capabilities hoped for.

The application of factor analysis to sensory analysis is not very common. In this application I was able to define from the sensory analysis a new set of interpretations of the same data consisting of five new factor variables. The five sensory descriptors were (1) Earthy organic aroma, (2) Basic raw carrot aroma, (3) Intensity of aromatics other than carrot, (4) Desirability of pleasant aromatics (non-earthy) and (5) Piney aroma. The fact that factor analysis has the capability to achieve the recalculation of new factor variables without loss of the original data is a very powerful tool. In this application five new variables, completely

independent of one another were established for use in a second application of factor analysis.

The second application of factor analysis allowed us to formulate possible relationships which could be tested with the use of regression techniques. Each of the new factor variables, identified as sensory parameters, had various peaks associated with it from the headspace analysis which were tested in a multiple regression analysis. Of the sensory characteristics, only one equation indicated significance and that was VB1 - The Earthy Organic Aroma in carrots with peaks 15, 16, 24, each at trace levels, too low to identify. Although the regression trend was significant when each variable (compound) in the equation was tested, none were significant. The possibility exists that the regression and variables are significant and that in this case variations in the peak areas for the compounds were too high to support the findings, yet low enough to indicate a significant trend.

The results of the study tend to support the belief that the taste parameters are far more important in the acceptance of a "good" carrot than the aroma characteristics. The implications to the carrot breeder are straight forward; breed for a better tasting carrot and generally disregard minor variations in associated aroma characteristics.

The use of the computer as a data gathering tool

seemed to generate vast amounts of interest by the panelists. It was felt that in this study, the computer eased the laborious process of requesting feedback for some twenty questions for each sample. The application of computers in the field of sensory data gathering has a potential for growth. The time savings can be recognized and interpreted into a cash savings due to the lowering cost of hardware investments. This concept may have far reaching effects in terms of industry applications. Further research appears to be unbounded in terms of direction and depth. An interesting area of study may be the use of micro-computers to not only collect response data from a panelist but also to monitor bodily changes as secondary or subconscious response to stimuli applied to the subject.

APPENDICES

Appendix A.

Volatile Constituents of Carrots

Table A1. Volatile Constituents of carrots identified by Buttery et al., 1968, 1978, 1979.

1968. -- Buttery et al.

alpha-pinene
camphene
sabinene
beta-pinene
myrcene
alpha-terpinene
p-cymene
limonene
gamma-terpinene
terpinolene
caryophyllene
beta-bisabolene
gamma-bisabolene

1978. -- Seifert and Buttery

alpha-bergamotene
beta-farnesene
alpha-humulene
gamma-murolene
gamma-bisabolene-A *
gamma-bisabolene-B *

* - originally thought to be beta and gamma now believed to be isomers noted as A & B.

1979. -- Buttery et al.

geranyl 2-methyl-butyrate
geranyl isobutyrate
beta-ionone
geranylacetone
p-cymen-8-ol
elemicin
eugenol
p-vinylguaiacol
4-methylisopropenylbenzene

Appendix A. (cont.)

Volatile Constituents of Carrots

Table A2. -- The volatile constituents of carrots identified
by Heatherbell et al., 1971, 1971, 1971.

1971. -- Heatherbell et al.

diethyl ether
acetaldehyde
acetone
propanal
methanol
ethanol
alpha-pinene
camphene
beta-pinene
sabinene
myrcene
alpha-phellandrene
limonene
gamma-terpinene
p-cymene
terpinolene
octanal
unknown
"
"
"
2-decenal
unknown
"
bornyl acetate
caryophyllene
terpinene-4-ol
sesquiterpene-a
beta-bisabolene
gamma-bisabolene
unkown
sesquiterpene-b
sesquiterpene-c
unkown
sesquiterpene-d
carotol
unknown
myristicin

1971. -- Heatherbell and Wrolstad, 1971a.
- same as above -

Appendix A. (cont.)

Volatile Constituents of Carrots

1971. -- Heatherbell and Wrolstad, 1971b.
 - same as above -

Table A3. -- Volatile constituents in carrots identified
 by Murray and Whitfield, 1975.

3-isopropyl-2-methoxypyrazine
 3-sec-butyl-2-methoxypyrazine

Table A4. -- Volatile constituents in carrots identified
 by Cronin and Stanton, 1975.

3-sec-butyl-2-methoxypyrazine **

** - claimed as very important odorant
 in carrots.

Table A5. -- Volatile constituents in carrots identified
 by Linko et al., 1978.

formaldehyde
 acetaldehyde
 acetone
 propanal
 2-methylpropanal
 Butan-2-one
 n-Butanal
 3-hydroxy-2-butanone
 3-methylbutanal
 pentan-2-one
 buten-2-al
 n-pentanal
 methylbutanal
 n-hexanal
 n-heptanal
 6-methyl-5-hepten-2-one
 5-methylfurfural
 n-octanal
 n-nonanal
 unknown
 decen-2-al
 u-Undecanal
 n-dodecanal
 alpha-ionone

Appendix A.(cont.)

Volatile Constituents of Carrots

Table A6. -- Volatile constituents in carrots identified by Simon et al., 1980.

alpha-pinene
beta-pinene
sabinene
myrcene
alpha-phellandrene
alpha-terpinene
limonene
gamma-terpinene
terpinolene
terpinen-4-ol
bornyl acetate
caryophyllene
gamma-bisabolene (a)
gamma-bisabolene (b)

Appendix B.
Relative Humidity Control System

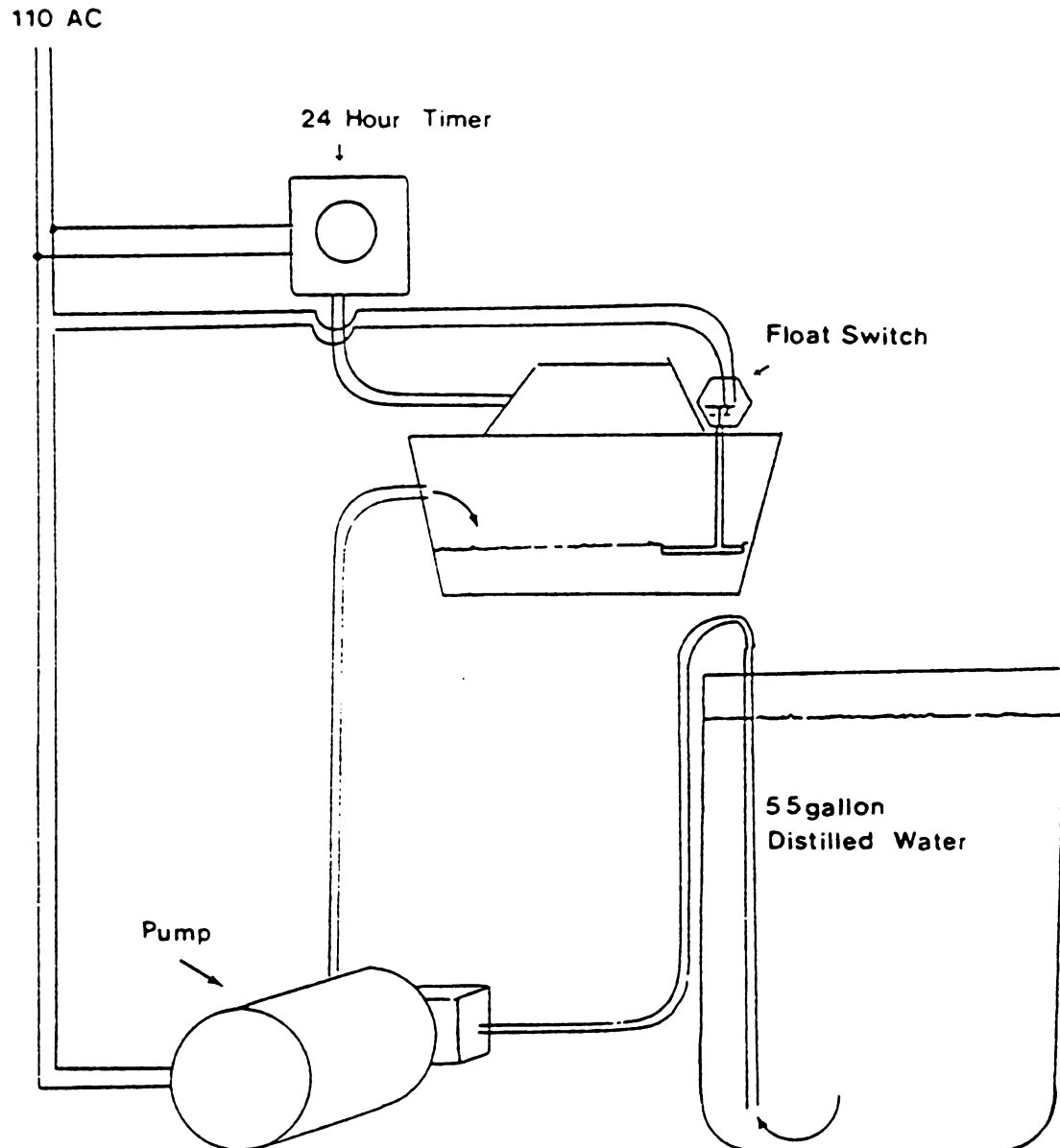


Figure B1. -- Schematic of the control system for maintenance of relative humidity in the environmental storage chamber.

Appendix C.
Volatile Collection System

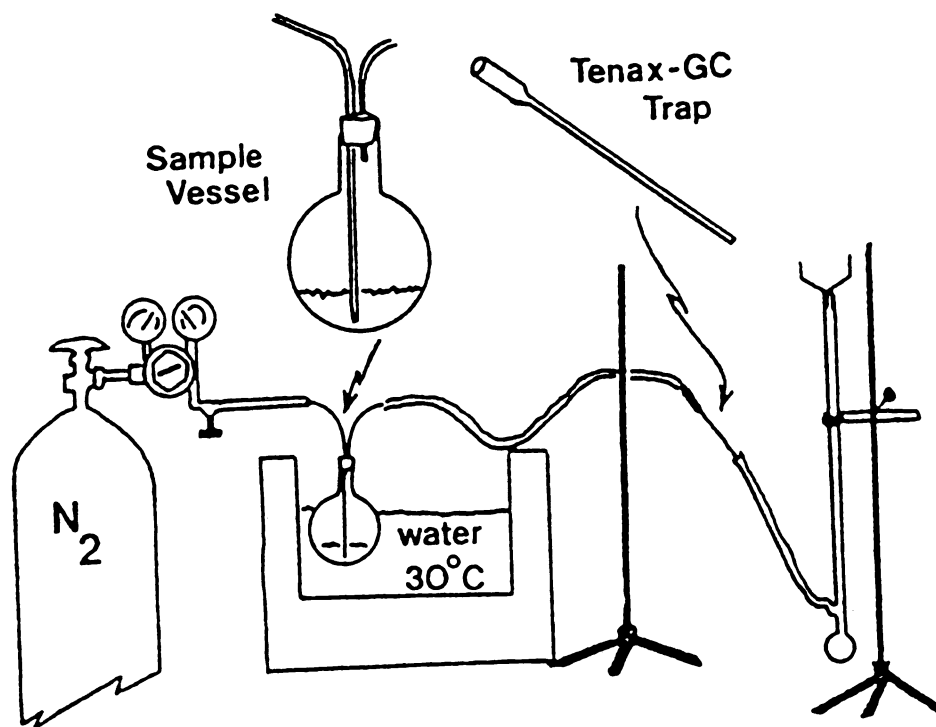


Figure C1. -- Schematic of the volatile collection system using the porous polymer traps and nitrogen sweep technique.

Appendix D.

Porous Polymer Trap Elution System

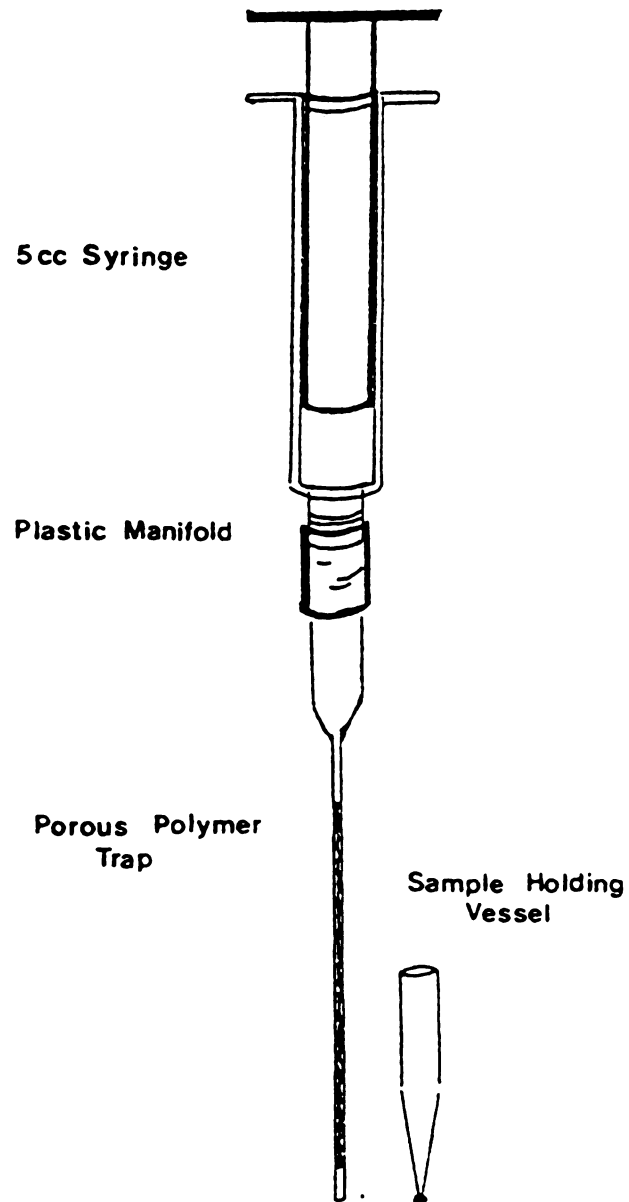


Figure D1. -- Schematic of the trap elution mechanism.

Appendix E.
Gas Chromatography

Void Volume, Flow Rate and Split Flow Calculations

Column Length = 25 meters

Column diameter = 0.2 mm.

$$\text{Total Volume} = \pi \times r^2 \times h \quad \text{where } \pi = 3.14$$

$r = \text{radius}$
 $h = \text{height or length}$

$$\begin{aligned} \text{Total Volume} &= 3.14 \times (0.1 \text{ mm.})^2 \times (25 \text{ m.} \times 1000 \text{ mm./m.}) \\ &= 785.3 \text{ cu. mm.} \\ &= 785.3 \text{ cu. mm.} / 1000 \text{ cu. mm. per cc.} \\ &= 0.785 \text{ cc.} \end{aligned}$$

An injection of Methane a non-retained compound gave a retention time of 1.50 min.

$$\text{Flow Rate} = 0.785 \text{ cc.} / 1.50 \text{ min.} = 0.52 \text{ cc.} / \text{min.}$$

$$\text{Split Vent Flow} = 60 \text{ cc.} / \text{min.}$$

$$\begin{aligned} \text{Split/Flow Ratio} &= \text{Split Vent Flow Rate} / \text{Column Flow Rate} \\ &= 60 \text{ cc.} / \text{min} / 0.5 \text{ cc.} / \text{min.} \\ &= 120 / 1 \end{aligned}$$

Column Sample = Amount that reaches the column.

$$= 1 / 121 \text{ of what is injected.}$$

Appendix E. (cont.)

Gas Chromatography

Van Dempter Equation - Height Equivalent Theoretical Plates

$$HETP = H_p + H_d + H_m + H_s$$

Multipath effect.

$$H_p = 2 L dp$$

where L is a measure of packing irregularities .
where dp is the average partical diameter.

Molecular Diffusion Term.

$$H_d = \frac{2 G D_{\text{gas}}}{v}$$

where G = a correction factor accounting for the tortuosity of the gas path.
where D_{gas} = diffusivity of the solute in the gas phase.

Resistance to Mass Transfer - Gas Phase.

$$H_m = \frac{w dp^2}{D_{\text{gas}} v}$$

where w = a constant of the order of unity.

Resistance to Mass Transfer - Solid Phase.

$$H_s = \frac{qR(1-R) d^2}{D_{\text{liquid}} v}$$

where q = a configuration factor depending on the slope of the phase (film, droplet, etc.)

Expected HETP for the 25 Meter Carbowax 20M Flexible Fused Silica Capillary Column ranges up to a maximum of 8170 (Dandeneau, 1979). An actual test run, with calculations based on Methyl Tetradecanoate indicated an HETP = 4000 (Anonymous, 1980).

Appendix E. (cont.)

Gas Chromatography

Mass Flow Rate Responding Detector - Flame Ionization.

$$R = K_2 (dm/dt)$$

where K_2 = a new constant of proportionality.
 dm = the instantaneous mass of the solute in the detector.

$$\text{Peak Area} = R dt \quad \text{where } R = \text{response.}$$

Substituting :

$$\text{Peak Area} = \int K (dm/dt) dt$$

$$\text{Peak Area} = K \int (dm/dt) dt$$

Integrating :

$$\text{Peak Area} = K_2 M$$

showing that peak area is proportional to the total mass of the eluted solvent and Peak Area is independent of mobile phase flow rate.

Appendix E. (cont.)

Gas Chromatography

Table E1. — Average peak area data for all carrot selections included in the aroma study.

Carrot Lines and Cultivars											
	1413	1385	1383	5987	107	(a) SpSW	(b) SpFN	(c) GdPk	6000	(c) Gos.	(d) StD.
P01	366	1742	857	1168	151	908	636	676	329	121	667
P02	0	23	0	55	0	0	0	0	0	6	32
P03	0	33	6	40	0	0	0	0	0	0	27
P04	448	754	441	316	122	318	352	376	174	609	329
P05	728	1181	840	346	165	362	957	934	209	367	683
P06	0	0	0	0	0	0	0	0	2	0	1
P07	8	0	0	36	0	0	0	0	0	0	22
P08	67	107	55	459	24	16	139	124	19	0	113
P09	244	512	276	1423	19	96	503	440	0	24	353
P10	0	0	84	0	0	0	41	79	11	0	57
P11	104	143	29	108	0	0	0	0	11	0	75
P12	21	63	59	0	0	0	0	304	0	0	170
P13	168	475	20	4362	0	0	280	0	0	0	1632
P14	0	39	0	0	0	0	0	0	3	0	21
P15	6	0	0	0	0	0	0	0	0	0	3
P16	11	0	0	0	0	0	0	0	16	0	28
P17	0	3	0	0	0	0	2	0	9	0	4
P18	0	0	0	0	0	0	0	0	10	0	5
P19	12	10	0	0	0	0	0	2	67	0	29
P20	0	4	0	10	0	0	22	8	4	0	13
P21	0	6	3	45	0	0	0	0	0	0	17
P22	5	3	8	29	0	0	0	0	0	0	14
P23	0	0	0	0	0	0	0	3	11	0	5
P24	71	41	36	35	3	12	0	12	25	26	35
P25	0	0	4	13	0	0	0	0	0	0	5
P26	0	0	0	6	0	0	0	0	0	0	11

(a)	(b)	(c)
Spartansweet	Sparatan Fancy	Goldpak
(d)		
Standard Deviation		

Appendix F.

Aroma Standards

Table F1. -- The ingredients of the standard aromas used in the training/testing of panelists.

Aroma	Ingredients
Piney	- Slivers of pine sapling, approximately 4 mm in width and 8 mm in length. Bark was included on the slivers and pieces.
Sweet	- Vanillian Crystals - 1 gram Eastman Kodak, Eastman Organic Chemicals, Rochester, NY. Lot-273.
Woody	- approximately 1 ounce of saw dust and chips from a mixture of woods.
Haylike	- Fresh mown hay and cured hay ground through Willy Mill No. 4 mesh screen.
Fruity	- Mixture of approx. orange extract and ethyl acetate dilluted with water.
Perfumy	- The unopened bottle of Loren perfume. Ralph Loren Co.
Earthy	- Various types of moistened soil including river banking, black clay, and sand ground together with decaying leaves, grass, and twigs.
Musty	- An old book was found which smelled very musty. The book was then compared to the aroma of 25 various mold cultures growing in a collection in the Dept. Food Science & Human Nutrition, MSU. Three molds were choosen which imparted an aroma similar to the book smell: Colvatia M-22 Trichodezina M-11 Fusarium M-20 All were grown on APDA. Scrappings from each plate were combined in a sample cup and well covered with the Dacron Fiberfill II batting.

Appendix F. (cont.)

Aroma Standards

Table F2. -- List of definitions made available to the panelists for both the testing/training panel and the carrot analysis panel.

D E F I N I T I O N S

CARROTY	- Aroma of fresh raw carrots.
PINEY	- Sharp characteristic aroma of pine.
SWEET	- A pleasant heavy fragrance.
WOODY	- Aroma of sawdust or woodchips.
HAY-LIKE	- Aroma of mowed and dried hay.
FRUITY	- The light essence of various fruits mixed together
PERFUMY	- Light, subtle fragrance.
EARTHY	- Aroma of mixed soils and organic matter.
MUSTY	- Moldy, stale aroma.
OVERALL AROMA	- The overall impact of all carrot volatiles.

Appendix G.

TRS-80 Model II Microcomputer System

System Overview.

The Radio Shack TRS-80 Model II is a disk-based microcomputer system consisting of two major components: (1) a display console with built in disk drive and (2) a separate keyboard enclosure. The operating system software is loaded from diskette by a built-in "bootstrap" program.

The Microprocessor.

A Z-80A microprocessor is at the heart of the computer and operates at its maximum design speed of 4MHz (4 million machine-cycles per second). A read only memory (ROM) provides power up and reset instructions to the processor. After the Disk Operating System initialization program is loaded from disk, the ROM is electronically switched out of the system and replaced with random access memory (RAM).

Random Access Memory (RAM).

Memory support for the system is in the form of volatile memory. This RAM comes at a minimum level 32K bytes (1K=1024 bits) which can be upgraded to a maximum level of 64K.

Appendix G (cont.)

TRS-80 Model II Microcomputer System

Video Display.

To free the Z-80A processor from display refresh and related tasks, there is included a large scale integrated (LSI) controller chip. The display offers two modes of operation: 80 characters by 24 lines, and 40 characters by 24 lines both of which are used in this application. Displayable characters include the full American Standard Code for Information Interchange (ASCII) upper and lower case as well as 32 graphics characters.

The Keyboard.

The keyboard also has it's own LSI controller to free the Z-80A processor from keyboard scan and related tasks. The keyboard is in a separate case and is connected to the display console via a built-in cable at the bottom front of the console.

Floppy Disk Drive.

Included in the Model II is an 8" disk drive unit. Three additional may be added to the system using a Disk Expansion Unit. A high density recording technique (Double Density) is used in the drive so that each diskette can contain 509,184 bytes of information. It would take a 70 word per minute typist 24 hours typing at maximum speed to fill the information area of an 8" diskette.

Appendix H.

Personalized Ballot

NAME : _____ DATE : Monday - November 17, 1980

OFFICE : 328 Food Science

, please match the characteristic odor from each cup with the list of characteristics below. Take your time - you may resample as many times as you wish.

For your own information your previous scores are recorded below.
Thank you.

PREVIOUS SCORES

TRAINING PANEL 1		TESTING PANEL-2 PANEL-3			
I	I	I	I	I	I
I	8/8	I	6/8	I	8/8
I	I	I	I	I	I

CARROT VOLATILES - TRAINING TESTING

CHARACTERISTIC SAMPLE NO.

=====

PINEY	-----
SHEET	-----
WOODY	-----
HAY-LIKE	-----
FRUITY	-----
PERFUMY	-----
EARTHY	-----
MUSTY	-----

=====

Figure H1. -- The personalized ballot produced for each panelist in the testing/training phase of the study.

Appendix I.

Sensory Evaluation Booth Construction

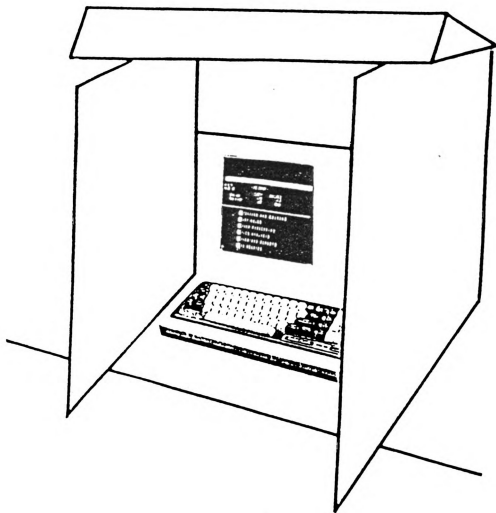


Figure 11. -- Schematic of the sensory evaluation booth constructed around the microcomputer system for use in the sample evaluation phase of the study.

Appendix J.

Data Collection Program

```

1000 ,
1010 ,
1020 '*****
1030 '*****
1040 ' PROGRAM NAME : BALLOT/BAS
1050 ' WRITTEN BY : MARK R. MCLELLAN
1060 ' DATE : NOV. 1980
1070 '*****
1080 '*****
1090 '***** ALL RIGHTS RESERVED *****
1100 '*****
1110 '*****
1120 '*****
1130 ,
1140 ,
1150 '***** RAM INITIATION *****
1160 '***** AND MATRIX FORMATION *****
1170 ,
1180 ,
1190 CLS: CLEAR 1000: DIM PP$(20), A$(10), H(30), H$(30)
1200 ,
1210 ,
1220 '***** ADD TO AN OLD FILE *****
1230 ,
1240 ,
1250 Q$="N": INPUT " NEW DATA FILE (Y/N) "; Q$: IF Q$="Y" THEN 1390
1260 ,
1270 ,
1280 '***** FULL OLD DATA FROM FILE : "INPUT/DAT" *****
1290 '***** REWRITE TO FILE : "OUTPUT/DAT" *****
1300 ,

```

```

1310 ,
1320 OPEN "I",1,"INPUT/DAT";OPEN "O",2,"OUTPUT/DAT"
1330 IF EOF(1) THEN 1370
1340 I=I+1:LINE INPUT #1,L$
1350 PRINT I;" - ";L$
1360 PRINT #2,L$;GOTO 1330
1370 PRINT "NUMBER OF DATA LINES READ IN =";I;" END INPUT
ROUTINE ***** OUTPUT FILE IS OPEN *****
1380 GOTO 1460
1390 OPEN "O",2,"OUTPUT/DAT"
1400 ,
1410 /*****
1420 /***** READY TO START PROGRAM PROPER *****/
1430 /***** READ IN PANELISTS NAMES *****/
1440 /*****
1450 ,
1460 FOR X=1 TO 18:READ PP$(X):NEXT X
1470 ,
1480 /*****
1490 /***** READ IN AROMA CHARACTERISTICS *****/
1500 /*****
1510 ,
1520 FOR X=1 TO 10:READ A$(X):NEXT X
1530 ,
1540 /*****
1550 /***** PANEL NUMBER AND NUMBER OF SAMPLES *****/
1560 /*****

```

```

1570 /
1580 INPUT "ENTER THE PANEL #";PA:H(21)=PA
1590 INPUT "THEN NUMBER OF SAMPLES TO BE GIVEN TO EACH PANELIST";SA
1600 /
1610 /=====
1620 /===== SAMPLE NUMBER AND RANDOM NUMBER =====
1630 /=====
1640 /
1650 /
1660 /
1670 /
1680 /
1690 /
1700 /=====
1710 /===== PANELIST ENTER THEIR NAMES =====
1720 /=====
1730 /
1740 CLS:PRINT@ (9,0),"Input your LAST NAME then press [ENTER].";
      :INPUT P$:IF P$="END" THEN CLOSE:SYSTEM
1750 /
1760 /=====
1770 /===== RANDOMIZE ORDER OF SAMPLES =====
1780 /=====
1790 /
1800 FOR X=1 TO SA:SS(X)=0:NEXT X
1810 X1=1
1820 XX=END(SA)
1830 FOR X2=1 TO X1
1840 IF SS(X2)=XX THEN 1820
1850 NEXT X2

```

```

1860 SS(X1)=XX:X1=X1+1:IF X1 <SA+1 THEN 1820
1870 /
1880 /
1890 / CHECK FOR PANELIST NAME =====
1900 / =====
1910 /
1920 FOR XZ=1 TO 18:IF INSTR(PP$(XZ),P$)>0 THEN 1990
    ELSE NEXT XZ:CLS:GOTO 1740
1930 /
1940 /
1950 / INITIATE PANELIST INTERACTION =====
1960 / =====
1970 /
1980 H(23)=ZX:H(22)=SN(ZZ)
1990 FOR ZZ=1 TO SA
2000 PRINTCHR$(31):PRINTCHR$(02):PRINT$(3,5),LEFT$(PP$(XZ),
    INSTR(PP$(XZ)," "));";":PRINT$(5,5),"YOUR ";:IF ZZ=1
    THEN PRINT "FIRST" ELSE PRINT"NEXT"
2010 PRINT$(7,5),"SAMPLE NUMBER IS ":PRINT$(14,17),RS(SS(ZZ))
2020 FOR X=1 TO 7000:NEXT X: TIME LAPSE *** FEW SECONDS ***
2030 CLS:PRINTCHR$(30):PRINT CHR$(02)
2040 FOR Z=1 TO 10:H=Z*2
2050 /
2060 /
2070 / INTENSITY QUESTION =====
2080 / =====
2090 /
2100 CLS:PRINTCHR$(02)
2110 PRINT$(0,0),
    "Panelist : Move the arrow to the appropriate place with the < and >"

```

```

2120 PRINT(1,0), keys ... To mark it press the space bar."
2130 PRINT(3,0),"A R O M A ";CHR$(26);" ";A$(Z);" ";
CHR$(25);" S A M P L E ";CHR$(26);" ";RS(SS(ZZ));
" ";CHR$(25);" N A M E ";CHR$(26);" ";PF$(XZ);" ";CHR$(25)
2140 PRINT(6,10),"LOW";PRINT(6,27),"MEDIUM";PRINT(6,47),"HIGH"
2150 PRINT(5,25),"INTENSITY"
2160 PRINT(7,10),CHR$(135);
2170 FOR X=11 TO 29:PRINT(7,X),CHR$(150);:NEXT X
2180 PRINT(7,30),CHR$(134);
2190 FOR X=31 TO 49:PRINT(7,X),CHR$(150);:NEXT X
2200 PRINT(7,50),CHR$(133)
2210 ,
2220 '=====
2230 '===== ARROW MOVEMENT - PLACE THE X =====
2240 '=====
2250 ,
2260 PRINT(8,30),CHR$(159);X1=30
2270 K$=INKEY$:IF K$="" THEN 2270
2280 IF K$="," THEN PRINT(8,X1)," ";X1=X1+1:IF X1>50 THEN X1=50
2290 IF K$<>"," THEN 2300ELSE PRINT(8,X1),CHR$(159):GOTO 2270
2300 IF K$="," THEN PRINT(8,X1)," ";X1=X1-1:IF X1<10 THEN X1=10
2310 IF K$<>"," THEN 2320ELSE PRINT(8,X1),CHR$(159):GOTO 2270
2320 IF K$=" " THEN PRINT(7,X1),"X":X1=X1-10:H(H-1)=X1*.25 : GOTO 2390
2330 GOTO 2270
2340 ,
2350 '=====
2360 '===== DESIRABILITY QUESTION =====
2370 '=====
2380 ,

```

```

2390 PRINT@ (13,10), "Too Weak";:PRINT@ (13,26), "Just Right";
      :PRINT@ (13,41), "Too Strong"
2400 PRINT@ (12,25), "DESIRABILITY"
2410 PRINT@ (14,10), CHR$(135);
2420 FOR X=11 TO 29:PRINT@ (14,X), CHR$(150);:NEXT X
2430 PRINT@ (14,30), CHR$(134);
2440 FOR X=31 TO 49:PRINT@ (14,X), CHR$(150);:NEXT X
2450 PRINT@ (14,50), CHR$(133)
2460 ,
2470 '=====
2480 '===== ARROW MOVEMENT - PLACE X =====
2490 '=====
2500 ,
2510 PRINT@ (15,30), CHR$(159):X1=30
2520 K$=INKEY$:IF K$="" THEN 2520
2530 IF K$="," THEN PRINT@ (15,X1), " ";:X1=X1+1:IF X1>50 THEN X1=50
2540 IF K$<>"," THEN 2550ELSE PRINT@ (15,X1), CHR$(159):GOTO 2520
2550 IF K$="," THEN PRINT@ (15,X1), " ";:X1=X1-1:IF X1<10 THEN X1=10
2560 IF K$<>"," THEN 2570ELSE PRINT@ (15,X1), CHR$(159):GOTO 2520
2570 IF K$=" " THEN PRINT@ (14,X1), "X":X1=X1-10:H(H)=X1*.25: GOTO 2530
2580 GOTO 2520
2590 ,
2600 '=====
2610 '===== RE-DO OF CONTINUE ON =====
2620 '=====
2630 ,
2640 PRINT@ (24,6),
      "To Re-do your answers ... press the =>";CHR$(26);
      " ? ";CHR$(25);" key."
2650 PRINT@ (19,0),

```

```

2660 K$=INKEY$:IF K$="" THEN 2660
2670 IF K$="/" THEN GOTO 2100
2680 IF K$=" " THEN 2710
2690 GOTO 2660
2700 ,
2710 NEXT Z , ===== NEXT AROMA - NEXT SAMPLE =====
2720 ,
2730 H(21)=PA:H(22)=SN(SS(ZZ)):H(23)=XZ
2740 CLS:FOR X=1 TO 100:Z=END(22):Y=RND(78):PRINT@ (Z,Y),"x";:
      NEXT X:PRINT@ (12,35),"THANK-YOU"
2750 ,
2760 , =====
2770 , ===== FLOPPY STORAGE ROUTINE =====
2780 , =====
2790 , =====
2800 PRINT#2,USING"###.##"
      ;H(21);H(22);H(23);H(1);H(2);H(3);H(4);H(5);H(6);H(7)
      ;H(8);H(9);H(10);H(11);H(12);H(13);H(14);H(15);H(16)
      ;H(17);H(18);H(19);H(20)
2810 NEXT ZZ:CLS:PRINT@ (10,5),"Message for => ";FF$(XZ)::
      PRINT@ (12,5),
      ",Thank-you. You are done now and may leave ... Again Thank you!"
      :FOR X=1 TO 1000:NEXT X:GOTO 1740

```

```
2820 ,
2830 ,
2840 ,==== TRAP FOR NO PREVIOUS DATA ERROR =====
2850 ,
2860 ,
2870 IF ERR=53 THEN RESUME NEXT
2880 ,
2890 STOP , ===== END OF PROGRAM =====
2900 ,
2910 ,
2920 ,==== DATA FOR READ STATEMENTS =====
2930 ,
2940 ,
2950

2960

2970
```

Appendix K.

Mass Spectra of Some Compounds
Found in the Headspace of
Raw Carrots

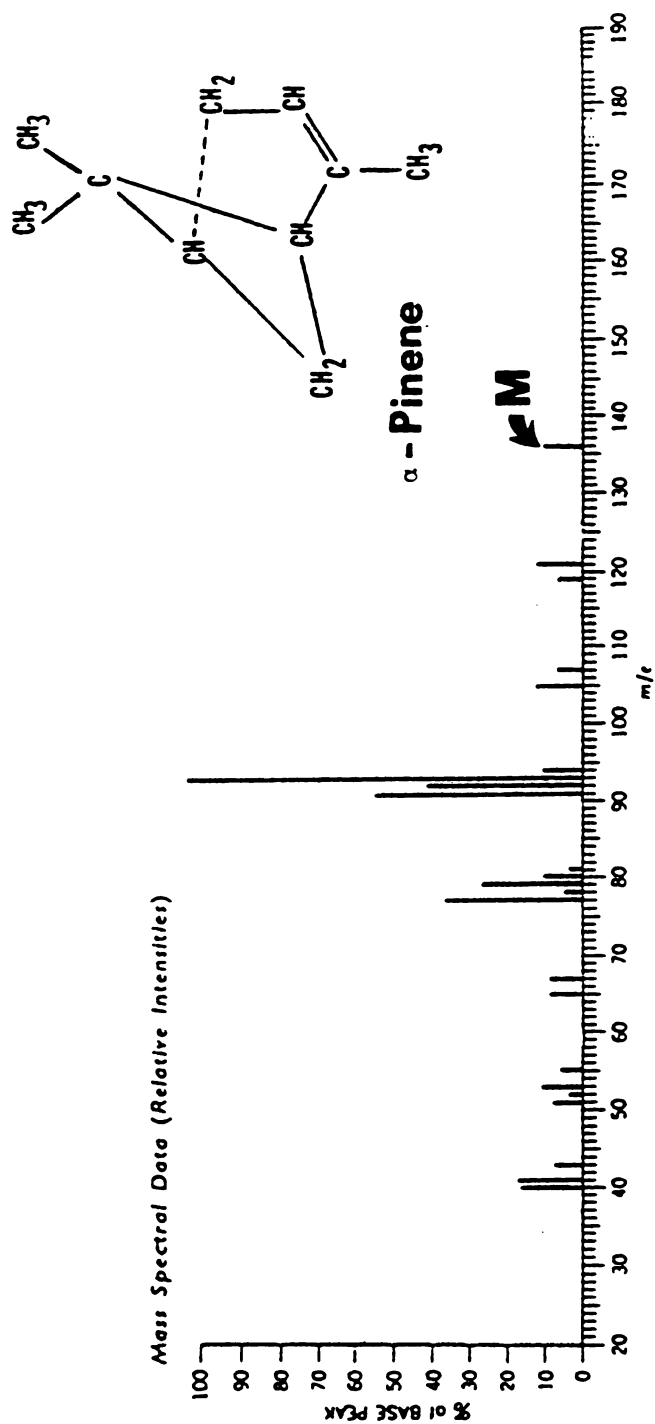


Figure K1. -- Mass spectrum of peak #1 with the molecular ion denoted as "M".

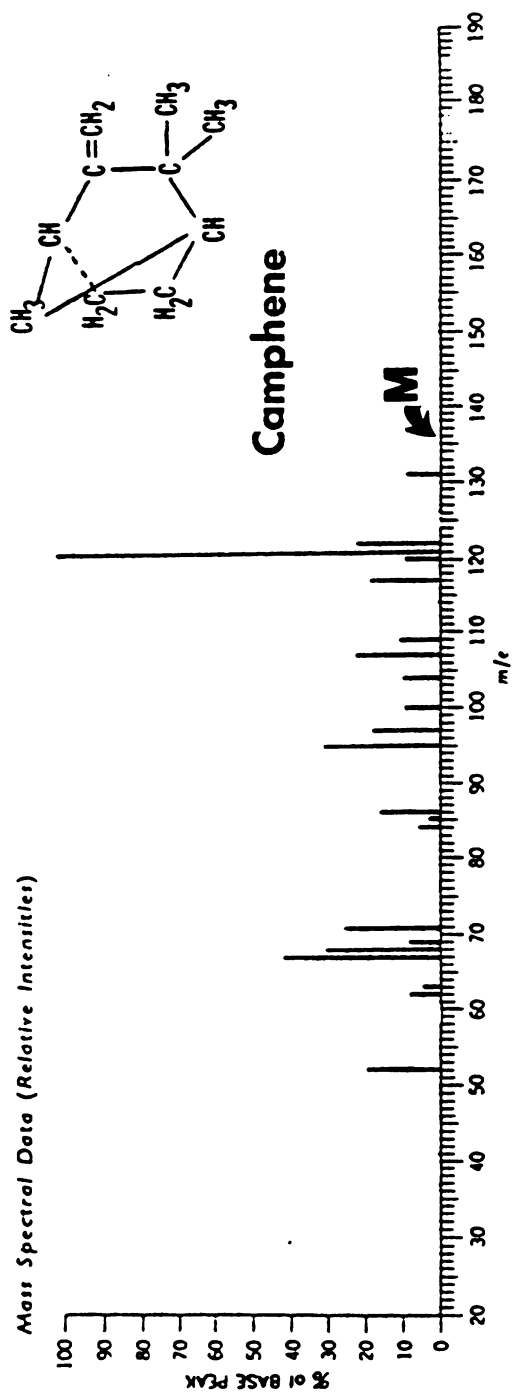


Figure K2. -- Mass spectrum of peak #2 with the molecular ion denoted as "M".

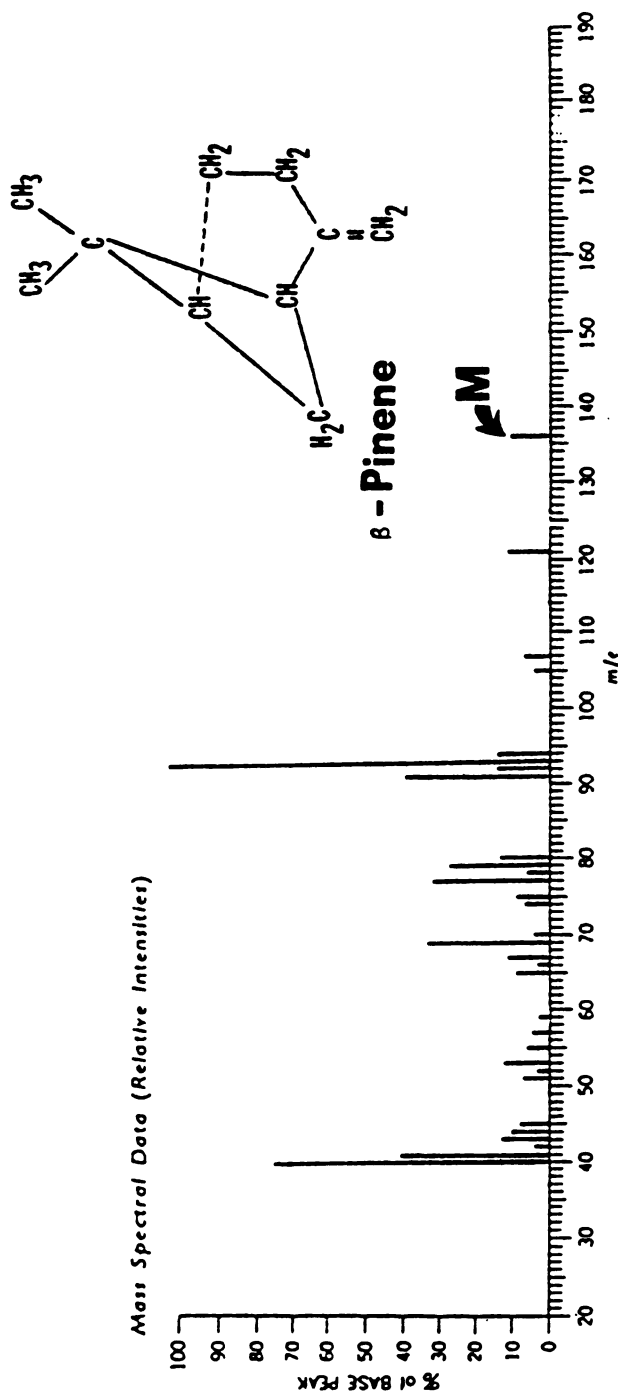


Figure K3. --- Mass spectrum of peak #4 with the molecular ion denoted as "M".

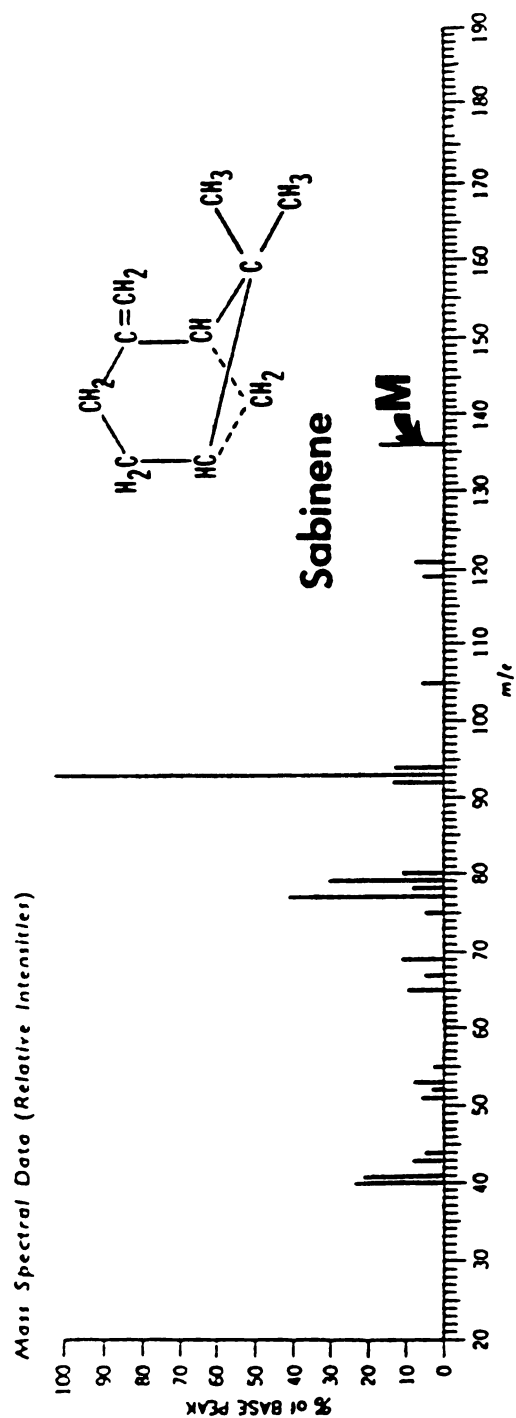


Figure K4. --- Mass spectrum of peak #5 with molecular ion denoted as "M".

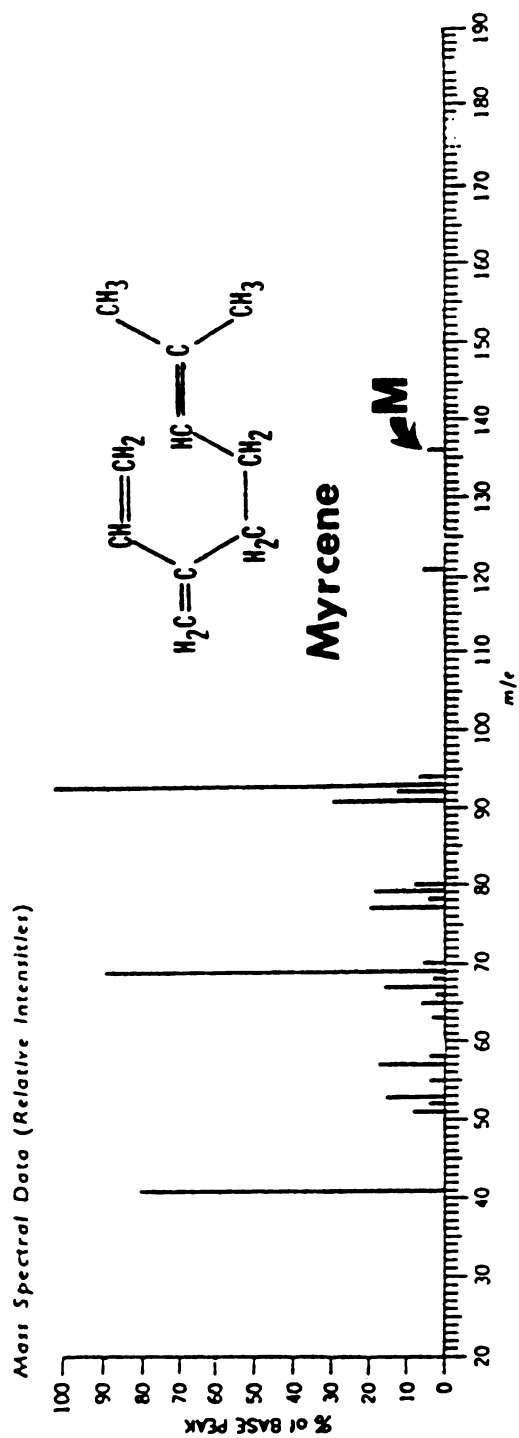


Figure K5. -- Mass spectrum of peak #9 with the molecular ion denoted as "M".

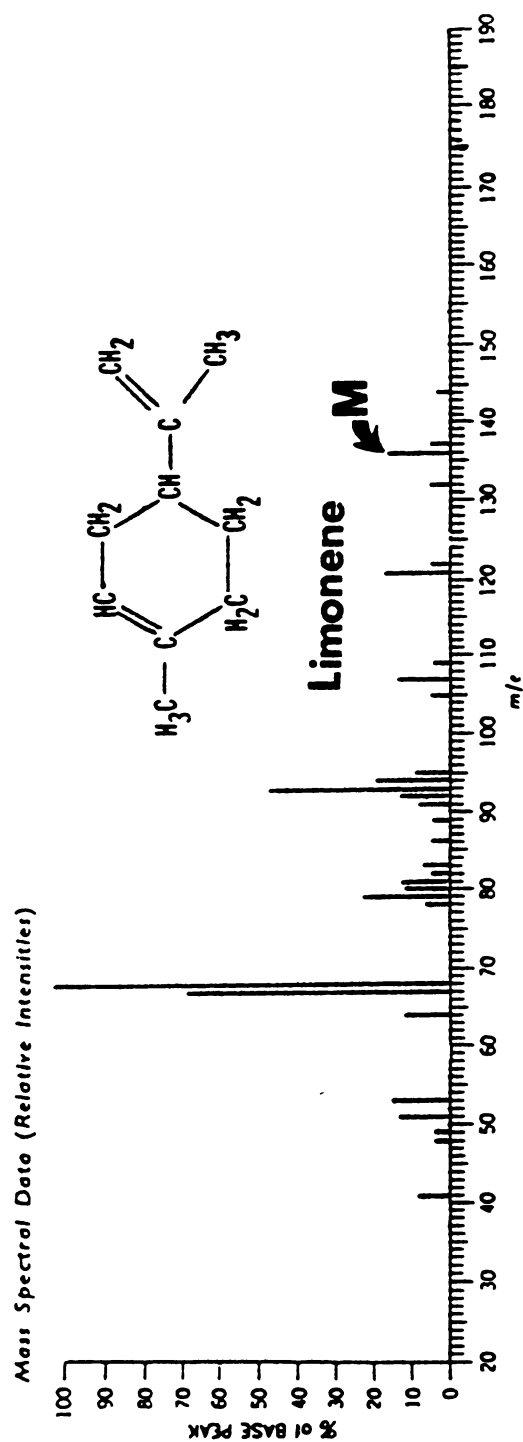


Figure K6. -- Mass spectrum of peak #11 with the molecular ion denoted as "M".

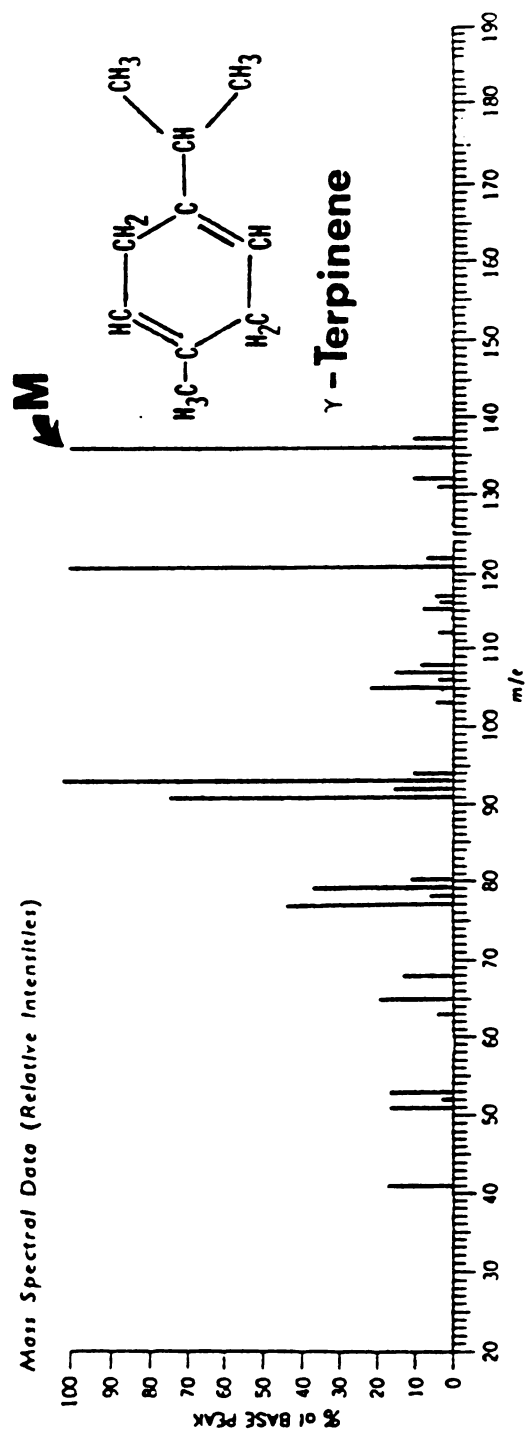


Figure K7. -- Mass spectrum of peak #13 with the molecular ion denoted as "M".

Appendix L.

Calculations for The Coefficient of Concordance, "W".

	A	B	C	D	E	
Sample Totals :	48	29	37	40	41	Grand Total = 195

$$(T)^2 = \begin{matrix} 2304 & 841 & 1369 & 1600 & 1681 \\ & & & & 7795 \end{matrix}$$

$$\text{Correction Term (C)} = (195)^2 / 13 \times 5 = 585$$

$$\text{Samples } 7795/13 - 585 = 14.61$$

$$\text{Ranks } 13(1^2 + 2^2 + 3^2 + 4^2 + 5^2) - 585 = 130$$

$$W = \frac{\text{Samples} - 1/n}{\text{Ranks} + 2/n} = 0.119$$

$$F = \frac{W(n-1)}{1-W} = \frac{0.119(13-1)}{1-0.1119} = 1.5119$$

$$\begin{aligned} \text{Degrees of Freedom in the Numerator} \\ = (5-1) - 2/3 = 3.84 \end{aligned}$$

$$\begin{aligned} \text{Degrees of Freedom in the Denominator} \\ = (13-1)((5-1)-2/13) = 46.08 \end{aligned}$$

The F VALUE at 5% for 4 and 46 = 2.57

The F Value indicates insignificance. The judges were not able to agree in their ranking.

Same analysis was completed for the second set of five samples with a calculated F value = 2.29 again falling short of the F value for the 95% significance level.

Appendix M.

Motivational Literature

Michigan State Univ. Sniffer's Association
NEWSLETTER

Editor : Mark McLellan

Date : Nov.29,1980

Letter From the Editor:

Early in 1980, plans were laid for a special "taste panel". This taste panel was to be the mainstay of an analysis of the volatile constituents of RAW CARROTS. The ground work for the panel was not introduced until mid 1980 when it was decided that the panel was to be trained and tested in it's ability to distinguish between smells similar to (but not necessarily identical to) those found in RAW CARROTS.

On October 14th, two Open Discussion Panels were convened to discuss, gather, and develop descriptors for ten largely different varieties of RAW CARROTS. After reviewing the comments and recommendations of the panels, the following ten descriptors were chosen for their frequent use and common agreement between discussion panelists:

Piney Sweet Woody Hay-like Fruity Perfumey Earthy Musty

On November 12th some thirty seven people were asked to sniff ten standards related to those found by the discussion panel to be important. Each panelist had a COMPLETED ballot before him/her and was told to identify the volatiles using the completed ballot such that on later occasions the panelist may be able to complete the ballot him/herself. This was the only time all of the volatiles were identified for panelists. One day later all forty panelists were tested in their ability to separate and identify the ten aromas, five of the forty panelists were dropped from the panel due to poor scores (more than one wrong). Of the five dropped, three were older than the average age of the panelists, another was a full time smoker, and the last was of the average age of the panelists.

One day after the first test, the second test was conducted, with thirty five panelists remaining. Seven panelists were dropped from the study due to their scores (less than perfect) and three others were dropped due to availability.

Three days after this second test, the third and final test was run on the remaining twenty two panelists. Of those, two were dropped due to their scores (less than perfect) and two were dropped due to availability.

Eighteen panelists remained and constitute the trained and tested panel. The panel consists of 66% females and 44% males.

DATA COLLECTION

Data collection is now be performed on the TPS-80 MOD II microcomputer. All measurements are made by the computer, coded and stored for transfer to the Control Data Computer on campus. This is a great help in reducing time for statistical analysis. The average time to take measurements and code the data on one ballot is 5 minutes. So assuming at any one panel only three samples are given that results in 15 minutes of measurements per panelist, throwing in a two minute rest between panelist produces a total time of 17 minutes per panelist times 18 panel members. The result is just over 3 hours data preparation time. This does not include the additional time for keypunching and data checking which could easily run the total up to 8 hours total. All of this is

Figure M1. -- A Newsletter distributed to the panelists as a motivation for achievement.

Appendix M. (cont.)
Motivational Liturature

accomplished instantaneously by the microcomputer when each sample is completed by the panelist, requirering no additional manipulation, recoding or rewriting of data.

JUST A REMINDER

All panelists are reminded that when three samples are given to them, they are to treat each individually. DO NOT compare between samples presented.

WHATS NEW !

Starting with the next panel, the computer will make an extra effort to remind each panelist which sample is to be sniffed and also let you know in no uncertain terms when you are done with the set of samples.

A WORD OF THANKS

I'd like to thank all of those who are on the panel for your considerate donation of time in this study. Your help has been and will be most appreciated.

"How long will the study run ?", you say. I hope to have all sniff panels completed by the second to third week in January.

Figure M1. -- A Newsletter distributed to the panelists as
a motivation for achievement.(cont.)

Appendix N.

Factor Analysis Results

Table N1. -- Correlation coefficients for the factor analysis of sensory evaluation data.

=====					
Sensory					
Parameter	Q01	Q02	Q03	Q04	Q05
=====					
Q01					
Q02	.82140				
Q03	.01522	-.01444			
Q04	.04218	.07486	.50299		
Q05	.38199	.26774	.01992	.01669	
Q06	.41248	.41896	-.18700	-.03908	.51477
Q07	-.08568	-.10173	.42058	.29884	-.08188
Q08	-.03525	-.03932	.19093	.34505	-.09061
Q09	-.09087	-.07730	.39030	.22406	-.00679
Q10	-.08795	-.06582	.19463	.35214	-.08979
Q11	.15453	.08875	.28141	.12284	.37740
Q12	.30615	.34430	-.22470	.05904	.17485
Q13	.00395	-.09173	.31873	.09224	.24268
Q14	-.07304	-.08440	-.18355	-.03135	.14086
Q15	-.11470	-.11932	.36645	.18169	.03099
Q16	-.00688	.02634	.15597	.24940	-.08624
Q17	-.09766	-.12523	.38122	.20966	.14132
Q18	-.04704	-.06166	.13616	.21817	-.00232
Q19	.61714	.49944	.12179	.20722	.32245
Q20	.42532	.45239	.09816	.24215	.20234

	Q06	Q07	Q08	Q09	Q10
=====					
Q01					
Q02					
Q03					
Q04					
Q05					
Q06					
Q07	-.32441				
Q08	-.19582	.53142			
Q09	-.28953	.71467	.39248		
Q10	-.19354	.43532	.68802	.63498	
Q11	-.01904	.16015	.00506	.23216	.03991
Q12	.50745	-.30535	-.11833	-.31350	-.06985
Q13	-.14800	.28070	.07507	.34562	.08053
Q14	.28763	-.16567	.04673	-.14764	.05216
Q15	-.33845	.60319	.21722	.64279	.28590
Q16	-.11169	.40024	.39870	.37808	.47795
Q17	-.27362	.52641	.24893	.62415	.29024
Q18	-.07458	.26975	.44668	.32229	.46118
Q19	.34129	.03617	.21953	.06657	.23224
Q20	.27505	.15363	.29832	.19213	.35396

Appendix N.(cont.)

Factor Analysis Results

Table N1. -- Correlation coefficients for the factor analysis of sensory evaluation data.(cont.)

=====

Sensory
Parameter

	Q11	Q12	Q13	Q14	Q15
--	-----	-----	-----	-----	-----

 =====

Q11					
Q12	.12036				
Q13	.51390	-.14878			
Q14	.08069	.39458	.30936		
Q15	.27812	-.38341	.31568	-.26154	
Q16	-.02956	-.08659	-.01358	.00473	.53771
Q17	.34235	-.35869	.45272	-.10949	.77166
Q18	.02431	-.12761	.10572	.23088	.32591
Q19	.12075	.24951	.06425	.05826	-.02513
Q20	.11196	.22202	-.08401	-.04580	.05207

	Q16	Q17	Q18	Q19	Q20
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Q11					
Q12					
Q13					
Q14					
Q15					
Q16					
Q17	.30633				
Q18	.49753	.48357			
Q19	.14428	.06959	.23670		
Q20	.21342	.10158	.31536	.74368	

Appendix N. (cont.)

Factor Analysis Results

Table N2. -- The Factor Matrix Using Alpha Factor for Sensory Evaluation Data.

	Fact(1)	Fact(2)	Fact(3)	Fact(4)	Fact(5)
Q01	-.12133	.76464	.07478	-.34613	.09633
Q02	-.13254	.70396	-.03007	-.33776	.06169
Q03	.52973	.04907	.25662	-.20823	-.43806
Q04	.42741	.21596	-.08379	-.20823	-.43806
Q05	-.04677	.50922	.41134	.08949	.13581
Q06	-.38840	.61305	.01491	.13945	.08491
Q07	.75574	-.06892	.02520	-.10516	-.03987
Q08	.60789	.11389	-.36246	.13911	-.11920
Q09	.78603	-.02826	.09868	-.05564	.08178
Q10	.67731	.13321	-.38002	.18695	-.08005
Q11	.24306	.25174	.57162	.09558	-.08939
Q12	-.35485	.49274	-.08253	.23682	-.14982
Q13	.36538	.04826	.62899	.26640	-.06379
Q14	-.12180	.21218	.03607	.85374	-.04032
Q15	.75813	-.12802	.24874	-.16005	.32785
Q16	.55184	.09043	-.29363	.05991	.17512
Q17	.74113	-.03299	.35567	.00740	.27191
Q18	.54827	.14962	-.24352	.28390	.21382
Q19	.16302	.76323	-.11953	-.09710	.02702
Q20	.26429	.67250	-.25483	-.11746	.03803

Table N3. -- Explained variation for new sensory data and peak area used in the second factor analysis.

Factor	Eigenvalue	Pct of Var (based on) (Total)	Cum Pct (based on) (Total)	Cum Pct (based on) (9 Factors)
1	6.64602	21.4	21.4	25.3
2	4.98273	16.1	37.5	42.7
3	4.15600	13.4	50.9	59.1
4	2.93359	9.5	60.4	71.1
5	2.08736	6.7	67.1	79.5
6	1.89174	6.1	73.2	87.0
7	1.40087	4.5	77.7	92.2
8	1.16378	3.8	81.5	96.3
9	1.10497	3.6	85.1	100.0

Appendix N. (cont.)

Factor Analysis Results

Table N4. -- Varimax Rotated Factor Matrix for new sensory data (previous factor variables) and peak data.

	Fact(1)	Fact(2)	Fact(3)	Fact(4)	Fact(5)
VB1	.09831	-.00004	-.08039	.84114	-.00985
VB2	-.08172	.18386	.00177	.01418	.20498
VB3	.09537	-.04371	-.13641	.80224	-.05495
VB4	-.11974	.08285	.12211	-.63461	.06513
VB5	-.16916	.01798	-.13569	.52658	.20821
P01	.02377	.43827	.14963	-.18130	.08595
P02	-.03972	.78380	.03712	-.08320	.30737
P03	-.03269	.66078	.13314	-.11475	.53908
P04	-.10538	.05358	.26515	.10191	.38090
P05	-.09543	-.02590	.82888	-.01277	.37963
P06	.96319	-.01919	-.04839	.05664	.01077
P07	-.04083	.05110	.96944	-.06775	.12357
P08	-.05234	.32286	.90515	-.08011	.16799
P09	-.06308	.92107	-.06997	.03207	.02444
P10	.05792	-.06693	.73277	-.06161	-.18953
P11	-.02006	.42224	.15104	.06969	.80327
P12	.01331	-.05630	.67370	-.13012	.03337
P13	-.04969	.91041	.04147	.02902	.05333
P14	.03436	-.00662	.15661	-.08030	.92235
P15	.01904	.01807	-.01460	.40092	.12658
P16	.80931	.00799	-.04306	.29694	.12216
P17	.90615	-.05754	-.12651	-.10682	-.05102
P18	.96319	-.01919	-.04839	.05664	.01077
P19	.96186	-.02737	-.05390	.07908	.01179
P20	.12006	.19572	-.11179	-.04028	.07050
P21	-.04465	.33295	.01897	-.09496	.14297
P22	-.04740	.81996	.03231	-.05375	.07318
P23	.92166	-.07358	.21161	-.02019	-.06649
P24	.09034	.08190	-.08636	-.29133	.25960
P25	-.05170	.48684	-.08683	-.01340	-.04578
P26	-.03028	-.13301	-.04676	-.04754	-.01024

Table N4. -- Varimax Rotated Factor Matrix for new sensory data (previous factor variables) and peak data. (cont.)

	Fact(6)	Fact(7)	Fact(8)	Fact(9)
VB1	-.05625	-.12845	-.06238	.03025
VB2	.00449	.68541	-.01976	-.12826
VB3	-.03378	.17280	.08946	-.05802
VB4	.04016	.34286	.11043	.06686
VB5	.03305	-.09546	-.15380	.48755
P01	.00679	.19033	.31137	.16614
P02	.18065	.00212	.28986	.25742
P03	.15446	.02729	.28190	.21374
P04	-.00913	.09192	.62426	-.13532
P05	.01849	-.04121	.32299	-.06743
P06	.00071	-.01745	.04467	-.06581
P07	-.03284	.06587	-.04991	.01414
P08	-.01749	.11430	-.10836	-.01007
P09	.04276	.09010	-.20223	-.09016
P10	-.04038	-.00886	.23266	-.13375
P11	.05032	-.06289	.06649	.09557
P12	-.01855	-.05543	-.00146	-.00300
P13	.01338	.16653	-.25403	-.08571
P14	-.00770	.13001	.09016	.01520
P15	-.03878	-.58191	-.14777	.05227
P16	-.03085	-.48427	-.09556	-.00172
P17	-.08048	.20280	.02165	.28709
P18	.00071	-.01745	.04467	-.06581
P19	-.04598	-.10171	-.04487	.01364
P20	-.01323	.13524	.00552	.51047
P21	.93212	.02604	.07238	.04924
P22	.30935	-.12127	.28381	.22416
P23	-.00705	-.00303	-.09352	-.01629
P24	.07777	.06831	.06349	-.26420
P25	.78915	-.02741	.09737	.07386
P26	.88666	.03869	-.10974	-.11086

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