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SHORT COMMUNICATION

GAS CHROMATOGRAPHY OF THE FIELD-, GLASS- GREENHOUSE-GROWN, AND ARTIFICIALLY RIPENED TOMATOES.

(*LYCOPERSICON ESCULENTUM* MILL.)

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Abstract—Fifteen distinct peaks were resolved from red-ripe tomato flavor extract by gas chromatographic techniques. Except isobutanol, *n*-hexanol, and *n*-hexanal, concentrations of the volatile components in the field-grown tomatoes were higher than those in the greenhouse-grown tomatoes. Artificially ripened tomatoes contained less volatile components.

INTRODUCTION

STUDIES on the physiology and biochemistry of tomatoes have been reported elsewhere. Little information is available, however, concerning the differences in aroma composition between the field-, greenhouse-grown, and the artificially ripened green-ripe tomatoes. The present paper is concerned with studies on the volatile components of the field- and greenhouse-grown, and the artificially ripened green-ripe tomatoes.

RESULTS

A typical chromatogram obtained from the flavor extract of red-ripe tomatoes grown in the field is shown in Fig. 1. Similar chromatographic patterns were obtained with the greenhouse-grown and the artificially ripened green-ripe tomatoes. Quantitative analysis,

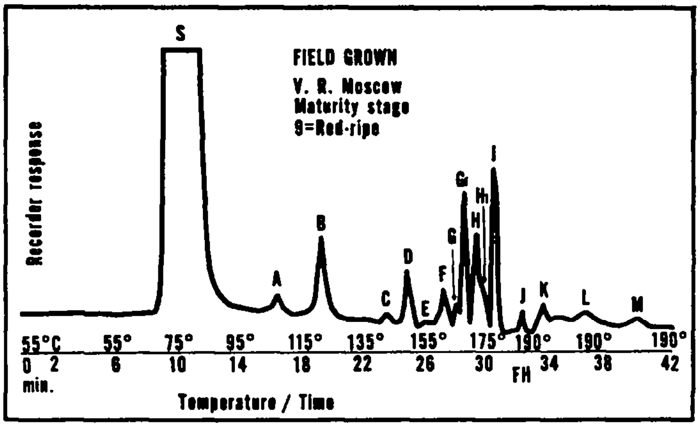

FIG. 1. A TYPICAL GAS-LIQUID CHROMATOGRAPH OF FIELD-GROWN RED-RIPE TOMATO FRUIT.

however, showed a considerable difference in concentration between them. Except isobutanol, *n*-hexanol, and *n*-hexanal, concentrations of all the volatile components in the field-grown tomatoes were found to be higher than those in the greenhouse-grown tomatoes. In general, the artificially ripened green tomatoes were found to contain much less volatile components than both field- and greenhouse-grown ripe tomatoes.

Among the fifteen peaks obtained by gas chromatographic techniques, isobutanol, isopentanol, *n*-hexanol, and 2-methyl-3-butanol were the four major alcohols, and benzaldehyde, *n*-hexanal, and isopentanal were the three predominating aldehydes found in the extract. In addition, five esters were identified, namely, isopentyl acetate, isopentyl butyrate, isopentyl-isovalerate, *n*-butyl hexanoate, and *n*-hexyl-hexanoate. None of these esters have hitherto been reported as tomato aroma constituents. The presence of furfural, α-pinene, methyl salycilate, reported elsewhere as tomato aroma constituents,[1,2] was also confirmed.

DISCUSSION

Results obtained in this study showed that the field-grown red-ripe tomatoes were richer in volatile components than either the greenhouse-grown red-ripe or the artificially red ripened tomatoes. The lower concentrations of the volatile components in the artificially ripened tomatoes might be attributable to the insufficient ripening process. A slight emanation of the volatile components during the process could also occur.

TABLE 1. GAS CHROMATOGRAPHIC ANALYSIS* OF THE VOLATILE COMPONENTS OF RED-RIPE TOMATOES (variety: V. R. Moscow)

Peak Description†	Component	Retention time (min)	Field grown (ppm)	Greenhouse grown (ppm)	Artificially ripened (ppm)
A	Isobutanol	16·3	1·5	1·8	0·87
B	Isopentanal	18·6	4·0	3·9	2·2
C	Isopentanol	23·2	1·4	1·2	0·60
D	*n*-hexanol	24·6	2·0	3·8	1·8
E	Isopentyl acetate	25·5	1·0	0·06	0·04
F	*n*-hexanal	26·4	1·8	3·7	1·2
G	α-pinene ‡	28·0	0·03	trace	trace
Bromo derivation of	α-pinene	29·4	trace	trace	trace
G_1	2-methyl 3-hexanol	28·1	6·0	4·7	3·7
H	Isopentyl-butyrate	28·5	4·0	3·7	2·6
H_1	Furfural				
I	Isopentyl-isovalerate	29·6	6·5	4·9	3·7
J	*n*-butyl hexanoate	32·2	1·2	0·16	1·0
K	Methyl salycilate	33·5	1·1	0·20	0·82
L	Benzaldehyde	36·4	0·90	0·30	0·44
M	*n*-hexyl hexanoate	40·4	0·82	0·70	0·40
S	Solvent (Benzene)	8·2	—	—	—

* Column (¼ in. × 10 ft) packed with carbowax 20 M.
† Peaks as shown in Fig. 1.
‡ Tentative identification based on retention data only.

[1] A. W. PYNE and E. L. WICK, *J. Food Sci.* **30**, 192 (1965).
[2] M. S. SPENCER and W. L. STANLEY, *J. Agr. Food Chem.* **2**, 1113 (1954).

It has been suggested that enzymatic degradation of sugars and amino acids may eventually result in the synthesis of the volatile aroma components. Many of the components identified in this study are compounds with carbon skeletons ranging from 1 to 7. The isoprene unit ($CH_2=C(CH_3)$-$CH=CH_2$), a parent structure of carotenoids, might also serve as a precursor for the different aroma components found in this investigation, as it has the same carbon skeleton as isopentanol, isopentanal, and various isopentyl esters.

The odors of many of the compounds listed in Table 1 are normally considered rather obnoxious. A mixture containing all the compounds, however, gives less objectionable, and even pleasant, odor. This has been demonstrated by a synthetic mixture prepared by mixing a certain amount (in ml) of each of those volatile compounds found in the red-ripe tomatoes used in this study. The mixture had a "spicy" or "clove oil" type smell. Upon dilution of this mixture with water the odor changed to a pleasant "cherry-like" one. Another synthetic mixture was then prepared. It consisted of glucose, citric and malic acids and volatiles and deodorized puree in the concentrations present in red-ripe tomato fruit. These concentrations are based upon earlier studies from our laboratories.[3,4] This synthetic mixture gave an odor similar to that of tomatoes. Among the volatile components identified in this investigation, isopentanal, *n*-hexanol, and 2-methyl-3-hexanol, in very dilute solutions, exhibited a "green leafy" odor.

EXPERIMENTAL

Tomatoes (variety: V. R. Moscow) were grown in the field and the glass greenhouse during the year 1964. They were harvested at the red-ripe stage. The tomatoes used for artificial ripening were sampled from the field at the large green stage (2–3 in. or larger)[3,4], placed in wooden trays with appropriate space between two fruits. They were then kept at 15–20°C. No supplemental lighting was provided. Artificial ripening of the green tomatoes was carried out until the majority of the fruits turned red-ripe. The red-ripe stage was tentatively judged by color and the degree of softness.

The tomatoes were blended, and the aroma was extracted using benzene and ethyl chloride. The extract was then subjected to gas-liquid chromatography. The column ($\frac{1}{4}$ in. × 10 ft) was packed with carbowax 20 M (Fig. 1). Fifteen distinct peaks were resolved from the aroma extract. In order to identify the individual peaks, the components were separated from the original aroma extract according to their functional groups, viz., alcohols, aldehydes, and esters. The procedures were based upon the method outlined by Dalal *et al.*[5] The individual components in each group were then separated and identified by thin-layer chromatography on aluminium oxide-G or silica sel-G using benzene:ether (1:1 or 1:1·3) and benzene:hexane (1:1). The identification of all the volatile components was further confirmed by the retention time in the gas chromatography and also by the melting point determination of the corresponding derivative of each component. Hydrolysis into their corresponding alcohol and acid was found necessary in order to identify the esters.[5] Quantitative determination of the concentration of all the identified volatile components was made by measurement of the area under the individual peaks.

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[3] K. B. Dalal, D. K. Salunkhe, A. A. Boe and L. E. Olson, *J. Food Sci.* **30**, 504 (1965).
[4] K. B. Dalal, D. K. Salunkhe and L. E. Olson, *J. Food Sci.* In press.
[5] K. B. Dalal, L. E. Olson and D. K. Salunkhe, Manuscript in preparation.