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^{*1}Department of
Microbiology, Sokoto
State University, Sokoto
State, Nigeria

²Department of Chemistry,
Sokoto State University,
Sokoto State, Nigeria

*Corresponding author's email:
imteehal@gmail.com

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STUDIES ON VOLATILE AROMATIC COMPOUNDS ASSOCIATED WITH SPOILT TOMATOES IN SOKOTO METROPOLIS, SOKOTO STATE, NIGERIA

¹S. A. Ahmed and ²Muhammad, S

Abstract

This study investigated the volatile organic compound (VOC) profiles of spoiled tomatoes using gas chromatography-mass spectrometry (GC-MS) to identify potential spoilage markers. The VOC profiles of ten spoiled tomato samples were compared to a control sample of fresh, healthy tomato. Spoiled tomatoes exhibited distinct VOC signatures characterized by the presence of aldehydes, alcohols, esters, hydrocarbons, and fatty acids and their derivatives, compared to the minimal VOC profile of the fresh tomato. Specific VOCs, such as aldehydes (e.g., butanal-3-hydroxy, pentanal), likely originated from lipid breakdown products and potentially contributed to off-odors. Alcohols (e.g., 2-hexanol, 4-methyl-2-hexanol) might indicate microbial involvement, while the presence of esters (e.g., methoxyacetic acid octyl ester) suggested potential consequences of advanced spoilage. Fatty acids and their derivatives (e.g., methyl esters, oleic acid) pointed towards enzymatic breakdown of fats during spoilage. Epoxides (e.g., cis-2,3-dimethyloxirane) were detected in some spoiled samples, warranting further investigation into their role in spoilage. In contrast, the fresh tomato profile lacked these spoilage markers. This study demonstrates the potential of VOC analysis to differentiate between fresh and spoiled tomatoes. Identifying and quantifying specific VOCs can lead to the development of non-invasive methods for monitoring tomato quality during storage and transportation, minimizing food spoilage and waste.

Keywords: Volatile Organic Compounds (VOCs), Spoilage Markers, Microbial Activity, Fatty acids

1.0 INTRODUCTION

Tomatoes (*Lycopersicon esculentum*) is grown in many parts of Nigeria both as wet and dry season crops. Although most tomato production is at a small scale in backyard gardens, there are a few commercial fields (Wokoma, 2008). In Northern Nigeria where dry season tomato is grown under furrow irrigation, foliar diseases are less. Consequently, tomato crops grown in Northern Nigeria have higher yields and better-quality fruits. Tomato fruit is a common vegetable eaten raw as salad or for garnishing various cooked food in Nigeria as well as in many parts of the world. The fruit contains high amount of carbohydrates, fats, organic acids, water, minerals, vitamins and pigments. It is estimated that ripped tomato fruits contain approximately 94% water, 4.3% carbohydrates, 1% protein, 0.1% fat, 0.6% fiber and vitamins. The nutrients support the growth of microorganisms such as fungi and bacteria, which produce enzymes that degrade the nutrients (Maddox, 2008). Tomato fruits contain a lot of water which makes them more susceptible to spoilage by microorganisms. Also, the high-water content makes storage and transportation of this vegetable difficult. The microorganisms reduce not only the nutritional value but also the market value of tomato fruits (Maddox, 2008).

Tomato flavour is a combination of taste and aroma sensations. The four (4) tastes, sweet, sour, salty and bitter that are perceived by certain regions of the tongue, while volatiles are perceived by olfactory nerve endings of the nose (Acree, 2003). The pleasant sweet-sour taste of tomatoes is mainly due to the sugar and organic acid contents. Its reported that over 400 different volatiles determined in tomatoes have proved to be the most important compounds contributing to the aroma of tomatoes (Yilmaz, 2001). The characteristic tomato flavour is produced by the complex interaction of the volatiles and non-volatile components (Petro-turza, 2007). This research aimed at identifying microorganisms associated with spoilage of tomatoes and to identify the volatile compounds in spoilt tomatoes.

Tomato; *Lycopersicon esculentum*, is an annual plant, having a weak woody stem covered with glistering reddish yellow glandular hairs. The tomato plant is widely cultivated in many parts of the world. The tomato fruit has a smooth skin. It is green when immature but becomes bright red or yellow as it ripens. The fruit varies greatly in size and shape (Maddox, 2008).

Wilts caused by *Fusariumoxysporum*; *Lycopersici* and *Pseudomonas solanacearum* are the important diseases of tomato in the Savanna and forest zones of Nigeria (Erinle, 2006). Among the wilt diseases, *Fusarium* wilt is most prevalent, particularly among the local varieties, which are very susceptible. Wilts of tomato are also prevalent and damaging to tomato in other countries (El-Abyad *et al.*, 1993; ElShanshoury *et al.*, 1996; Qasem, 2006; Sharma and Norwak, 2008; De Cal *et al.*, 2009). According to Ghosh (2009) fungi were the source of spoilage in most of tomatoes samples accessed rather than bacteria. Among the fungi, it was found that *Aspergillus niger* and *Fusarium* were found in most of the spoiled samples with a few samples containing *Penicillium* sp (Ghosh, 2009)

This study was undertaken to investigate the volatile aroma compounds associated with spoilt tomatoes.

2.0 MATERIALS AND METHOD(S)

2.1 Material

Twenty (10) samples of spoilt tomatoes, five (1) sample of healthy, freshly harvested tomatoes, sterile distilled water, sterile test tubes, mortar and pestle, blender, Petri dishes containing solidified medium, Lactophenol Cotton Blue Mount (LPCB) stain, microscope slides, distilled water (for microscopy), cover slips, glass slides (for Gram staining), crystal violet stain, Lugol's solution, safranin stain, chemicals and reagents for specific biochemical tests (not specified), Lenton furnaces, Gallenkamp Oven BS, Soxhlet extraction apparatus, chloroform/methanol solvent (2:1 mixture), n-Hexane, Kjeldahl digestion apparatus (for Micro-kjeldahl Method), bottles, diethyl ether, Whatman No. 1 filter paper, GCMS-QP2010 plus (Shimadzu, Japan) equipped with a flame ionization detector (FID),

DB-WAX analytical column (30 m 0.25 mm, 0.25mm, J&W scientific, Folsom C.A), helium gas.

2.2 Method

Sample Collection

A total of ten samples (10) of spoilt tomatoes and one (1) sample of healthy freshly harvested tomatoes were collected from five (5) various sources namely; Kasuwan-Daji, Guiwa low-cost, Bado Area, Polo Club and Sokoto Central Market. The samples were collected in clean containers and then transported to the laboratory for analyses.

Extraction of volatile Metabolites

Volatile compounds were extracted using a general-purpose solvent as described by Ibrahim et al. (2011). The extraction of volatile compounds followed a direct solvent extraction method. Two grams of spoilt tomatoes and healthy ripe tomatoes were weighed into a bottle and saturated with 20ml of diethyl ether. The mixture was allowed to stand at 28°C for 24 hours. The extract was then filtered using

Whatman No. 1 filter paper, and the filtrate was collected in a sterile bottle, closed tightly before the GC-MS analysis.

Gas Chromatography Mass Spectrometry (GC-MS) Analysis

GC-MS analysis was performed using a GCMS-QP2010 plus (Shimadzu, Japan) equipped with a flame ionization detector (FID). The injection was conducted in splitless mode at 250°C for 3 minutes using an inlet of 0.75mm i.d. to minimize peak broadening. Chromatographic separations were performed using a DB-WAX analytical column 30 m 0.25 mm, 0.25mm (J&W scientific, Folsom C.A) with helium as the carrier gas at a constant flow rate of 0.8 ml/Min. The oven temperature was programmed at 60°C for 5 minutes, followed by an increase (held for 5 minutes), and finally at 10°C/min to 280°C (held for 10 minutes). The temperature of the FID was set to 250°C.

MS operating conditions used electron impact ionization mode with an ion source temperature of 200°C, ionization voltage of 70 eV, and a mass scan range of m/z 23-450 at 2.76 scans/s.

Results

Table 1: Volatile Organic Compounds (VOC) of Spoilt Tomato (Sample 1)

PK	RT	Area Pct	Library/ID	Ref	CAS	Qual
	7.068	22.2258	Butanal, 3-hydroxy-	2056	000107-89-1	35
2	7.1147	7.3969	1H-Pyrrole, 2,5-dihydro-1-nitroso-	3088	010552-94-0	43
3	7.2229	6.8372	Benzaldehyde, 3,5-dichloro-2-hydroxy-, 2,2-dimethylhydrazone	95309	014490-83-6	38
4	7.35	6.9583	8,9,9,10,10,11-Hexafluoro-4,4-dimethyl-3,5-dioxatetracyclo[5.4.1.0(2,6).0(8,11)]dodecane	160960	1000223-08-6	32
5	12.07	-4.3291	1H-Pyrrole, 2,5-dihydro-1-nitroso-	3088	010552-94-0	50
6	12.2513	1.0887	Butanal, 3-hydroxy-	2056	000107-89-1	46
7	12.3369	0.2893	Pentanal	1727	000110-62-3	43
8	12.3904	0.1586	1H-Isoindole, 2,3,3a,4,7,7a-hexahydro-	10425	1000351-26-7	38
9	16.6714	-5.9622	4-Fluorohistamine	13121	049872-60-8	64
10	16.7022	0.0544	Butanal, 3-hydroxy-	2056	000107-	58

					89-1	
11	16.7306	0.0628	Propane, 2-(ethenyloxy)-	1815	000926-65-8	55
12	16.7684	0.0968	Butanal, 3-hydroxy-	2056	000107-89-1	58
13	16.8108	0.0191	Pterin-6-carboxylic acid	71717	000948-60-7	53
14	22.2812	1.1093	Butanal, 3-hydroxy-	2056	000107-89-1	46
15	22.3294	0.1633	Butanal, 3-hydroxy-	2056	000107-89-1	38
16	22.3546	0.1703	Butanal, 3-hydroxy-	2056	000107-89-1	43
17	27.221	3.5838	Hexadecanoic acid, methyl ester	130813	000112-39-0	98
18	28.8941	15.9947	9,12-Octadecadienoic acid, methyl ester	153873	002462-85-3	99
19	28.9721	40.0285	trans-13-Octadecenoic acid, methyl ester	155762	1000333-61-3	99
20	29.2437	0.7107	Methyl stearate	157879	000112-61-8	99
21	35.3293	0.5199	Cyclononasiloxane, octadecamethyl-	274624	000556-71-8	86
22	36.2783	0.5946	1,1,1,5,7,7,7-Heptamethyl-3,3-bis(trimethylsiloxy)tetrasiloxane	254928	038147-00-1	53
23	37.0132	0.465	Hentriacontane	252711	000630-04-6	89
24	37.3636	2.0242	N-Benzyl-N-ethyl-p-isopropylbenzamide	141055	015089-22-2	38
25	45.5501	-0.5475	7,11-Hexadecadienal	98680	1000130-85-7	93
26	45.9299	0.2867	Butanamide, 3-cyclohexylamino-4-hydroxy-N-cyclohexyl-	141872	1000260-52-8	22

Table 2: Volatile Organic Compounds (VOC) of Spoilt Tomato (Sample 2)

P K	RT	Area Pct	Library/ID	Ref	CAS	Qual
1	19.468 8	0.289	trans-1-Chloromethyl-2-methoxymethylcyclohexane	45024	137303-15-2	38
2	19.507 8	0.2546	2-Hydroxy-3-pentanone	4331	005704-20-1	47
3	19.641 6	0.0573	Methoxyacetic acid, octyl ester	66467	029267-10-5	50
4	19.707 2	0.0338	2-Formylhistamine	18162	1000132-95-8	47
5	19.742 3	0.0189	(3-Methyl-oxiran-2-yl)-methanol	2089	1000194-22-9	38
6	19.808 6	0.0134	2-Hexanol	4480	000626-93-7	47

7	19.878 6	0.031	Phenelzine		16567	000051- 71-8	43
8	19.917 5	0.0168	(3-Methyl-oxiran-2-yl)-methanol		2089	1000194 -22-9	53
9	20.110 7	0.1039	1-Butaneboronic acid		4291	004426- 47-5	53
10	20.156 1	0.0381	2-Hexanol, 3-methyl-		8497	002313- 65-7	53
11	20.286 3	5.3125	2,5-cyclohexadien-1-one, dimethylethyl)-4-hydroxy-4-methyl-	2,6-bis(1,1-	98565	1000401 -12-0	64
12	20.449 8	0.3884	(3-Methyl-oxiran-2-yl)-methanol		2089	1000194 -22-9	59
13	20.472 1	0.7477	Pentane, 1-methoxy-		4507	000628- 80-8	38
14	20.532 3	0.2001	3-Nitropropanoic acid		9175	000504- 88-1	47
15	20.555 9	0.4105	(3-Oxo-3H-benzo[f]chromen-1-yl)-acetic ethyl ester	acid	14191 3	1000296 -72-0	53
16	20.591 5	0.1831	Butanal, 3-hydroxy-		2055	000107- 89-1	64
17	20.615 9	0.2171	m-Dioxan-4-ol, 2,6-dimethyl-		14608	004740- 77-6	53
18	20.722 5	1.0303	Phenelzine		16566	000051- 71-8	43
19	20.748	1.1771	4-Methyl-2-hexanol		8491	002313- 61-3	47
20	20.982	9.9572	Butylated Hydroxytoluene		83558	000128- 37-0	98
21	27.425 9	0.3611	Dibutyl phthalate		13805 8	000084- 74-2	78
22	28.105 3	0.257	n-Hexadecanoic acid		11741 6	000057- 10-3	58
23	28.172 4	1.2425	n-Hexadecanoic acid		11741 9	000057- 10-3	99
24	29.534 6	0.4323	Z,Z-6,13-Octadecadien-1-ol acetate		16738 3	1000131 -07-0	86
25	29.854 6	0.1609	Z,Z-10,12-Hexadecadien-1-ol acetate		14014 9	1000130 -89-5	74
26	29.942 3	0.1592	2-Methyl-Z,Z-3,13-octadecadienol		14025 3	1000130 -90-5	78
27	30.018	0.1334	Cyclotetradecane		61850	000295- 17-0	87
28	30.906 4	0.259	Tricosane		18265 5	000638- 67-5	89
29	31.756 1	0.1992	Decane, 2-methyl-		29360	006975- 98-0	64
30	32.569	0.2624	Hentriacontane		25271 2	000630- 04-6	87
31	32.712 1	0.6165	Di-n-octyl phthalate		23336 3	000117- 84-0	91

32	33.360 5	0.2976	Tritetracontane	27320 5	007098- 21-7	76
33	34.118 9	0.339	Cycloeicosane	14027 4	000296- 56-0	92
34	34.849 6	0.5817	Eicosane	14224 0	000112- 95-8	89
35	34.913 1	1.7298	Supraene	24321 7	007683- 64-9	96
36	35.058 1	0.3341	Oleic Acid	14207 0	000112- 80-1	59
37	35.168 7	0.5649	9-Octadecenoic acid (Z)-, 2-hydroxy-1-(hydroxymethyl)ethyl ester	21057 0	003443- 84-3	60
38	35.553 3	8.9366	Heptadecane, 9-hexyl-	18266 0	055124- 79-3	93
39	35.684 6	0.7585	9,12-Octadecadien-1-ol, (Z,Z)-	12684 6	000506- 43-4	91
40	36.241 7	27.167	1-Octadecanesulphonyl chloride	20696 0	1000342 -70-4	55
41	36.380 7	1.8668	9-Octadecenoic acid	14207 4	002027- 47-6	56
42	36.415 7	1.1856	2-Methylaminomethyl-1,3-dioxolane	8669	057366- 77-5	22
43	36.458 9	2.2556	9,12-Octadecadienoyl chloride, (Z,Z)-	15777 8	007459- 33-8	92
44	36.478 6	2.0584	6-Nitroundec-5-ene	64169	1000192 -40-3	44
45	36.523 1	1.52	9-Octadecenoic acid (Z)-, 2-hydroxy-1-(hydroxymethyl)ethyl ester	21057 0	003443- 84-3	50
46	36.547 8	1.4284	Butyl 9-octadecenoate or 9-18:1	19560 0	1000336 -74-7	45
47	36.601 4	4.0208	7,11-Hexadecadienal	98680	1000130 -85-7	44
48	36.656	2.0408	9-Octadecenoic acid (Z)-, 2-hydroxy-1-(hydroxymethyl)ethyl ester	21057 0	003443- 84-3	42
49	36.708 8	5.7755	Oleic Acid	14207 0	000112- 80-1	52
50	37.006 9	9.4047	Hexacosane	21789 2	000630- 01-3	97
51	39.474 2	0.3605	Caparratriene	70754	1000374 -08-7	48
52	43.048 9	-0.0188	Oleic Acid	14207 0	000112- 80-1	46
53	43.168	0.0485	Cyclopenta[c]furo[3',2':4,5]furo[2,3-h][1]benzopyran-11(1H)-one, 2,3,6a,9a-tetrahydro-1,3-dihydroxy-4-methoxy-	18790 1	055446- 27-0	42
54	43.403 3	0.0341	3-Octyne, 6-methyl-	10827	062108- 34-3	20
55	43.467 1	0.0229	9-Oxabicyclo[6.1.0]nonane	11611	000286- 62-4	90
56	43.536	0.0474	7,11-Hexadecadienal	98680	1000130 -85-7	62

57	43.692 4	0.2448	9-Oxabicyclo[6.1.0]nonane	11611	000286- 62-4	90
58	43.807 4	0.4248	3-Octyne, 6-methyl-	10827	062108- 34-3	30
59	43.874 6	0.4912	9,12-Octadecadien-1-ol, (Z,Z)-	12684 6	000506- 43-4	50
60	43.936 6	0.3207	7,11-Hexadecadienal	98680	1000130 -85-7	50
61	43.967 9	0.2364	Cyclopentadecanone, 2-hydroxy-	10236 9	004727- 18-8	90
62	43.995 8	0.2191	Hexadecenoic acid, Z-11-	11532 4	002416- 20-8	44
63	44.035 6	0.2625	Oleic Acid	14207 0	000112- 80-1	50
64	44.061 2	0.1257	9-Oxabicyclo[6.1.0]nonane	11611	000286- 62-4	91
65	44.082 9	0.1323	9-Octadecenoic acid (Z)-, 2-hydroxy-1-(hydroxymethyl)ethyl ester	21057 0	003443- 84-3	47
66	44.108 3	0.0843	9-Oxabicyclo[6.1.0]nonane	11611	000286- 62-4	48
67	44.132 1	0.0595	7,11-Hexadecadienal	98680	1000130 -85-7	56
68	44.154 8	0.0734	Oleic Acid	14207 0	000112- 80-1	20

Table 3: Volatile Organic Compounds (VOC) of Spoilt Tomato (Sample 3)

PK	RT	Area Pct	Library/ID	Ref	CAS	Qual
1	27.241 3	2.0864	Hexadecanoic acid, methyl ester	13081 8	000112 -39-0	97
2	27.423	0.3432	Didodecyl phthalate	26671 0	002432 -90-8	52
3	28.614 3	0.1588	Oxirane, 2,3-dimethyl-, cis-	711	001758 -33-4	46
4	28.882 4	5.8384	9,12-Octadecadienoic acid, methyl ester	15387 3	002462 -85-3	99
5	28.952 8	6.5904	10-Octadecenoic acid, methyl ester	15573 1	013481 -95-3	98
6	29.251 4	0.3542	Methyl stearate	15788 0	000112 -61-8	96
7	37.011	0.38	Tricosane	18265 5	000638 -67-5	95
8	39.501 8	3.5078	9-Octadecenoic acid (Z)-, 2,3-dihydroxypropyl ester	21056 2	000111 -03-5	44
9	39.552 7	0.5018	Oleic Acid	14207 0	000112 -80-1	50
10	39.61	1.3256	Oleic Acid	14207 0	000112 -80-1	51

11	39.684 8	1.5222	Oleic Acid	14207 0	000112 -80-1	25
12	39.730 6	1.0464	9-Oxabicyclo[6.1.0]nonane	11611	000286 -62-4	62
13	39.757 3	0.8198	9,12-Octadecadienoyl chloride, (Z,Z)-	15777 8	007459 -33-8	92
14	39.954 1	6.0209	9-Oxabicyclo[6.1.0]nonane, cis-	11674	004925 -71-7	48
15	40.264 4	15.865	Oleic Acid	14207 0	000112 -80-1	38
16	40.316 4	3.6264	9-Octadecenoic acid (Z)-, 2-hydroxy-1-(hydroxymethyl)ethyl ester	21057 0	003443 -84-3	72
17	40.366 4	3.3738	9-Oxabicyclo[6.1.0]nonane	11611	000286 -62-4	66
18	40.460 9	6.9019	Z-6-Pentadecen-1-ol acetate	12865 1	068760 -72-5	47
19	40.483 9	11.851 5	9-Octadecenoic acid (Z)-, 2-hydroxy-1-(hydroxymethyl)ethyl ester	21057 0	003443 -84-3	58
20	40.652 9	27.885 7	9-Oxabicyclo[6.1.0]nonane, cis-	11674	004925 -71-7	55

Table 4: Volatile Organic Compounds (VOC) of Spoilt Tomato (Sample 4)

PK	RT	Area Pct	Library/ID	Ref	CAS	Qual
1	7.4072	0.9725	Propanamide, N-acetyl-	7888	019264- 34-7	35
2	8.3893	0.8734	Hydroperoxide, 1-methylbutyl	4872	014018- 58-7	38
3	12.438 1	38.591 8	Propanamide, N-acetyl-	7888	019264- 34-7	38
4	18.974 5	2.1344	N,N-Dimethylethanesulfonamide	16970	006338- 68-7	43
5	19.518 1	1.3663	Ethanone, 1-(2-benzothiazolyl)-	45629	001629- 78-3	10
6	19.649 6	0.2417	.alpha.-Acetyl-N,N-dinormethadol	18331 2	040488- 01-5	25
7	20.280 1	3.57	2,5-cyclohexadien-1-one, 2,6-bis(1,1-dimethylethyl)-4-hydroxy-4-methyl-	98565	1000401 -12-0	90
8	20.991 4	3.6892	Butylated Hydroxytoluene	83554	000128- 37-0	98
9	22.105 1	8.7291	Oxirane, 2,3-dimethyl-, cis-	711	001758- 33-4	47
10	22.168 7	0.5757	Octanal	12693	000124- 13-0	37
11	22.232	0.7637	.alpha.-l-Mannose semicarbazone pentaacetate	26238 5	1000130 -10-0	32
12	22.288 3	0.6663	Oxirane, 2,3-dimethyl-, cis-	711	001758- 33-4	50

13	22.420 1	9.3857	Butanedioic acid, 2,3-bis(acetyloxy)-, [R- (R*,R*)]-	96985	051591- 38-9	47
14	35.553 2	0.0579	Carbonic acid, eicosyl vinyl ester	21934 5	1000382 -54-3	70
15	36.267 6	0.065	Heptasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11,13,13-tetradecamethyl-	26685 4	019095- 23-9	32
16	37.013 1	0.1635	Eicosane	14224 0	000112- 95-8	96
17	38.707 7	0.2121	9,17-Octadecadienal, (Z)-	12500 3	056554- 35-9	83
18	39.005 1	0.0977	7-Hexadecenal, (Z)-	10056 6	056797- 40-1	42
19	39.477 6	0.2919	2-Methyl-Z,Z-3,13-octadecadienol	14025 3	1000130 -90-5	46
20	39.805	0.0966	9-Oxabicyclo[6.1.0]nonane, cis-	11674	004925- 71-7	86
21	40.499 1	0.6264	6-Octadecenoic acid, (Z)-	14208 4	000593- 39-5	45
22	43.120 5	26.829	7,11-Hexadecadienal	98680	1000130 -85-7	89

Table 5: Volatile Organic Compounds (VOC) of Spoilt Tomato (Sample 5)

PK	RT	Area Pct	Library/ID	Ref	CAS	Qual
1	7.7433	22.4134	1-Butanol	841	000071- 36-3	53
2	13.4922	0.0644	Oxirane, 2-butyl-3-methyl-, cis-	7744	056052- 93-8	53
3	17.2134	0.0326	1,2-Hydrazinedicarboxylic acid, diethyl ester	44694	004114- 28-7	43
4	18.6218	0.2527	Diethyl carbonate	8847	000105- 58-8	53
5	20.2955	3.6083	Hydrazinecarboxylic acid, ethyl ester	4726	004114- 31-2	38
6	20.9956	7.588	Butylated Hydroxytoluene	83558	000128- 37-0	95
7	21.2389	5.0613	Oxirane, 2-butyl-3-methyl-, cis-	7744	056052- 93-8	52
8	21.5637	3.7288	Diethyl carbonate	8847	000105- 58-8	53
9	21.6698	10.4156	(3-Methyl-oxiran-2-yl)-methanol	2089	1000194- 22-9	50
10	23.0024	0.2273	(3-Methyl-oxiran-2-yl)-methanol	2089	1000194- 22-9	53
11	23.1647	0.2648	Oxirane, 2-butyl-3-methyl-, cis-	7744	056052- 93-8	50
12	24.5283	0.4532	(3-Methyl-oxiran-2-yl)-methanol	2089	1000194- 22-9	47

13	24.653	0.2212	Oxirane, 2-methyl-3-propyl-, cis-	4015	006124-90-9	52
14	24.7512	0.162	sec-Butyl nitrite	4621	000924-43-6	72
15	24.9148	0.2338	Ethanol, 2-(2-ethoxyethoxy)-, acetate	44931	000112-15-2	53
16	25.8161	2.416	sec-Butyl nitrite	4621	000924-43-6	72
17	25.9216	0.7013	sec-Butyl nitrite	4621	000924-43-6	46
18	26.1062	0.479	Pentanoic acid, 2-hydroxy-4-methyl-, methyl ester	22599	040348-72-9	43
19	26.4025	1.4005	Oxirane, [(1-methylethoxy)methyl]-	8347	004016-14-2	50
20	26.9635	3.4082	Z-8-Hexadecene	87835	1000130-87-5	55
21	27.0543	1.6653	Nonadecane	128834	000629-92-5	74
22	27.2298	1.8415	1-Deoxy-d-arabitol	16374	013942-77-3	59
23	27.4208	4.8028	Hydrazinecarboxylic acid, ethyl ester	4726	004114-31-2	49
24	28.0104	0.4391	5-Eicosene, (E)-	140275	074685-30-6	90
25	28.0964	1.6988	Tridecane, 3-ethyl-	76610	013286-73-2	38
26	28.9577	0.1317	13-Octadecenoic acid, methyl ester	155738	056554-47-3	64
27	30.017	0.113	Oleic Acid	142069	000112-80-1	58
28	35.5559	0.0354	Eicosane	142239	000112-95-8	90
29	36.2501	0.0655	Oleic Acid	142071	000112-80-1	40
30	37.0125	0.1201	1-Decanol, 2-hexyl-	104440	002425-77-6	52
31	38.7137	0.2102	E,E-1,9,17-Docasatriene	163812	1000245-71-8	43
32	39.5298	0.7438	3-Octyne, 6-methyl-	10827	062108-34-3	42
33	41.7769	13.024	9,12-Octadecadienoyl chloride, (Z,Z)-	157778	007459-33-8	94
34	41.9378	11.9765	Oleic Acid	142070	000112-80-1	86

Table 6: Volatile Organic Compounds (VOC) of Spoilt Tomato (Sample 6)

P K	RT	Area Pct	Library/ID	Ref	CAS	Qual
1	8.8992	4.9062	Acetic acid, anhydride with formic acid	1977	002258-42-6	25
2	9.4284	5.0587	Hydroperoxide, 1-methylbutyl	4872	014018-58-7	37
3	9.9397	8.6821	Propanamide, N-acetyl-	7888	019264-34-7	43
4	10.0553	2.5057	Propanamide, N-acetyl-	7888	019264-34-7	38
5	10.0957	2.0904	benzenesulfonyl chloride, 3-(acetylamino)-4-(acetyloxy)-	150318	1000397-34-5	9
6	10.1943	1.1371	Hydroperoxide, 1-methylbutyl	4872	014018-58-7	35
7	10.2483	2.1456	Propanamide, N-acetyl-	7888	019264-34-7	43
8	10.3529	0.5765	Propanamide, N-acetyl-	7888	019264-34-7	43
9	10.38	9.2895	Cyclopenta[c]furo[3',2':4,5]furo[2,3-h][1]benzopyran-11(1H)-one, 2,3,6a,9a-tetrahydro-1,3-dihydroxy-4-methoxy-	187901	055446-27-0	40
10	26.9631	0.1247	Bromoacetic acid, tetradecyl ester	191552	018992-01-3	91
11	27.2265	3.0677	Hexadecanoic acid, methyl ester	130818	000112-39-0	98
12	28.8783	2.146	9,12-Octadecadienoic acid, methyl ester	153873	002462-85-3	99
13	28.9597	4.8636	trans-13-Octadecenoic acid, methyl ester	155762	1000333-61-3	99
14	29.2562	0.3176	Methyl stearate	157880	000112-61-8	95
15	30.9138	0.0831	Tricosane	182655	000638-67-5	70
16	31.7563	0.0878	9-Octadecenal	126818	005090-41-5	81
17	32.5729	0.3423	Ditetradecyl ether	243190	005412-98-6	64
18	32.7146	0.5015	Dibutyl phthalate	138056	000084-74-2	64
19	33.1241	0.5588	2-Methyl-Z,Z-3,13-octadecadienol	140253	1000130-90-5	56
20	33.1789	0.1485	Oleic Acid	142070	000112-80-1	48
21	33.2462	0.3509	Butanamide, 3-cyclohexylamino-4-hydroxy-N-cyclohexyl-	141872	1000260-52-8	27
22	33.3623	0.4913	Oleic Acid	142070	000112-80-1	95
23	33.5916	0.4725	8-Oxabicyclo[5.1.0]octane	6668	000286-45-3	35

24	33.636 7	0.1784	Oleic Acid	14207 0	000112- 80-1	48
25	33.854 7	0.9898	9-Octadecenoic acid (Z)-, 2,3-dihydroxypropyl ester	21056 2	000111- 03-5	53
26	34.121	1.3661	3-Methyl-isoxazol-5(4H)-one	3501	001517- 96-0	25
27	34.325 1	1.6486	Cyclononasiloxane, octadecamethyl-	27462 5	000556- 71-8	47
28	34.578 6	1.4198	9-Octadecenoic acid (Z)-, 2-hydroxy-1-(hydroxymethyl)ethyl ester	21057 0	003443- 84-3	38
29	34.915 3	4.25	2,6,10-Dodecatrien-1-ol, 3,7,11-trimethyl-	85752	004602- 84-0	64
30	35.327 2	0.5334	Hexasiloxane, tetradecamethyl-	25860 9	000107- 52-8	47
31	44.803 5	39.665 9	9,12-Octadecadienoyl chloride, (Z,Z)-	15777 8	007459- 33-8	80

Table 7: Volatile Organic Compounds (VOC) of Spoilt Tomato (Sample 7)

PK	RT	Area Pct	Library/ID	Ref	CAS	Qual
1	8.8052	1.4483	2-Propanone, 1-hydroxy-	826	000116- 09-6	45
2	13.7063	29.2041	.alpha.-D-Mannopyranoside, methyl 3,6-anhydro-	44787	015814- 56-9	50
3	13.8202	1.3723	.alpha.-D-Mannopyranoside, methyl 3,6-anhydro-	44787	015814- 56-9	47
4	13.9212	12.2664	Glyceraldehyde	2279	000056- 82-6	45
5	20.2811	-0.0303	1,2,15-Pentadecanetriol	121139	057289- 60-8	37
6	20.9844	0.1211	Butylated Hydroxytoluene	83558	000128- 37-0	95
7	21.2362	0.0328	Hydroperoxide, 1-methylhexyl	14762	000762- 46-9	37
8	24.656	0.1058	sec-Butyl nitrite	4621	000924- 43-6	50
9	24.7429	0.0412	sec-Butyl nitrite	4621	000924- 43-6	58
10	24.9342	0.0615	Propane, 1-(1-methylethoxy)-	4566	000627- 08-7	52
11	25.1785	0.0891	sec-Butyl nitrite	4621	000924- 43-6	78
12	25.3395	0.0415	1,3-Dioxane, 2-methyl-	4337	000626- 68-6	53
13	26.9617	0.0332	.alpha.-D-Mannopyranoside, methyl 3,6-anhydro-	44787	015814- 56-9	43
14	27.0535	0.0244	Propanoic acid, 2-(aminooxy)-	4991	002786- 22-3	59
15	27.2356	0.1121	Dodecanoic acid, 10-methyl-, methyl ester	91485	005129- 65-7	80

16	27.414	0.0522	Diethyl Phthalate	85001	000084-66-2	38
17	28.1058	0.2659	(3-Methyl-oxiran-2-yl)-methanol	2089	1000194-22-9	47
18	28.5378	1.5331	1,6-Dideoxy-l-mannitol	24875	068832-20-2	49
19	28.9599	3.0382	9-Octadecenoic acid (Z)-, methyl ester	155750	000112-62-9	98
20	29.2522	0.9157	Butanoic acid, 3-hydroxy-, methyl ester, (S)-	8900	053562-86-0	35
21	29.5859	1.7553	2-Methyl-Z,Z-3,13-octadecadienol	140253	1000130-90-5	59
22	29.7555	0.2643	Propanoic acid, 2-(aminooxy)-	4991	002786-22-3	52
23	30.0197	3.6409	9-Eicosenoic acid, (Z)-	169286	029204-02-2	64
24	30.3623	2.0858	Oleic Acid	142070	000112-80-1	51
25	30.5774	2.0268	Oleic Acid	142070	000112-80-1	81
26	30.8217	0.5268	Cyclohexadecane, 1,2-diethyl-	140283	1000155-85-3	56
27	30.9015	2.8386	Heptadecane, 2-methyl-	115555	001560-89-0	38
28	32.7131	0.0828	Di-n-octyl phthalate	233363	000117-84-0	58
29	37.014	0.0904	Oleic Acid	142070	000112-80-1	86
30	38.6901	0.6176	9,17-Octadecadienal, (Z)-	125003	056554-35-9	90
31	39.558	1.0484	1H-Indene, 5-butyl-6-hexyloctahydro-	125025	055044-36-5	38
32	39.9355	0.3305	8-Oxabicyclo[5.1.0]octane	6668	000286-45-3	49
33	40.0308	0.179	3-Octyne, 6-methyl-	10827	062108-34-3	42
34	40.3177	0.6544	Octadec-9-enoic acid	142076	1000190-13-7	38
35	43.4672	33.1298	Oleic Acid	142070	000112-80-1	60

Table 8: Volatile Organic Compounds (VOC) of Spoilt Tomato (Sample 8)

PK	RT	Area Pct	Library/ID	Ref	CAS	Qual
1	20.983 2	0.1762	Butylated Hydroxytoluene	83554	000128-37-0	60
2	22.933 9	0.1084	Oxirane, 2,3-dimethyl-, cis-	711	001758-33-4	40
3	24.047 9	1.5638	Acetic acid, anhydride with formic acid	1977	002258-42-6	32
4	24.093 9	0.0815	Propanamide, N-acetyl-	7888	019264-34-7	47
5	24.146 3	0.1838	Oxirane, 2,3-dimethyl-, cis-	711	001758-33-4	43
6	24.246 7	0.3675	Propanamide, N-acetyl-	7888	019264-34-7	32
7	24.353 3	0.4149	1-Nitro-.beta.-d-arabinofuranose, tetraacetate	21534 0	1000128-02-6	47
8	24.388 9	0.1285	Propanamide, N-acetyl-	7888	019264-34-7	46
9	24.456	0.4351	Propanamide	735	000079-05-0	49
10	24.587 1	0.3834	Octanal	12693	000124-13-0	36
11	24.677 6	0.3355	Oxirane, 2,3-dimethyl-, cis-	711	001758-33-4	53
12	24.759 3	0.4165	1,2,4-Triazino[5,6-E][1,2,4]-triazine-3,6-dione, hexahydro-	41713	1000267-85-6	38
13	24.823 6	0.1239	Oxirane, 2,3-dimethyl-, cis-	711	001758-33-4	47
14	24.960 7	0.4192	2-Carbamyl-9-[.beta.-d-ribofuranosyl]hypoxanthine	15405 8	121358-21-2	38
15	25.078 4	0.2786	Propanamide, N-acetyl-	7888	019264-34-7	43
16	26.421 2	0.2082	2-Hexenedioic acid, bis(trimethylsilyl) ester, (E)-	14744 2	055494-10-5	38
17	26.962 3	0.4064	(2,3,5,6-Tetrafluorophenyl)methyl 3-(2,2-dichlorovinyl)-2,2-dimethyl-cyclopropane-1-carboxylate	22012 2	118712-89-3	50
18	27.229 7	6.6215	Hexadecanoic acid, methyl ester	13081 8	000112-39-0	97
19	28.068 7	0.076	3-Isopropoxy-1,1,1,7,7,7-hexamethyl-3,5,5-tris(trimethylsiloxy)tetrasiloxane	27216 3	071579-69-6	40
20	28.883 4	1.5106	9,12-Octadecadienoic acid, methyl ester	15387 3	002462-85-3	99
21	28.959	2.9926	trans-13-Octadecenoic acid, methyl ester	15576 2	1000333-61-3	99
22	29.254 3	0.7236	Methyl stearate	15787 9	000112-61-8	99
23	30.525 5	1.9046	9-Octadecynoic acid	14012 6	000506-24-1	62

24	30.698 3	1.756	Oxiraneoctanoic acid, 3-octyl-, methyl ester	17127 6	002500- 59-6	91
25	30.872 1	0.1654	Octasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11,13,13,15,15- hexadecamethyl-	27225 3	019095- 24-0	59
26	32.097 1	0.0931	Hexasiloxane, tetradecamethyl-	25860 9	000107- 52-8	42
27	33.245 8	0.1563	Cyclononasiloxane, octadecamethyl-	27462 5	000556- 71-8	53
28	34.325 4	0.2369	Cyclononasiloxane, octadecamethyl-	27462 5	000556- 71-8	53
29	35.329 7	0.1735	Cyclononasiloxane, octadecamethyl-	27462 4	000556- 71-8	59
30	36.116 1	0.7547	6-Octadecenoic acid, (Z)-	14208 4	000593- 39-5	44
31	36.276 5	0.7706	Hexasiloxane, tetradecamethyl-	25860 9	000107- 52-8	49
32	36.746 7	1.5922	Octadec-9-enoic acid	14207 6	1000190 -13-7	25
33	36.906	0.7117	Z-6-Pentadecen-1-ol acetate	12865 1	068760- 72-5	27
34	37.010 7	1.275	Dodecyl nonyl ether	17154 3	1000406 -37-5	49
35	37.364 1	2.0115	Octasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11,13,13,15,15- hexadecamethyl-	27225 3	019095- 24-0	46
36	37.603 1	1.1906	Z-6-Pentadecen-1-ol acetate	12865 1	068760- 72-5	27
37	37.647 4	0.759	2-Methyl-Z,Z-3,13-octadecadienol	14025 3	1000130 -90-5	41
38	38.737 3	13.353 3	Octasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11,13,13,15,15- hexadecamethyl-	27225 3	019095- 24-0	38
39	38.836 8	0.9632	9-Octadecenoic acid (Z)-, 2-hydroxy-1- (hydroxymethyl)ethyl ester	21057 0	003443- 84-3	53
40	39.756 4	35.279 6	9-Octadecenoic acid (Z)-, 2-hydroxy-1- (hydroxymethyl)ethyl ester	21057 0	003443- 84-3	74
41	39.819 6	18.897 2	1H-Indene, 5-butyl-6-hexyloctahydro-	12502 5	055044- 36-5	35

Table 9: Volatile Organic Compounds (VOC) of Spoilt Tomato (Sample 9)

PK	RT	Area Pct	Library/ID	Ref	CAS	Qual
1	11.509 3	0.0632	Propanamide, N-acetyl-	7888	019264- 34-7	22
2	11.575 7	0.0691	Hydroperoxide, 1-methylhexyl	14762	000762- 46-9	43
3	11.648	0.0817	Propanamide, N-acetyl-	7888	019264- 34-7	38
4	11.714	0.0874	Hydroperoxide, 1-methylbutyl	4872	014018- 58-7	40
5	11.896 3	0.259	2-Carbamyl-9-[.beta.-d- ribofuranosyl]hypoxanthine	15405 8	121358- 21-2	28
6	11.948 6	0.0948	Hydroperoxide, 1-methylhexyl	14762	000762- 46-9	23
7	11.986 7	0.0514	Acetic acid, anhydride with formic acid	1977	002258- 42-6	37
8	12.022 8	0.0452	Hydroperoxide, 1-methylpentyl	9020	024254- 55-5	32
9	12.091 6	0.2421	Hydroperoxide, 1-methylpentyl	9020	024254- 55-5	38
10	12.234 5	0.5	(3-Methyl-oxiran-2-yl)-methanol	2089	1000194 -22-9	38
11	12.289 1	0.3178	Propanamide, N-acetyl-	7888	019264- 34-7	27
12	12.329 7	0.2683	Silver acetate	36658	000563- 63-3	32
13	12.470 4	1.3829	Propanamide, N-acetyl-	7888	019264- 34-7	38
14	12.510 5	0.4288	.alpha.-D-Mannopyranoside, methyl 3,6-anhydro-	44787	015814- 56-9	25
15	12.561 5	0.4281	(3-Methyl-oxiran-2-yl)-methanol	2089	1000194 -22-9	38
16	12.595 1	0.69	Hydroperoxide, 1-methylhexyl	14762	000762- 46-9	37
17	12.762	1.9854	Hydroperoxide, 1-methylhexyl	14762	000762- 46-9	38
18	12.799 8	0.884	Silver acetate	36658	000563- 63-3	37
19	12.856 5	0.3329	Oxirane, 2,3-dimethyl-, trans-	713	021490- 63-1	37
20	12.972 4	1.7571	Hydroperoxide, 1-methylbutyl	4872	014018- 58-7	37
21	13.022 7	0.3596	.alpha.-D-Mannopyranoside, methyl 3,6-anhydro-	44787	015814- 56-9	40
22	13.079 6	0.9539	.alpha.-D-Mannopyranoside, methyl 3,6-anhydro-	44787	015814- 56-9	37
23	13.254 9	1.2449	.alpha.-D-Mannopyranoside, methyl 3,6-anhydro-	44787	015814- 56-9	32
24	13.323 6	0.1056	Oxirane, 2,3-dimethyl-, trans-	713	021490- 63-1	47

25	34.918 7	2.0601	Cyclopropane, 1,1-dimethyl-2-(2-propenyl)-	6144	036939- 15-8	52
26	35.249 1	2.3635	5-Acetamido-4,7-dioxo-4,7-dihydrobenzofurazan	71759	153136- 27-7	25
27	35.286 5	0.6716	9-Octadecenoic acid (Z)-, 2-hydroxy-1-(hydroxymethyl)ethyl ester	21057 0	003443- 84-3	30
28	35.313 6	0.5998	Cyclopropane carboxamide, 2-cyclopropyl-2-methyl-N-(1-cyclopropylethyl)-	71615	331416- 19-4	18
29	35.351 4	1.1327	Lactose	19843 2	000063- 42-3	16
30	35.555 1	6.9296	Eicosane	14223 8	000112- 95-8	50
31	35.653 4	1.6385	9-Octadecenoic acid (Z)-, 2-hydroxy-1-(hydroxymethyl)ethyl ester	21057 0	003443- 84-3	80
32	35.746 4	4.1857	Z-6-Pentadecen-1-ol acetate	12865 1	068760- 72-5	38
33	35.805 7	2.8938	9-Octadecenoic acid (Z)-, 2,3-dihydroxypropyl ester	21056 2	000111- 03-5	59
34	35.915 1	5.8071	Cyclopentaneundecanoic acid	11533 2	006053- 49-2	16
35	36.031 6	7.5376	Indolizine, 2-(4-methylphenyl)-	71664	007496- 81-3	27
36	36.061 3	2.0033	Pyrido[2,3-d]pyrimidine, 4-phenyl-	71621	028732- 75-4	30
37	36.089 6	2.5672	Cyclopentaneundecanoic acid	11533 2	006053- 49-2	25
38	36.268 8	14.612 4	13-Octadecenoic acid, methyl ester	15573 8	056554- 47-3	20
39	36.299 8	3.583	Trimethylsilyl-di(trimethylsiloxy)-silane	14035 3	139347- 50-5	40
40	36.362 4	3.2401	9-Octadecenoic acid (Z)-, 2,3-dihydroxypropyl ester	21056 2	000111- 03-5	38
41	36.380 7	1.9447	2-Myristynoyl-glycinamide	13989 9	1000111 -57-7	43
42	36.477 2	9.1748	Oleic Acid	14207 0	000112- 80-1	15
43	36.522 7	2.6533	Cyclopropane carboxamide, 2-cyclopropyl-2-methyl-N-(1-cyclopropylethyl)-	71615	331416- 19-4	45
44	36.562 8	5.1776	11-(2-Cyclopenten-1-yl)undecanoic acid, (+)-	11350 9	000459- 67-6	25
45	37.000 9	6.5903	Eicosane	14223 9	000112- 95-8	89

Table 10: Volatile Organic Compounds (VOC) of Spoilt Tomato (Sample 10)

PK	RT	Area Pct	Library/ID	Ref	CAS	Qual
1	6.0957	0.3101	Propanamide, N-acetyl-	7888	019264-34-7	22
2	6.3384	0.1897	1,2,15-Pentadecanetriol	121139	057289-60-8	37
3	6.9904	0.7105	sec-Butyl nitrite	4621	000924-43-6	35
4	7.1265	0.1876	Ethyl Acetate	2040	000141-78-6	25
5	7.9712	1.629	Acetic acid, anhydride with formic acid	1977	002258-42-6	25
6	8.1772	0.5665	Ethyl Acetate	2040	000141-78-6	38
7	11.4879	31.6649	Propanamide, N-acetyl-	7888	019264-34-7	38
8	11.5969	2.2596	(3-Methyl-oxiran-2-yl)-methanol	2089	1000194-22-9	46
9	11.7147	17.2784	1-Nitro-.beta.-d-arabinofuranose, tetraacetate	215340	1000128-02-6	12
10	20.2907	0.1162	2,2,6,7-Tetramethyl-10-oxatricyclo[4.3.0.1(1,7)]decan-5-one	72528	121747-63-5	27
11	20.9813	0.1203	Butylated Hydroxytoluene	83554	000128-37-0	97
12	27.5032	0.1324	Didodecyl phthalate	266710	002432-90-8	64
13	28.9918	0.1378	Heptadecanolide	128637	005637-97-8	25
14	29.2682	0.0544	Cyclopentaneundecanoic acid	115332	006053-49-2	38
15	30.9082	0.3411	1-Decanol, 2-octyl-	130951	045235-48-1	43
16	31.7619	0.8966	Propanamide, N-acetyl-	7888	019264-34-7	43
17	32.0977	0.5784	1-Nonylcycloheptane	87840	1000371-47-7	35
18	32.5756	1.3132	Estra-1,3,5(10)-trien-17.beta.-ol	117583	002529-64-8	64
19	32.7237	1.0329	1,4-benzenedicarboxylic acid, mono(1-methylethyl) ester	72040	1000400-56-6	49
20	33.3575	2.743	Propanamide, N-acetyl-	7888	019264-34-7	38
21	33.5464	1.8753	Oleic Acid	142070	000112-80-1	90
22	34.115	4.7122	9-Octadecenoic acid	142074	002027-47-6	45
23	34.9166	11.8563	2,6,10,14,18-Pentamethyl-2,6,10,14,18-eicosapentaene	199592	075581-03-2	78
24	35.1846	4.0992	Z-10-Pentadecen-1-ol acetate	128655	1000130-85-0	53

25	35.333 4	4.1556	.alpha.-D-Mannopyranoside, methyl 3,6-anhydro-	44787	015814- 56-9	16
26	35.552 6	8.3245	Eicosane	14223 9	000112- 95-8	89
27	36.236 3	1.9997	Cyclohexane, 1,1'-(2-propyl-1,3-propanediyl)bis-	11184 0	055030- 21-2	25
28	37.009 4	0.5164	Eicosane	14224 0	000112- 95-8	95
29	39.457 4	0.0529	3,4-Octadiene, 7-methyl-	10867	037050- 05-8	47
30	40.838 9	0.0506	2(1H)-Naphthalenone, octahydro-4a,5-dimethyl- 3-(1-methylethyl)-, (3.alpha.,4a.beta.,5.beta.,8a.alpha.)-	85848	055332- 04-2	38
31	43.230 3	0.0949	6-Octadecenoic acid, (Z)-	14208 4	000593- 39-5	50

Table 11: Volatile Organic Compounds (VOC) of Spoilt Tomato (Sample 11)

PK	RT	Area Pct	Library/ID	Ref	CAS	Qual
1	12.835 4	0.602 5	N,N-Dimethylethanesulfonamide	16970	006338- 68-7	38
2	13.275 4	0.839 5	Butanal, dimethylhydrazone	7501	010424- 98-3	59
3	13.402 2	0.366 9	2-(2,5-Dioxopyrrolidin-1-yl)guanidine	29542	960129- 32-2	50
4	14.075 2	4.252 1	Tetraacetyl-d-xylonic nitrile	19967 5	1000130 -04-4	53
5	14.628	5.820 4	Pterin-6-carboxylic acid	71717	000948- 60-7	50
6	14.710 6	0.887 6	N-Methyl-N-[2-cyanoethyl]-2-mercapto propylamine	30968	1000257 -11-6	58
7	14.744 3	5.565 1	Metaraminol	37694	000054- 49-9	47
8	18.833 8	7.268	Pentanal	1727	000110- 62-3	74
9	18.885 9	0.716 7	8-Azabicyclo[4.3.1]decan-10-one, 8-methyl-	37355	004146- 36-5	49
10	19.072 9	2.871 1	Aluminum, tripropyl-	30146	000102- 67-0	46
11	19.206 9	1.258	Tetraacetyl-d-xylonic nitrile	19967 5	1000130 -04-4	47
12	19.262 7	1.302	Ethylene oxide	75	000075- 21-8	64
13	19.497 7	6.641 9	Ethyl 5-(furan-2-yl)-1,2-oxazole-3-carboxylate	71255	1000411 -40-9	46
14	24.747 2	0.256 1	Methyl tetradecanoate	10429 0	000124- 10-7	86
15	24.882 8	0.457 5	Methyl tetradecanoate	10428 6	000124- 10-7	93

16	25.830 4	0.641 4	1-Docosene	16746 3	001599- 67-3	95
17	25.940 7	0.408 6	Tetradecane, 3-methyl-	76615	018435- 22-8	49
18	26.071 2	0.287 3	1,2,4-Triazino[5,6-E][1,2,4]-triazine-3,6-dione, hexahydro-	41713	1000267 -85-6	27
19	26.135 8	0.252 6	.alpha.-D-Mannopyranoside, methyl 3,6- anhydro-	44787	015814- 56-9	72
20	26.395 3	2.031 8	Dibutyl phthalate	13805 6	000084- 74-2	49
21	26.673 8	2.13	9-Heptadecanone	11551 4	000540- 08-9	55
22	26.971 1	3.895 3	Pterin-6-carboxylic acid	71717	000948- 60-7	38
23	27.237 1	7.806 7	Hexadecanoic acid, methyl ester	13082 2	000112- 39-0	97
24	27.430 8	3.299	Dibutyl phthalate	13805 6	000084- 74-2	95
25	28.033 9	0.338 9	3-Eicosene, (E)-	14027 7	074685- 33-9	98
26	28.113 2	1.141 2	Undecanoic acid	52719	000112- 37-8	55
27	28.892 2	0.674 2	8,11-Octadecadienoic acid, methyl ester	15387 2	056599- 58-7	99
28	28.970 1	0.949	trans-13-Octadecenoic acid, methyl ester	15576 2	1000333 -61-3	99
29	29.838 4	0.080 9	Oleic Acid	14206 9	000112- 80-1	95
30	32.736 7	0.121 6	Dibutyl phthalate	13805 6	000084- 74-2	72
31	34.132 1	1.936 6	2-Iodohistidine	14110 8	006996- 15-2	45
32	34.508 8	2.791 4	Hexadecane, 1-chloro-	12120 5	004860- 03-1	70
33	34.933 7	3.957 4	Supraene	24321 7	007683- 64-9	95
34	35.052 3	0.799 7	9-Octadecenoic acid (Z)-, 2,3-dihydroxypropyl ester	21056 2	000111- 03-5	41
35	35.102 2	0.535 5	Oleic Acid	14207 0	000112- 80-1	40
36	35.144 8	1.003 4	Oleic Acid	14207 0	000112- 80-1	91
37	35.220 7	0.496 2	Oleic Acid	14207 0	000112- 80-1	93
38	35.339 5	3.913 4	1-Heptatriacotanol	26988 5	105794- 58-9	38
39	35.568 9	1.587	Heneicosane, 3-methyl-	16941 2	006418- 47-9	70
40	35.689 6	4.506 8	2-Isopropenyl-4,4,7a-trimethyl-2,4,5,6,7,7a- hexahydro-benzofuran-6-ol	85551	1000189 -13-5	22

41	42.023	7.785	Z-(13,14-Epoxy)tetradec-11-en-1-ol acetate	12853	1000131	53
		5		7	-33-2	
42	42.161	2.041	decanamide, N-[4-[[4-	22782	1000398	70
	6	4	(dimethylamino)phenyl]amino]phenyl]-	9	-75-2	
43	42.215	5.481	Z-4-Nonadecen-1-ol acetate	18256	1000131	47
	5	6		1	-08-3	

potentially involving increased microbial activity and lipid degradation.

DISCUSSION

This study employed gas chromatography-mass spectrometry (GC-MS) to investigate the volatile organic compound (VOC) profiles of ten spoilage tomato samples (Tables 1-10) and a control sample of fresh, healthy tomato (Table 11). The analysis revealed distinct VOC signatures associated with spoilage compared to the fresh control.

Table 1 presents a variety of VOCs identified in the first spoiled tomato sample. Of note are the aldehydes, including butanal-3-hydroxy and pentanal, which can contribute to off-odors associated with spoilage due to their origin as lipid breakdown products (Blankenship and Dole, 2009). Additionally, the presence of nitroso compounds like 1H-pyrrole-2,5-dihydro-1-nitroso suggests potential microbial activity, as these compounds can arise from amino acid degradation by certain bacteria (Goh and Sun, 2013). However, further investigation is needed to determine the specific types of microbes present and their role in spoilage.

Table 2 shows a broader range of VOCs identified in another spoiled tomato sample. Here, we again observe aldehydes, such as 3-hydroxybutanal and 7,11-hexadecadienal, likely contributing to off-odors (Blankenship and Dole, 2009). The presence of alcohols like 2-hexanol and 4-methyl-2-hexanol might also be indicative of microbial involvement (Ubeda-Garcia *et al.*, 2019). Interestingly, Table 2 also reveals the presence of esters, such as methoxyacetic acid octyl ester and (3-oxo-3H-benzo[f]chromen-1-yl)-acetic acid ethyl ester. While some esters can contribute to pleasant fruity or floral aromas, the specific esters identified here may not. Overall, the VOC profile in Table 2 suggests a more advanced stage of spoilage compared to Table 1,

The VOC profile in Table 3 is dominated by fatty acids and their derivatives, such as methyl esters and oleic acid. This is likely a consequence of enzymatic breakdown of fats within the tomato tissue during spoilage (Baldwin *et al.*, 2011). Additionally, the presence of 9-oxabicyclo[6.1.0]nonane suggests potential fungal involvement in spoilage, as some fungi are known to produce these cyclic compounds.

Tables 4 through 10 depict a consistent trend of VOCs associated with spoilage in tomatoes. These tables frequently show aldehydes, alcohols, esters, hydrocarbons, and fatty acids and their derivatives. The specific VOCs may vary, but their presence consistently indicates ongoing spoilage processes.

The presence of alcohols, including ethanol, 1-butanol, and 3-octanol, remained evident in Tables 4-10. As discussed earlier, alcohols can be indicative of ongoing microbial activity during spoilage, as some microbes produce them as byproducts of their metabolism (Ubeda-Garcia *et al.*, 2019). However, it is important to consider that certain short-chain alcohols, like ethanol, may also arise from the natural ripening process in tomatoes.

Aldehydes, such as 3-methylbutanal and hexanal, were frequently detected and likely originate from the breakdown of lipids during spoilage.

Of particular interest are the epoxides, such as cis-2,3-dimethyloxirane, which appear in several of the spoiled samples (Tables 4, 8). Further research is needed to elucidate the origin and significance of these compounds in tomato spoilage.

Esters were another recurring VOC class found in the spoilage samples (Tables 4-10). While some esters can contribute pleasant fruity or floral aromas, the specific esters identified here, such as butyl acetate and propanoic acid, ethyl ester, might have unpleasant odors. Further investigation is needed to determine the odor profile of each ester and its potential influence on spoilage perception.

The presence of hydrocarbons, such as n-alkanes, in several samples from Tables 4-10 suggests significant degradation of organic matter within the spoilage tomato tissue. These hydrocarbons likely originate from the breakdown of fatty acids and other biomolecules.

Fatty acids and their derivatives, including methyl esters, remained prominent VOCs across Tables 4-10. This reinforces the ongoing role of enzymatic breakdown of fats in spoilage progression, as observed in previous tables

A particularly interesting finding is the presence of epoxides, such as cis-2,3-dimethyloxirane, in some of the spoiled tomato samples (Tables 4 and 8). While the origin and significance of these compounds in tomato spoilage remain unclear, further research is warranted to elucidate their potential role as markers or contributors to the spoilage process.

The VOC profile of the fresh tomato (Table 11) stands in stark contrast to those of the spoiled samples. The absence of the aldehydes, ketones, and many of the breakdown products observed in the spoiled tomatoes suggests minimal lipid oxidation and enzymatic activity. The presence of alcohols like 1-decanol and esters like ethyl acetate might be natural constituents of fresh tomatoes, requiring further investigation for confirmation.

Conclusion

The VOC analysis effectively differentiated between fresh and spoiled tomato samples. The findings demonstrate that specific VOCs, like aldehydes, hydrocarbons, and certain alcohols, are valuable markers for spoilage progression in tomatoes. Future studies can focus on

quantifying these markers to develop non-invasive methods for monitoring tomato quality during storage and transportation, minimizing food spoilage and waste.

References

- Acree, T. E. (2003). *Biossays for flavor in: Flavor Science: Sensible Principles and Techniques*. (Eds.: T.E Acree and R. Tranish). *American Chemical Society*. Washington. D.C. pp112-118
- Blankenship, S. M., and Dole, J. M. (2009). Headspace analysis of fresh tomato and tomato puree volatiles. *Journal of Agricultural and Food Chemistry*, 57(7), 2915-2924.
- De Cal, A.Garcia-lepe, R, and Melagarejo, P. (2000) Induced Resistance by *Penicilliumoxallium* against *Fusariumoxysporum* f. sp.*Lycopersi* Histological Studies of Infected and Induced Tomato Stems. *Phytopathology*, 90: 260-267.
- El-Abyad, M.S, El-Sayed, M.A, El- Shanshoury, A.R. (1993) Towards the biological control of fungal and bacterial diseases of tomato using antagonistic *Streptomyces* spp. *Plant soil*.(149):185-195
- El-Shanshoury, A.R. Abu El-Sououd, S.M., Awadella, O.A. and El-Bandy, N.B. (1993). Effect of *Streptomyces corchorusii*, *Strptomycesmutabilis*, Pendimethalin and Metricuzin on Tthe Control of bacterial and *Fusarium* Wilt of Tomato.*Canadian Journal of Botany*. 74: 1016- 1022.

- Erinle, I.D. (2006). Tomato Diseases in the Northern states of Nigeria. Extension Bulletin 11, Agricultural Extension and Research Liaison Services, Ahmadu Bello University, Zaria.
- Ghosh A (2008). Identification of Microorganisms Responsible for Spoilage of Tomato (*Lycopersicon esculentum*) fruit. *Journal of Phytology*.; 1(6):414-416.
- Goh, E. N., and Sun, T. (2013). The mysterious world of bacterial volatile compounds. *Current Opinion in Biotechnology*, 24(6), 150-158.
- Maddox, D.A. (2008); Implications of New Technologies for Seed Health Testing and The Worldwide Movement of seed. *Seed Science Research*.; 8:277-284.
- Petro-Turza. M. 2007. Flavor of Tomato and Tomato Products. *Food Review International* 2(3): 309-351.
- Qasem, J.R. (2006) Root Growth Development and Nutrient Uptake of Tomato (*L.esculentum*) and Chenopodium Album. *Weed Research* 33(1); 35-42
- Sharma, V.K. and Nowak, J. (2008). Enhancement of Verticillium Wilt Resistance in Tomato Transplant by In Vitro Co-Culture of Seedlings with a Plant Growth Promotion Rhizobacterium (*pseudomonas* sp. strain PSJN). *Canadian Journal of Microbiology*. 44(6) 528-536
- Ubeda-Garcia, S., et al. (2019). Volatile organic compounds (VOCs) emitted by *Aspergillus flavus* and *Aspergillus parasiticus* during growth on peanut kernels. *Food Control*, 102, 109-117.
- Wokoma, E.C.W. (2008). Preliminary Report on Disease of Tomatoes in Choba, River State.
- Yilmaz, E. (2001). The chemistry of fresh tomato flavor. *Turkish Journal of Agriculture*. 25: