The University of Tehran Press

Pollution

https://jpoll.ut.ac.ir/

Print ISSN: 2383-451X
Online ISSN: 2383-4501

Research of Eventual Residues of Pesticides in Strawberry Fruits Using Gas Chromatography Combined with Mass Spectrometry

Fatima Naili[1]✉ | **Boualem Mayache**[1,2]

1. Laboratory of Biotechnology, Environment and Health, Faculty of Nature and Life Sciences, University of Jijel, 18000 Jijel, Algeria.
2. Faculty of Sciences, University of M'Sila, PO box Ichebilia, M'Sila 28000, Algeria

Article Info

Article type:
Research Article

Article history:
Received: 12 October 2024
Revised: 11 December 2024
Accepted: 19 January 2025

Keywords:
Pollutant
Metabolites
Plasticizer derivatives
Antioxidant
Phthalate

ABSTRACT

Our research focused on the Jijel region, where strawberry cultivation expanded considerably from 4 hectares in 2002 to 661 hectares in 2023. This study aimed to identify any pesticide residues in strawberries (*Fragaria x ananassa* Duch). Over two years, strawberries were cultivated in a plastic greenhouse using pesticides to either prevent or treat diseases as they developed. The fruit samples were collected and analyzed using a gas chromatograph coupled with a mass spectrometer. Numerous components were identified in the treated strawberry fruits; some are unique to strawberries, while others have not been documented in literature as strawberry constituents. The majority of the compounds found in the strawberry fruit were polyphenolic metabolites, alkanes, esters, aldehyde, aromatic alcohol, fatty acids, carbohydrates, phthalates, plasticizer derivatives, and others. All treated strawberry samples from both seasons showed no detectable pesticide compounds in the fruit. Nevertheless, certain samples contained hazardous pollutants such as 1,2,4-Benzenetriol and hydroquinone, as well as pesticide metabolites like di-n-octyl phtalate. The strawberry extract contained compounds similar to those naturally present in strawberries, but they appeared to have changed. Among the major components detected was a plasticizer compound: 1,2-benzenedicarboxylic acid mono (2-ethylhexyl) ester, identified as a pollutant result from the use of plastic materials in strawberry growing. These compounds were found to exhibit antioxidant, antimicrobial, antifungal, and insecticide properties. Some compounds were reported to have unknown activity. In conclusion, the fruits of treated strawberries contain a variety of bioactive compounds along with pollutants that could affect human health.

Cite this article: Naili, F., & Mayache, B. (2025). Research of Eventual Residues of Pesticides in Strawberry Fruits Using Gas Chromatography Combined with Mass Spectrometry. *Pollution*, 11(2), 560-575.
https://doi.org/10.22059/poll.2024.383647.2603

DOI: https://doi.org/10.22059/poll.2024.383647.2603

INTRODUCTION

Strawberry is one of the most ideal fruit in terms of health benefits. It is high in bioactive compounds like as polyphenols (anthocyanins, ellagitannins, phenolic acids...etc.) and vitamins (vit C, B9...etc.) that may help to prevent chronic diseases caused by oxidative stress and inflammation (Battino *et al*., 2021; Shiomi and Savitskaya, 2022). Strawberry also contains fibres, proteins, minerals, fatty acids, and sugars (Peris-Felipo *et al*., 2020), which are responsible for the sweetness and tartness of fruits (Hussain *et al*., 2021). It also includes volatile compound (esters, aldehydes, ketones, alcohols, terpenes, furanones and sulphur…) that contribute to the aroma and flavor of the fruit (Zamorska, 2022).

Numerous factors, such as plant variety, developmental stage, agricultural practices, environment (light and growing area), planting date, and others, affect the presence of compounds in fruits (Wang and Lin, 2000; Anttonen *et al*., 2006 and Simkova *et al*., 2024). We were interested in agronomic practices in this study, including the use of pesticides. During

---

*Corresponding Author Email: *fattim.nai@gmail.com* cultivation, many farmers believe that using pesticides like fungicides, insecticides, acaricides, and nematicides is the best method to protect their crops from pests and increase yield (Mahmood *et al*., 2016; Tudi *et al*., 2021). Since pesticides are persistent and non-biodegradable, they have polluted the soil, water, air, and food chain (Gill and Garg, 2014). However, it may degrade due to photodegradation and biodegradation; Photodegradation, a chemical reaction induced by photons or light, can occur in the atmosphere, on the surface of water, or in soil. Biodegradation occurs in the presence of several microorganisms (Dabrowska *et al*., 2004; Elumalai *et al*., 2022).

Farmers have used a variety of pesticides during strawberry cultivation, both as a preventative measure and in response to the emergence of diseases such as Mildieu, Phytophthora, Botrytis, thrips, and aphids. Furthermore, they frequently combine pesticides to treat multiple diseases concurrently or in cases of misdiagnosis. The use of greenhouses and tunnels to grow strawberries contributes to the contamination. According to the Agriculture Directorate, the strawberry planting area for 2023 was divided into 0.36 Ha Multichapelle, 390.49 Ha Tunnels, and 270.92 Ha greenhouses. The greenhouses use solar energy to create an appropriate internal microclimate for improving crop growth and development conditions. However, the current surge in the use of plastic materials in agriculture is also having an increasing negative impact on the agro-ecosystem (Vox *et al*., 2016; Bazgaou *et al*., 2021). In addition, two pesticides (pyrethroids and atrazine) were tested in greenhouse and open-field soils to determine their concentrations and distributions. The greenhouse had higher contamination levels than the open fields (Dou *et al*., 2020).

The analytical techniques used influence the search for different compounds in strawberries (Forney *et al*., 2000). Several chemicals specific to strawberry fruit or potentially pesticide residues in fruit have been identified using capillary gas chromatography coupled with mass spectrometry (Stachniuk and Fornal, 2016; Pico et al., 2020).

The objective of this study was to investigate the potential presence of pesticide residues in strawberry fruit resulting from intensive pesticide application during strawberry cultivation, using the capillary gas chromatography coupled with mass spectrometry technique.

MATERIALS AND METHODS

Plant material and treatment

For two years, from 2018 to 2020, the experiment was conducted in a greenhouse located in the Wilaya of Jijel (North-East Algeria), where strawberry cultivation has been considerably developed from 4 hectares in 2002, when it produced 1200 Qx, to 661 Ha in 2023, when it produced 221350 Qx (Directorate of Agriculture). Strawberry (*Fragaria x ananassa* Duch.) cultivar Camarosa was the plant material used in this study. Tables 1 and 2 show the pesticides used at the occurrence of diseases against insects, mites, and fungi based on a survey of farmers. The greenhouse was divided into three parts. A composite sample covering all of the plot's treatment areas was established by selecting subsamples of healthy fruits at random from various points within the greenhouse beginning in March and continuing each month thereafter. The treatment was continued until June. All of the samples collected for each part were combined and used as a single sample for analysis. As a result, three samples were collected from the greenhouse each season. The samples were cleaned with distilled water, dried and stored at (-20°c) until analysis.

Extraction of pesticides from strawberries

We are extremely interested in organophosphate pesticides since they are the most widely used. The extraction of pesticides from strawberries was carried out according to the method of Charles & Raymond, (1991). It is a liquid-liquid extraction. The procedure consists of weighing 50 g of ground sample in a container. The mixture was homogenized for two minutes after

Table 1. Pesticides used in strawberry cultivation during the 2018-2019 season

Pesticide	Active substance	Chemical group	Dose
Fongicide Aliette® Flash	Fosétyl-aluminium	Phosphonates	250 g/hl
Insecticide Cyren C	Cypermethrine + Chlorpyriphos-Ethyl	Pyrethroid + Organophosphorus	40 ml/hl
Acaricide Vertimec	Abamectine	Avermectin	0,5L/ ha
Fongicide Scolti flow	Sulfure + Copper	Inorganic fungicide	3 L/ha

Table 2. Pesticides used in strawberry cultivation during the 2019-2020 season

Pesticide	Active substance	Chemical group	Dose
Insecticide Cyren C	Cypermethrine, Chlorpyriphos-ethyl	Pyrethroid+ Organophosphorus	40 mL/ hL
Acaricide Medamec	Abamectine	Avermectin	0,5 L/ha
Fongicide Scolti Flow	Sulfur+ Copper	Inorganic fungicide	3 L/ha
Fongicide Bayvadan	Triadimenol	Triazoles	20 mL/hL
Insecticide Dursban	Chlorpyriphos-ethyl	Organophosphorus	80 g/hL

adding 100 mL of acetone. The container was then agitated horizontally for two hours. The resulting mixture was decanted through a funnel fitted with a glass wool filter. After that, 50 mL of acetone was added into the container and shaken for another two minutes. The new extract was poured into the funnel. A 1000-ml separatory funnel was filled with 300 mL of distilled water and 30 mL of saturated sodium chloride solution. The extraction was performed using 70 mL of dichloromethane. We were agitated for about five minutes. The decantation was completed once the two phases had separated. The lower phase was extracted and collected in a flask using a funnel lined with a filter pad coated with 2 cm of sodium sulfate. The aqueous phase was extracted again with 70 ml of dichloromethane. After shaking for five minutes, it was decanted in the same flask for ten minutes. After washing the funnel with 20 ml of hexane, the filtrates were evaporated in a rotary evaporator at temperatures less than 50°C. Finally, 10 ml of acetone/hexane solution (10%/90%) was added to the residue, which was analyzed using gas chromatography coupled with a mass spectrometer.

Purification

The SI type cartridge was cleaned with a 5 ml acetone/hexane solution (60%/40%), then a 5 ml hexane solution. 1 ml of the filtered solution was deposited and eluted with 4 ml of ether/hexane solution (60%/40%).

Chromatographic conditions and analysis

The analysis was performed using a gas chromatography coupled with a mass spectrometer as a detector type Shimadzu GCMS QP 2010 of type E1 70 eV quadrupole. 1 µl of each sample was injected in split mode at a temperature of 250°C. Helium was used as the carrier gaz. The temperature program for the GC column was 90°C for 1 minute, 180°C for 1 minute, and finally 240° C for 5 minutes. The column flow was 0.97 ml/min. The actual split ratio was 20:0. The ion source temperature was at 200 °c. The solvent Cut time was 3.00 min. The MS program: Interval: 1.00 sec. The speed of scan was: 416. The start masse/charge (m/z) equals 50. The final m/z was 450.The compounds found in the samples were identified by comparing the results to those in the National Institute of Standards and Technology (NIST) Mass spectral library.

RESULTS AND DISCUSSION

Figures (1-6) and (Tables 3-8) present all the compounds and contaminants detected in strawberry fruit samples by GC-MS analysis for both seasons. Table 9 highlights the notable large peaks and predominant molecules to determine the nature and relevance of the compound. All tables listing molecules found include the compound name, retention time, area, percentage of peak area, height, height percentage, and mass-to-charge ratio. The compounds were identified based on a direct comparison of retention times and mass spectra with the library of spectra of known compounds stored in the spectral database, NIST (The National Institute of Standards Technology).

The GC-MS analysis of treated strawberry fruit samples revealed the presence of a variety of components, some of which are specific to strawberries and others not, that can reduce strawberry fruit quality. Despite being taken in the same greenhouse during both seasons, the

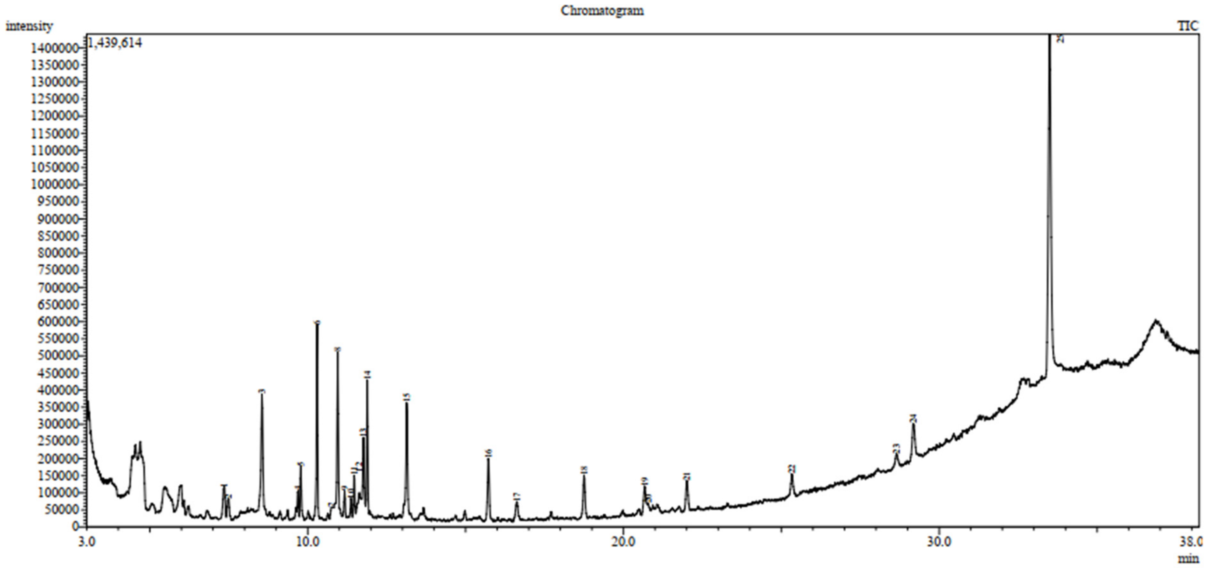

Fig. 1. Chromatographic profile of treated sample n° 1 of strawberry fruit for the first season.

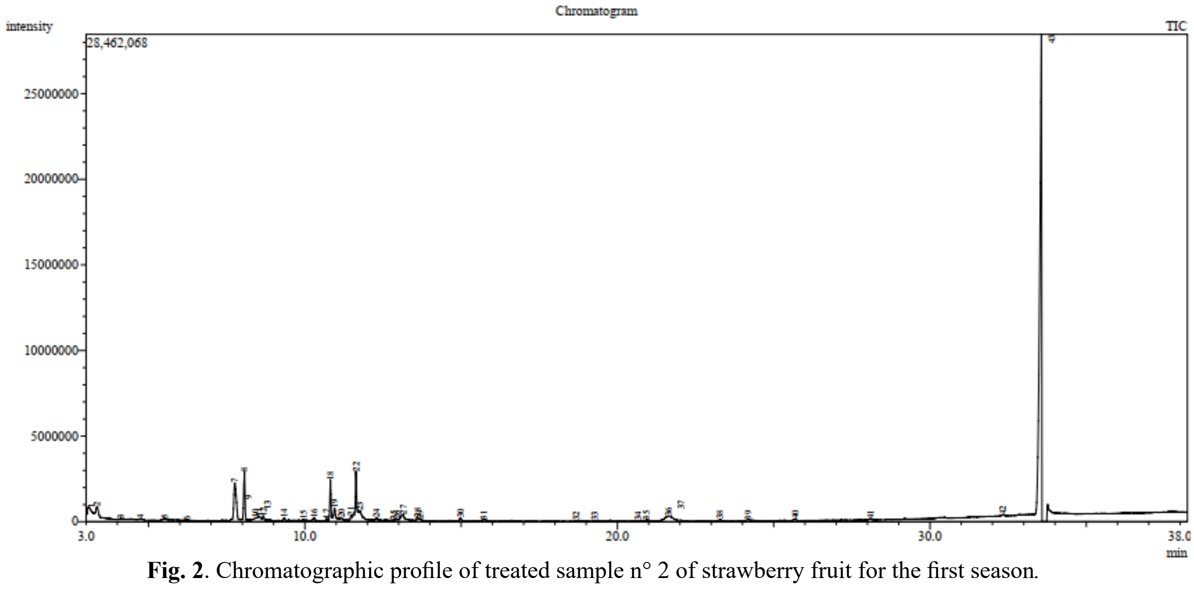

Fig. 2. Chromatographic profile of treated sample n° 2 of strawberry fruit for the first season.

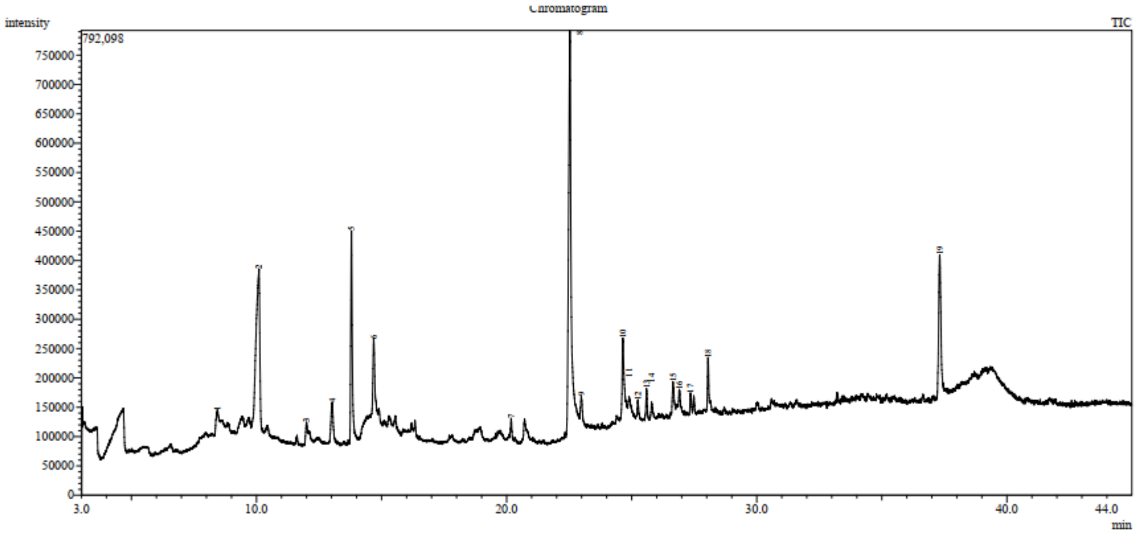

Fig. 3. Chromatographic profile of treated sample n° 3 of strawberry fruit for the first season.

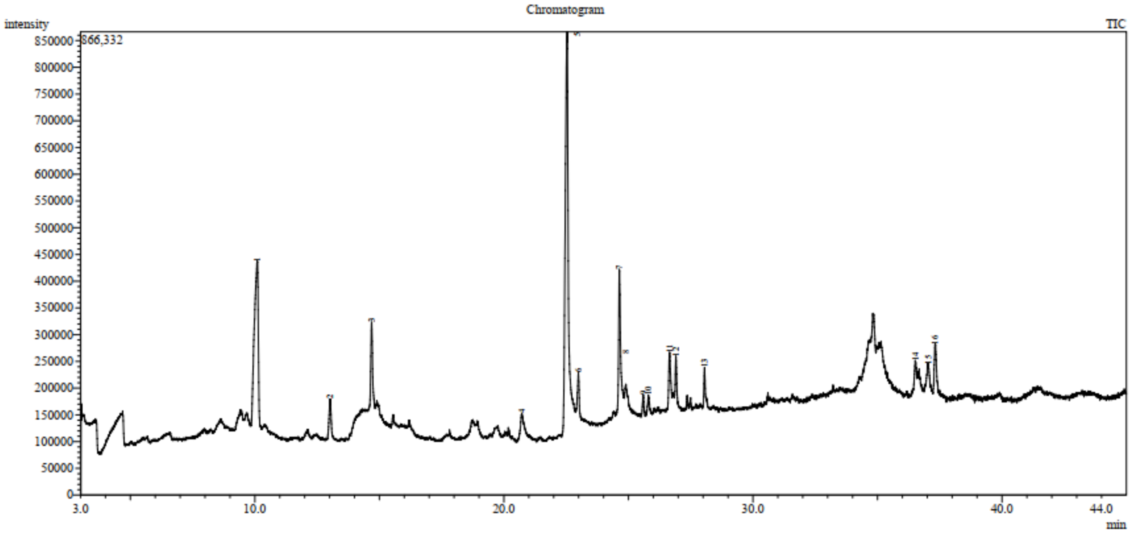

Fig. 4. Chromatographic profile of treated sample n°1 of strawberry fruit for the second season.

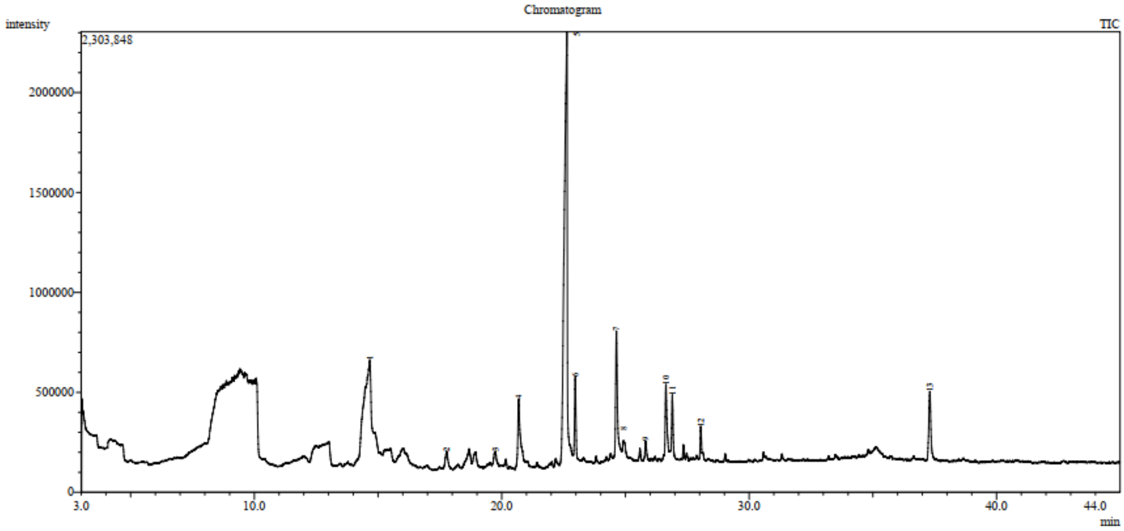

Fig. 5. Chromatographic profile of treated sample n° 2 of strawberry fruit for the second season.

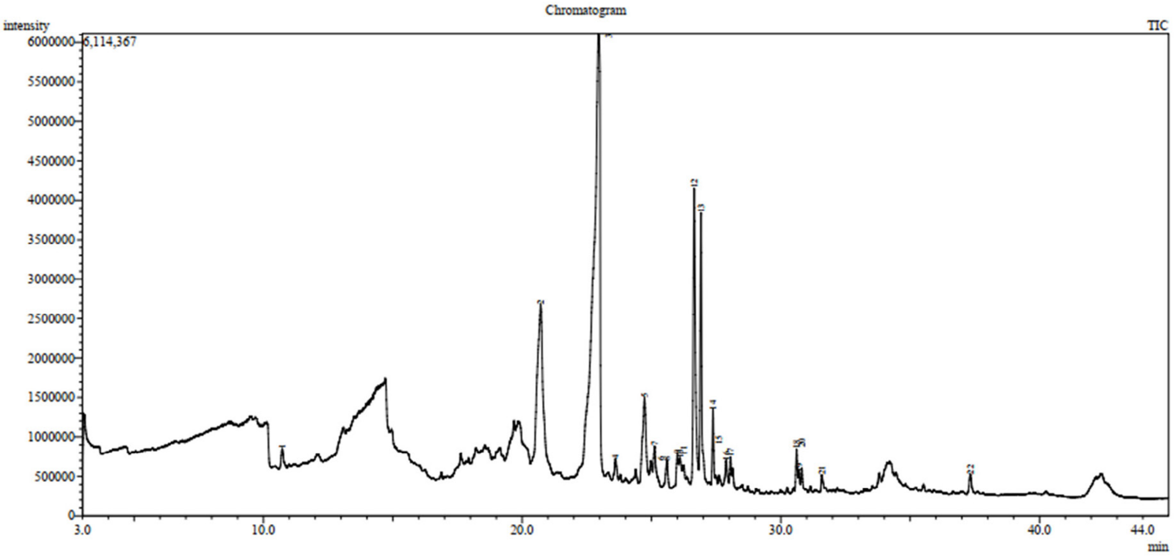

Fig. 6. Chromatographic profile of treated sample n° 3 of strawberry fruit for the second season.

Table 3. Retention time, area, peak area percentage, height, height percentage, base and compound name detected by GC-MS in strawberry extract from sample 1 of the first season.

Peak N°	R.Time	Area	Area (%)	Height	Height (%)	Name	Base (m/z)
1	7.357	457540	2.09	92790	1.86	1-Decanol, 2-hexyl-	57.10
2	7.487	275770	1.26	60920	1.22	Ethanol, 2-phenoxy-	94.05
3	8.553	1492830	6.81	348142	6.99	Cycloheptasiloxane, tetradecamethyl-	73.05
4	9.693	324188	1.48	82283	1.65	Z,Z-2,5-Pentadecadien-1-ol	97.10
5	9.781	459937	2.10	156052	3.13	Z,Z-2,5-Pentadecadien-1-ol	57.05
6	10.296	1550377	7.07	570554	11.45	Butylated Hydroxytoluene	205.10
7	10.750	412952	1.88	37286	0.75	Cyclooctasiloxane, hexadecamethyl-	73.05
8	10.950	1540903	7.02	490985	9.86	Cyclooctasiloxane, hexadecamethyl-	73.05
9	11.168	275775	1.26	84864	1.70	1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (E)-	69.10
10	11.373	231849	1.06	63153	1.27	Iridomyrmecin	95.10
11	11.473	367908	1.68	129269	2.59	Phenol, 2,4-bis(1,1-dimethylethyl)-	191.10
12	11.634	538174	2.45	78634	1.58	Sulfurous acid, hexyl pentyl ester	85.10
13	11.767	1000546	4.56	239998	4.82	Pentanoic acid, 2,2,4-trimethyl-3-carboxyisopropyl, isobutyl ester	71.05
14	11.885	1057305	4.82	408433	8.20	Cyclohexane, 1-(cyclohexylmethyl)-2-methyl-, trans-	97.10
15	13.139	1427434	6.51	340070	6.83	Cyclononasiloxane, octadecamethyl-	73.05
16	15.723	782885	3.57	184545	3.70	Heptasiloxane, hexadecamethyl-	73.05
17	16.623	329664	1.50	56495	1.13	Hexadecanoic acid, methyl ester	74.05
18	18.754	562706	2.57	125588	2.52	Cyclooctasiloxane, hexadecamethyl-	73.05
19	20.672	474959	2.17	84127	1.69	9-Octadecenoic acid (Z)-, methyl ester	55.05
20	20.783	149730	0.68	33153	0.67	Chloroacetic acid, 10-undecenyl ester	82.10
2	22.008	446837	2.04	88875	1.78	Cyclononasiloxane, octadecamethyl-	73.05
22	25.337	423285	1.93	70481	1.41	Cyclononasiloxane, octadecamethyl-	73.05
23	28.651	255228	1.16	39658	0.80	Cyclononasiloxane, octadecamethyl-	73.05
24	29.181	678577	3.09	106629	2.14	Hexanedioic acid, bis(2-ethylhexyl) ester	129.05
25	33.497	6417815	29.26	1008759	20.25	1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester	149.00

samples have different numbers and types of components.GC-MS analysis found compounds whose chemical nature was varied and included: polyphenolic metabolites, alkanes, esters, aldehyde, aromatic alcohol, phthalate, carbohydrate, plasticizer derivatives and others (Table 9). Pesticide detection in fruit is difficult due to the low concentration and complex matrix (Zhang & Ruan, 2016). According to the results of all treated strawberry samples from both

Table 4. Retention time, area, peak area percentage, height, height percentage, base and compound name detected by GC-MS in strawberry extract from sample 2 of the first season.

PeakN°	R. Time	Area	Area (%)	Height	Height (%)	Name	Base (m/z)
1	3.074	3922463	1.94	426889	0.94	2-Amino-8-[3-d-ribofuranosyl]imidazo[1,2-a]-s-triazin-4-one	57.05
2	3.354	3463116	1.72	604921	1.33	Cyclohexasiloxane, dodecamethyl-	73.05
3	4.110	372596	0.18	63851	0.14	Cyclohexasiloxane, dodecamethyl-	73.05
4	4.732	463014	0.23	55828	0.12	Phenol	94.05
5	5.527	762239	0.38	103538	0.23	Nonane, 5-butyl-	71.10
6	6.228	282982	0.14	53333	0.12	Undecane, 5,7-dimethyl-	57.10
7	7.761	12811847	6.35	2182838	4.80	3-Butoxy-1,1,1,7,7,7-hexamethyl-3,5,5-tris(trimethylsiloxy)tetrasiloxane	73.05
8	8.065	8260051	4.09	2880270	6.33	3-Butoxy-1,1,1,7,7,7-hexamethyl-3,5,5-tris(trimethylsiloxy)tetrasiloxane	73.05
9	8.200	260218	0.13	61309	0.13	Cyclopentaneundecanoic acid, methyl ester	74.05
10	8.417	1256741	0.62	160313	0.35	138.05	
11	8.534	2098021	1.04	267568	0.59	3-Isopropoxy-1,1,1,7,7,7-hexamethyl-3,5,5-tris(trimethylsiloxy)tetrasiloxane	73.05
12	8.667	959490	0.48	287459	0.63	Eicosane	71.10
13	8.809	264821	0.13	66151	0.15	Hexane, 3,3-dimethyl-	71.10
14	9.341	523506	0.26	153521	0.34	Dodecane, 2,6,11-trimethyl-	71.10
15	9.950	239002	0.12	88361	0.19	Undecanoic acid, 10-methyl-, methyl ester	74.00
16	10.294	548481	0.27	192569	0.42	Butylated Hydroxytoluene	205.15
17	10.701	450452	0.22	148886	0.33	Cyclooctasiloxane, hexadecamethyl-	73.05
18	10.818	6191799	3.07	2392534	5.26	Cyclooctasiloxane, hexadecamethyl-	73.05
19	10.951	3863700	1.91	741720	1.63	Cyclooctasiloxane, hexadecamethyl-	73.05
20	11.167	1020764	0.51	189270	0.42	1,6,10-Dodecatrien-3-ol, 3,7,11-trimethyl-, (E)-	69.05
21	11.483	1337408	0.66	291797	0.64	Phenol, 3,5-bis(1,1-dimethylethyl)-	191.10
22	11.637	10715675	5.31	2891973	6.35	Propanoic acid, 2-methyl-, 1-(1,1-dimethylethyl)-2-methyl-1,3-propanediyl ester	71.05
23	11.756	4224452	2.09	584456	1.28	Propanoic acid, 2-methyl-, 1-(1,1-dimethylethyl)-2-methyl-1,3-propanediyl ester	71.05
24	12.295	543619	0.27	182705	0.40	Dodecane, 2,6,11-trimethyl-	71.05
25	12.836	149764	0.07	50014	0.11	Diethyl Phthalate	149.05
26	12.942	404371	0.20	78065	0.17	Thiocarbamic acid, N,N-dimethyl, S-1,3-diphenyl-2-butenyl ester	207.05
27	13.146	2687940	1.33	381278	0.84	Heptasiloxane, hexadecamethyl-	73.05
28	13.602	692096	0.34	202984	0.45	Apiol	222.05
29	13.679	445347	0.22	113524	0.25	Apiol	222.05
30	14.979	678536	0.34	203610	0.45	Eicosane	85.10
31	15.721	709101	0.35	92204	0.20	Octasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11,13,13,15,15-hexadecamethyl-	73.05
32	18.683	406539	0.20	52359	0.12	Tridecanol, 2-ethyl-2-methyl-	57.10
33	19.270	248352	0.12	52140	0.11	Decane, 1-iodo-	71.10
34	20.667	273028	0.14	29451	0.06	13,16-Octadecadienoic acid, methyl ester	55.00
35	20.935	375909	0.19	91501	0.20	Eicosane	57.05
36	21.644	4686004	2.32	268620	0.59	1,2-Benzenedicarboxylic acid, diisooctyl ester	149.05
37	22.033	313832	0.16	34307	0.08	73.05	
38	23.287	390636	0.19	87551	0.19	Eicosane	57.10
39	24.179	331622	0.16	62798	0.14	Acetic acid, chloro-, hexadecyl ester	55.05
40	25.685	355236	0.18	78449	0.17	Eicosane	57.05
41	28.095	309088	0.15	61771	0.14	Eicosane	57.05
42	32.331	393280	0.19	56434	0.12	Di-n-octyl phthalate	149.05
43	33.560	123094613	61.00	28451958	62.50	1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester	149.05

seasons, shown in Figures (1-6) and Tables (3-8), none of the molecules detected in strawberry fruits were pesticides.

Figure 1 and Table 3 depict the 25 molecules detected in the first treated sample. Figure 2 and Table 4 show that sample 2 contained 43 peaks. Figure 3 and Table 5 show that the analysis of strawberry fruit sample 3 revealed the presence of 19 distinct compounds. Figure 4 and Table 6 show the 16 chemicals found in strawberry fruit sample 1 from the second season, while Figure 5 and Table 7 show the 13 chemicals found in strawberry sample 2 from the second season. Finally, Figure 6 and Table 8 show the 22 peaks discovered for treated fruit sample 3 from the second season. All of the chemical compounds in the strawberry samples were

Table 5. Retention time, area, peak area percentage, height, height percentage, base and compound name detected by GC-MS in strawberry extract from sample 3 of the first season.

Peak N °	R.Time	Area	Area (%)	Height	Height (%)	Name	Base (m/z)
1	8.436	190406	1.28	29616	1.24	Glycerin	61.00
2	10.098	2682479	18.06	269533	11.32	Cyclopropyl carbinol	44.00
3	12.003	110823	0.75	26835	1.13	Benzenecarboxylic acid	105.05
4	13.028	406141	2.73	66926	2.81	1,4:3,6-Dianhydro-.alpha.-d-glucopyranose	69.05
5	13.796	1510207	10.17	359066	15.08	Bicyclo[2.2.2]oct-5-en-2-yldimethylamine	71.10
6	14.686	648566	4.37	128303	5.39	2-Furancarboxaldehyde, 5-(hydroxymethyl)-	97.05
7	20.182	110320	0.74	33772	1.42	2-Naphthalenemethanol, decahydro-.alpha.,.alpha.,4a-trimethyl-8-methylene-, [2R-(2.alpha.,4a.alpha.,8a.beta.)]-	59.05
8	22.529	5113610	34.43	685145	28.78	D-Allose	60.00
9	22.985	247238	1.66	48302	2.03	Pentadecanal-	82.10
10	24.649	761157	5.12	133117	5.59	1,2,4-Benzenetriol	126.10
11	24.897	68001	0.46	19739	0.83	Pentanoic acid, heptyl ester	124.00
12	25.250	108445	0.73	30078	1.26	Bicyclo[2.2.2]oct-5-en-2-yldimethylamine	71.10
13	25.594	152908	1.03	48566	2.04	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	149.10
14	25.798	106169	0.71	26330	1.11	1,6-Anhydro-.alpha.-d-galactofuranose	73.05
15	26.653	331817	2.23	61002	2.56	cis-1,2-Cyclododecanediol	55.00
16	26.906	359093	2.42	46326	1.95	Pentadecanal-	43.05
17	27.352	120320	0.81	33544	1.41	n-Hexadecanoic acid	73.05
18	28.053	350330	2.36	96418	4.05	9-Octadecenoic acid, methyl ester, (E)-	55.00
19	37.315	1476266	9.94	237965	10.00	1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester	149.10

Table 6. Retention time, area, peak area percentage, height, height percentage, base and compound name detected by GC-MS in strawberry extract from sample 1 of the second sason.

Peak N°	R.Time	Area	Area%	Height H	eight%	Name	Base m/z
1	10.097	3379953	20.95	308971	13.65	Cyclopropyl carbinol	44.00
2	13.022	424507	2.63	73513	3.25	1,4:3,6-Dianhydro-.alpha.-d-glucopyranose	69.10
3	14.689	762560	4.73	159998	7.07	2-Furancarboxaldehyde, 5-(hydroxymethyl)-	97.10
4	20.721	321870	2.00	40587	1.79	4H-Pyran-4-one, 5-hydroxy-2-(hydroxymethyl)-	142.15
5	22.541	6099833	37.81	733974	32.42	D-Allose	60.00
6	22.991	353288	2.19	79678	3.52	Hexadecanal	82.10
7	24.637	1644305	10.19	274380	12.12	1,2,4-Benzenetriol	126.05
8	24.900	440915	2.73	56813	2.51	2-Deoxy-D-galactose	103.05
9	25.594	141112	0.87	37190	1.64	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	149.10
10	25.802	130124	0.81	31721	1.40	1,6-Anhydro-.alpha.-d-galactofuranose	73.10
11	26.654	586382	3.63	105149	4.64	7-Hexadecenal, (Z)-	55.00
12	26.908	413621	2.56	96494	4.26	Octadecanal	82.10
13	28.057	300464	1.86	74244	3.28	9-Octadecenoic acid, methyl ester, (E)-	55.05
14	36.518	300053	1.86	56765	2.51	Cholesta-4,6-dien-3-ol, (3.beta.)-	135.15
15	37.041	254050	1.57	41776	1.85	Cholest-5-en-3-ol (3.beta.)-, carbonochloridate	147.15
16	37.311	578585	3.59	92707	4.09	149.10	

identified using GC-MS analysis, with the exception of a few unknowns, such as peak 10, 37 in sample 2 (Table 4), peak 16 in sample 1 (Table 6), and peak 15, 19 in sample 3 (Table 8). Chemical elements found in samples from both seasons include 1,2-Benzenedicarboxylic acid, mono (2-ethylhexyl) ester, 1,2,4-Benzenetriol, 2-Furancarboxaldehyde, 5-(hydroxymethyl), and more. However, some compounds, such as Z,Z-2,5-Pentadecadien-1-ol, Iridomyrmecin, Apiol, Aziridine, 1,2,3-trimethyl, trans, etc., are only found in certain samples.

Table 7. Retention time, area, peak area percentage, height, height percentage, base and compound name detected by GC-MS in strawberry extract from sample 2 of the second season.

Peak N°	R. Time	Area	Area (%)	Height	Height (%)	Name	Base (m/z)
1	14.666	6920270	18.17	384693	7.25	2-Furancarboxaldehyde, 5-(hydroxymethyl)-	97.05
2	17.777	459264	1.21	75351	1.42	Hydroquinone	110.05
3	19.747	325283	0.85	56065	1.06	Phloroglucitol	45.00
4	20.687	2175474	5.71	326710	6.15	1,2,3-Benzenetriol	126.05
5	22.632	17042548	44.74	2098356	39.53	D-Allose	60.00
6	22.973	1445958	3.80	399556	7.53	Hexadecanal	82.10
7	24.638	3266203	8.57	632129	11.91	1,2,4-Benzenetriol	126.05
8	24.923	575369	1.51	79091	1.49	Pentanoic acid, 2-(methoxymethyl)-4-oxo-	69.05
9	25.818	362448	0.95	88275	1.66	1,6-Anhydro-.beta.-D-glucofuranose	73.05
10	26.638	1756106	4.61	358288	6.75	cis-9-Hexadecenal	55.00
11	26.897	1355556	3.56	314018	5.92	Octadecanal	82.10
12	28.046	574006	1.51	163901	3.09	9-Octadecenoic acid, methyl ester, (E)-	55.00
13	37.304	1834633	4.82	331973	6.25	1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester	149.10

Table 8. Retention time, area, peak area percentage, height, height percentage, base and compound name detected by GC-MS in strawberry extract from sample 3 of the second season.

Peak N°	R.Time	Area	Area (%)	Height	Height (%)	Name	Base (m/z)
1	10.727	1066284	0.55	214971	1.01	Thymol	135.15
2	20.713	27411362	14.09	1962473	9.23	1,2,3-Benzenetriol	126.10
3	22.945	95167060	48.92	5562370	26.15	1,6-Anhydro-.beta.-D-glucopyranose (levoglucosan)	60.00
4	23.610	1167955	0.60	225803	1.06	3-Deoxyglucose	41.05
5	24.733	9678035	4.98	1058989	4.98	1,2,4-Benzenetriol	126.10
6	24.974	1287179	0.66	231839	1.09	Oxirane, hexadecyl-	82.10
7	25.124	2170816	1.12	406629	1.91	Pentanoic acid, 2-(methoxymethyl)-4-oxo-	69.10
8	25.600	1572005	0.81	311367	1.46	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	149.15
9	26.006	1861924	0.96	393408	1.85	1,6-Anhydro-.beta.-D-glucofuranose	73.05
10	26.109	1817253	0.93	314648	1.48	Pentaethylene glycol	45.05
11	26.249	1068709	0.55	193402	0.91	Aziridine, 1,2,3-trimethyl-, trans-	42.05
12	26.649	21415367	11.01	3721903	17.50	cis-9-Hexadecenal	55.05
13	26.913	14570275	7.49	3399748	15.98	Octadecanal	82.10
14	27.380	3608426	1.85	958077	4.50	n-Hexadecanoic acid	73.10
15	27.608	905699	0.47	128873	0.61	41.05	
16	27.889	1897089	0.98	335388	1.58	Oxirane, tetradecyl-	43.05
17	28.058	1545944	0.79	382844	1.80	8-Octadecenoic acid, methyl ester, (E)-	55.05
18	30.610	2057579	1.06	534937	2.52	9-Octadecenoic acid, (E)-	55.05
19	30.708	991411	0.51	234022	1.10	67.05	
20	30.812	1031541	0.53	267610	1.26	Octadecanoic acid	43.05
21	31.587	963212	0.50	202943	0.95	Hexagol	45.00
22	37.332	1277483	0.66	226980	1.07	1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester	149.10

Table 9. Nature and relevance of important compounds found in strawberry extracts

Name of the compound	Compound nature	The relevance of compound
3-Butoxy-1,1,1,7,7,7-hexamethyl-3,5,5-tris (trimethylsiloxy) tetrasiloxane	Miscellaneous (Oyedeji *et al*., 2021)	Beneficial health effect (antibacterial) (Al Bratty et al., 2020)
Propanoic acid , 2-methyl-, 1-(1,1-dimethyl-ethyl)-2-methyl-1, 3-propanediyl ester1	Ester (Wang *et al*., 2020).	Not Harmful
1,2-Benzenedicarboxylic acid, mono(2-ethylhexyl) ester	Phthalate Ester (Gushit *et al*., 2013; Oyedeji *et al*., 2021).	Harmful
2. Furancarboxaldehyde, 5-(hydroxymethyl)	Aldehyde (Amala & Jeyaraj, 2014)	Not Harmful
D-Allose	Carbohydrate (Sugar) (Amala & Jeyaraj, 2014)	Not Harmful
1,2,4-Benzenetriol	Polyphenol (Lee et al., 1995)	hazardous pollutants
Cyclopropyl carbinol	phenolic compounds (Akbarizare, 2021)	Not Harmful
7-Hexadecenal, (Z)	Aldehyde (Kong et al., 2017)	Not Harmful
1,2, 3-Benzentriol	Aromatic Alcohol (Amala & Jeyaraj, 2014), Polyphenol (Beulah et al., 2018)	Not Harmful
Hexadecanal	Aldehyde (Zhou et al., 2020)	Not Harmful
Cis-9-Hexadecenal	Aldehyde (Zhou et al., 2020)	Beneficial health effect (antimelanogenic) (Hoda, et al., 2020)..
Octadecanal	Aldehyde (Zhou et al., 2020)	Not Harmful
1,6-Anhydro-beta-D-glucopyranose	anhydro sugar (Kavipriya & Chandran, 2018)	Not Harmful
Cis-9-Hexadecenal	Aldehyde [28], fatty acid (Qadir et al., 2018)	Not Harmful
Cycloheptasiloxane, tetradecamethyl	Cyclic methyl siloxane (Prasher & Dhanda, 2017).	Beneficial health effect (Preservative) (Al Bratty et al., 2020)
Butylated Hydroxytoluene	Synthetic antioxidant (El-Korany & Mohamed, 2008).	Not Harmful
Cyclooctasiloxane, hexadecamethyl	Alkaloid compound (Jasim *et al*., 2015).	Beneficial health effect (Antimicrobial) (Al Bratty et al., 2020)
Pentanoic acid, 2,2,4-trimethyl-3-carboxyisopropyl, isobutyl ester	Acid (Youn *et al*., 2012).	Not Harmful
Cyclononasiloxane, octadecamethyl	Alkaloid compound (Jasim *et al*., 2015).	Beneficial health effect (Antifungal) (Al Bratty et al., 2020)
Heptasiloxane, hexadecamethyl	Alkane (Zhou *et al*., 2020)	Beneficial health effect (Antimicrobial) (Al Bratty et al., 2020)
Hexanedioic acid, bis (2-ethylhexyl) ester	Plasticizer Derivatives (Khaled *et al*., 2009).	Harmful but it has antifungal properties (Zhan, et al., 2023)

Similar findings have been reported for metabolites specific to strawberry fruit and obtained by GC analysis, such as 1, 2-Benzenedicarboxylic acid, bis (2-methylpropyl) ester (Figure 3, 4), an ester, However, Oz *et al.* (2016) found that the compound 1,2-Benzenedicarboxylic was absent in the strawberry variety Camarosa; n-Hexadecanoic acid, a fatty acid saturated (Figure 3and 6); Eicosane, an alkane (Figure 2) (Zhang *et al.*, 2011); Phenol, an aldehyde (Figure 2) (Kafkas & Kafkas, 2016). 3,7,11-trimethyl 1,6,10- dodecatrien-3-ol also called nerolidol appeared in sample 1 (Figure 1) among the minor compounds but it belongs to the strawberry specific compounds and has an important role in the aroma (Lambert *et al.*, 1999; Zhang *et al.*, 2011). Lambert et al. (1999) also discovered butylated hydroxytoluene (Figures 1 and 2) in strawberry *Fragaria ananassa* using GC-MS analyses. Apiol, a phenol derivative, is one of the metabolites achene identified in strawberry (*Fragaria ananassa*) (Wedde, 2014), and it appeared among the minor compounds in sample 2 (Figure 2). One of the achene metabolites found in strawberry *Fragaria ananassa* is levoglucosan, also known as 1,6-Anhydro-beta-D-glucopyranose (Figures 5, 6) (Wedde, 2014).

Strawberry extract contains compounds that are similar to those found in strawberries, but have changed because they have acquired additional functions such as: 2. Furancarboxaldehyde, 5-(hydroxymethyl), notwithstanding Dahlen *et al.* (2001) and Du *et al.* (2011) discoved that strawberries contain 2, 5-dimethyl-4-hydroxy-3(2H)-furanone, an aroma compound. The aroma composition of strawberries contains the metabolite Octadecane (Rohloff, 2011), however, Octadecanal, an aldehyde, was discovered throughout our analysis. Among the metabolites of strawberries were bis (2-ethylhexyl) phthalate (Zhang *et al.*, 2011) or dibutyl phthalate (Duan et al., 2021); however, the molecule we found in our investigation was diethyl phthalate. Zhang *et al.* (2011) reported the compound Nonane among the strawberry alkanes, but we obtained the compound Nonane, 5- butyl. Although decanal is one of the volatile substances found in strawberry *Fragaria ananassa* fruits (Duan *et al.*, 2021). Decanol, 2-hexyl was found in the sample extract. According to Park *et al.* (2000), one of the volatile compounds extracted and identified in the strawberry *Fragaria ananassa* was Hexadecanol, however Hexadecanal was detected in sample 1 (Figure 4) instead. Also, Hexadecanoic acid was revealed by Zhang *et al.* (2011) in strawberry fruits, although our sample 1 (Figure 1) contained hexadecanoic acid, methyl ester. Regarding sugars, Zhang *et al.* (2011) found in strawberry fruit Glucose, Galctose and pyran ring as B-D- Glucopyranose while in our strawberry samples we found: 2-Deoxy-D-galactose, 3- Deoxyglucose and furan ring as 1,6- Anhydro-beta-D-glucofuranose. The use of pesticides may be the cause of these changes in metabolites. Similar findings were supported by Zhao et al. (2016), who found that the application of nano copper as a fungicide altered the metabolite profile and disrupted biological pathways in cucumber (*Cucumis sativus*) fruits. Additionally, Pereira *et al.* (2014) reported that exposure to the drug mancozeb had a significant effect on the metabolism of lettuce plants (*Lactuca sativa* L).

Numerous other substances are absent in strawberry fruits, according to the previous research, including: 1,2,3-Benzenacid, mono (2-ethylhexyl) ester; Propanoic acid, 2-methyl-, 1-(1,1- dimethylethyl) -2-methyl-1, 3-propanediyl ester1; Cyclooctasiloxane, hexadecamethyl; Cyclononasiloxane, octadecamethy; 3-Butoxy-1,1,1,7,7,7-hexamethyl-3,5,5 tris (trimethylsiloxy) tetrasiloxane; ...etc. Depending on the samples, there are certain compounds that, based on previous study, are unknown, such as: Cholest-5-en-3 -ol(3.beta)-,carbonochloridate; Chloroacetic acid, 10- undecenylester….. etc

There are some substances found in the strawberry samples under study that are beneficial to human health. Among the major substances found to possess antioxidant and antimicrobial activities: Cis-9-Hexadecenal (Qadir *et al.*, (2018). The research of ElKorany and Mohamed, (2008) reported potentials of the antioxidants Butylated Hydroxytoluene as non-fungicidal, being capable to control grey mould and to increase strawberry production, same, in accordance with Yuan, (2010) exhibit antibacterial and antifungal activities.

1,6-Anhydro-beta-D-glucopyranose, has shown to be an effective synthon for the synthesis of a variety of biologically essential and structurally diverse compounds, including rifamycin S, macrolide antibiotics, and modified sugars (Kavipriya & Chandran, 2018). According to Akbarizare, (2021); Amala & Jeyaraj, (2014); Al Bratty *et al.* (2020) ; Musa *et al.* (2015) and Wadkar *et al.* (2017) respectively, the compounds cyclopropyl carbinol and furancarboxaldehyde, 5-(hydroxymethyl); Cyclooctasiloxane, hexadecamethyl; Heptasiloxane, hexadecamethyl ; Oxirane, hexadecyl and 3-Butoxy-1,1,1,7,7,7-hexamethyl-3,5,5-tris(trimethylsiloxy) tetrasiloxane have antibacterial characteristics.

Cyclononasiloxane, octadecamethyl, however, show antifungal properties (Al Bratty *et al.*, 2020). Furthermore, according to Amal et al. (2010) and Rangel-Sánchez et al. (2014), compounds with anti-fungal activity, such as decanol, 2-hexyl, phenol-2,4-bis (1,1-dimethylethyl) (Figure 1), and thymol (Figure 6), have the ability to improve strawberry quality and inhibit Botrytis cinerea.

The sugar D-Allose prescribed to be an antisecretory and preservative (Amala & Jeyaraj, 2014). 1,2, 3-Benzentriol a compound has the nature of antioxidant, antiseptic, fungicide, insecticide (Amala & Jeyaraj, 2014). Cholesta-4,6-dien-3-ol, (3.beta) with a potential anti a Candida compound (Kaur *et al.*, 2022). Wide-ranging biological activities were demonstrated by 4-H-pyran-4-one, 5-hydroxy-2-(hydroxymethyl), including tyrosinase inhibition, free radical scavenging, metal ion chelation, and photodamage prevention (Rho *et al.*, 2007).

1,2-Benzenedicarboxylic acid, mono (2-ethylhexyl) ester a phthalate ester suggested to be a persistent organic pollutant and plastifiant (Gushit *et al.*, 2013). Soil often contains phthalate esters because plasticulture is so widespread. They can be absorbed and accumulated by food plants from the soil, endangering human health when consumed (Sun *et al.*, 2015). The presence of phthalates in the samples may have been caused by the application of plastic mulch to the soil to suppress weeds during strawberry cultivation; as a result, consuming fruits exposes individuals to these substances. Shi et al. (2019) showed that the regular use of plastic film mulching pollutes wheat grains and field soils growing in crop production systems that use plastic film mulching with phthalate esters. The absorption of phthalate esters by strawberry plants was also confirmed by Sun et al. (2015); however, since strawberries were harvested before they reached full maturity, the absorption into leaves and roots might have only been a reflection of the possibility of later accumulation into berries. Among the compounds found, 1,2,4-benzenetriol was present in nearly all samples from both seasons, and sample 2 from the second season contained the compound hydroquinone. Both of these compounds are pesticide metabolites. The plot where the strawberry was grown has been used for many years in agriculture so the farmers have been using the necessary pesticides. Hydrolysis of organophosphorous insecticides results in the accumulaton of certain substances in the soil such as p-nitrophenol, which United States Environmental Protection Agency has classified as a priority pollutant. Prior to planting strawberries, farmers informed us that insecticides were sprayed on the farm. Several bacterial species can use p-nitrophenol as a source of energy and carbon (Chauhan et al., 2000). Chauhan et al. (2000) claim that hydroquinone is formed as p-nitrophenol degradation proceeds. Also. According to Chauhan et al., (2000) p-nitrophenol degradation proceeds with the formation of hydroquinone. And Tin Leung et al. (1999) found that p-nitrophenol was transformed into 4-nitrocatechol and 4-nitrocatechol into 1,2,4-benzenetriol. The compound 1,2,4-benzenetriol has been shown to have adverse effects on human health (Kawanishi *et al.*, 1989). di-n-octyl phthalate was discovered among minor metabolites in our study (Figure 2), but Susilawati et al. (2016) determined that it was possible to identify it as a pesticide residue by analyzing organophosphate pesticide residues on strawberry (*Fragaria ananassa*) samples.

This research did not focus on the components usually studied, such as polyphenols, sugars, anthocyanins ...., etc. Instead, it addressed an important contribution, particularly the identification of components and metabolites resulting from the reaction to excessive pesticide use. The results obtained offered new information into the effects of use massive of pesticides on strawberry metabolites. It has demonstrated the presence of both health-promoting and health-harming compounds, Others altered by pesticides, as well as those not naturally present in strawberry fruits, this rstudy call for further research to determine the potential of strawberries as a beoactive agent and to reduce the use of pesticides that may have unfavorable effects on the nature of their constituents.

CONCLUSION

Gas chromatography coupled with a mass spectrometer was used to determine the presence of pesticide residues in strawberry fruits samples. The results show that the GC-MS analysis of strawberry fruit extract revealed various components and dangerous pollutants in both seasons, such as: 1,2,4-benzenetriol, Di-n-octyl phthalate, and hydroquinone; as well as the presence of plasticizer compound: 1,2-benzenedicarboxylic acid mono(2-ethylhexyl) ester and Hexanedioic acid, bis (2-ethylhexyl) ester. Based on these results, farmers are advised to reduce pesticide use and practice field farming rather than plastic farming in order to protect consumers from the resulting pollutants.

GRANT SUPPORT DETAILS

The present research did not receive any financial support.

CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

REFERENCES

Akbarizare, M. (2021). GC-MS Analysis and Antimicrobial Activity of an Iranian Traditional Medicinal Smoke (Anbarnasara). J Infect Dis Med Microbiol., 9(3), 148-155.

Al Bratty, M., Makeen, H.A., Alhazmi, H.A., Syame, S.M., Abdalla, A.N., Homeida, H.E., & Khalid, A. (2020). Phytochemical, Cytotoxic, and Antimicrobial Evaluation of the Fruits of Miswak Plant, Salvadora persica L. J. Chem., 1-11.

Al-Rubaye, A. F., Kaizal, A.F., & Hameed, I. H. (2017). Phytochemical screening of methanolic leaves extract of Malva sylvestris. International Journal of Pharmacognosy and Phytochemical Research., 9, 537-552.

Amal, S.A., El-Mogy, M.M., Aboul-Anean, H.E., & Alsanius, B.W. (2010). Improving strawberry fruit storability by edible coating as a carrier of thymol or calcium chloride. Journal of Horticultural Science & Ornamental Plants., 2, 88-97.

Amala, V. E., & Jeyaraj, M. (2014). Determination of antibacterial, antifungal, bioactive constituents of triphala by FT-IR and GC-MS analysis. Int J Pharm Pharm Sci, 6(8), 123-126.

Anttonen, M. J., Hoppula, K. I., Nestby, R., Verheul, M. J., & Karjalainen, R. O. (2006). Influence of fertilization, mulch color, early forcing, fruit order, planting date, shading, growing environment, and genotype on the contents of selected phenolics in strawberry (Fragaria× ananassa Duch.) fruits. J. Agric. Food Chem., 54(7), 2614-2620.

Battino, M., Giampieri, F., Cianciosi, D., Ansary, J., Chen, X., Zhang, D., Zhang, D., Gil, E & Forbes-Hernández, T. (2021). The roles of strawberry and honey phytochemicals on human health: A possible clue on the molecular mechanisms involved in the prevention of oxidative stress and inflammation. Phytomedicine., 86, 153170.

Bazgaou, A., Fatnassi, H., Bouharroud, R., Ezzaeri, K., Gourdo, L., Wifaya, A., Demrati ' H , Elame, F. Carreño-Ortega, A., Bekkaoui, A., Aharoune, A., & Bouirden, L. (2021). Effect of active solar heating system on microclimate, development, yield and fruit quality in greenhouse tomato production. Renew. Energy., 165, 237-250.

Beulah, G. G., Soris, P. T., & Mohan, V. R. (2018). GC-MS determination of bioactive compound of Dendrophthoe falcata (LF) Ettingsh: An epiphytic plant. Int. J. Health Sci. Res, 8, 261-269.

Charles R. W., Raymond J.H.T. (1991). The Pesticide manual: a world compendium, 9th ed, British Crop Protection Council, Farnham, Surrey, UK, pp. 212.

Chauhan, A., Chakraborti, A. K., & Jain, R. K. (2000). Plasmid-encoded degradation of p-nitrophenol and 4-nitrocatechol by Arthrobacter protophormiae. Biochem Biophys Res Commun, 270(3), 733-740.

Dabrowska, D., Kot-Wasik, A., & Namiesnik, J. (2004). The Importance of Degradation in the Fate of Selected Organic Compounds in the Environment. Part II. Photodegradation and Biodegradation. Pol. J. Environ. Stud., 13(6).

Dahlen, T., Hauck, T., Wein, M., & Schwab, W. (2001). 2, 5-Dimethyl-4-hydroxy-3 (2H)-furanone as a secondary metabolite from D-fructose-1, 6-diphosphate metabolism by Zygosaccharomyces rouxii. J. Biosci. Bioeng., 91(4), 352-358.

Dou, R., Sun, J., Deng, F., Wang, P., Zhou, H., Wei, Z., Chen, M., He, Z., Lai, M., Ye, T & Zhu, L. (2020). Contamination of pyrethroids and atrazine in greenhouse and open-field agricultural soils in China. Sci. Total Environ., 701, 134916.

Du, X., Plotto, A., Baldwin, E., & Rouseff, R. (2011). Evaluation of volatiles from two subtropical strawberry cultivars using GC–olfactometry, GC-MS odor activity values, and sensory analysis. J. Agric. Food Chem., 59(23), 12569-12577.

Duan, W., Peng, L., Zhang, H., Han, L., & Li, Y. (2021). Microbial biofertilizers increase fruit aroma content of *Fragaria×ananassa* by improving photosynthetic efficiency. Alex. Eng. J., 60(6), 5323-5330.

El-Korany, A.E. & Mohamed, R.A. (2008). The use of antioxidants to control grey mould and to enhance yield and quality of strawberry. Alex. j. Agri. Sci., 7, 1-38.

Elleuch, L., Shaaban, M., Smaoui, S., Mellouli, L., Karray-Rebai, I., Fourati-Ben Fguira, L., Khaled, A., Shaaban, Kh.A., & Laatsch, H. (2009). Bioactive Secondary Metabolites from a New Terrestrial Streptomyces sp. TN262. Appl Biochem Biotechnol., 162, 579–593.

Elumalai, P., Yi, X., Chen, Z., Rajasekar, A., de Paiva, T. C. B., Hassaan, M. A., Ying, G., & Huang, M. (2022). Detection of Neonicotinoids in agriculture soil and degradation of thiacloprid through photo degradation, biodegradation and photo-biodegradation. Environ. Pollut., 306, 119452.

Forney, C. F., Kalt, W., & Jordan, M. A. (2000). The composition of strawberry aroma is influenced by cultivar, maturity, and storage. HortScience, 35(6), 1022-1025.

Gill, H.K. and Garg, H. (2014). Pesticide: environmental impacts and management strategies. In Pesticides-toxic aspects, Editor Sonia Soloneski. National University of La Plata. 8. pp 187.

Gushit, J. S., Ekanem, E. O., Adamu, H. M., & Chindo, I. Y. (2013). Analysis of herbicide residues and organic priority pollutants in selected root and leafy vegetable crops in plateau state, Nigeria. J. Anal. Chem., 1(2), 23-28.

Hoda, S., Gupta, L., Shankar, J., Gupta, A. K., & Vijayaraghavan, P. (2020). cis-9-hexadecenal, a natural compound targeting cell wall organization, critical growth factor, and virulence of Aspergillus fumigatus. ACS omega., 5(17), 10077-10088.

Hussain, S.Z., Naseer, B., Qadri, T., Fatima, T., & Bhat, T.A. (2021). Strawberry *(F.×ananassa)*-Morphology, Taxonomy, Composition and Health Benefits. In: Fruits Grown in Highland Regions of the Himalayas. Springer, Cham.

Jasim, H., Hussein, A. O., Hameed, I. H., & Kareem, M. A. (2015). Characterization of alkaloid constitution and evaluation of antimicrobial activity of Solanum nigrum using gas chromatography mass spectrometry (GC-MS). J. Pharmacognosy Phytother., 7(4), 56-72.

Kafkas, E., & Kafkas, S. (2016, August). Identification of strawberry (*Fragaria* × *ananassa* 'Rubygem') volatiles using various SPME fibres by GC/MS. In VIII International Strawberry Symposium 1156 (pp. 689-694).

Kaur, B., Kumar, N., Chawla, S., Sharma, D., Korpole, S., Sharma, R., ... & Saxena, S. (2022). A comparative study of in-vitro and in-silico anti-candidal activity and GC–MS profiles of snow mountain garlic vs. normal garlic. J. Appl. Microbiol., 133(3), 1308-1321.

Kavipriya, K., & Chandran, M. (2018). FTIR and GCMS analysis of bioactive phytocompounds in methonalic leaf extract of *Cassia alata*. Biomed. Pharmacol. J., 11(1), 141-147.

Kawanishi, S., Inoue, S., Kawanishi, M. (1989). Human DNA damage induced by 1, 2, 4-benzenetriol, a benzene metabolite. Cancer research., 49, 164-168.

Kong, Q., Yan, W., Yue, L., Chen, Z., Wang, H., Qi, W., & He, X. (2017). Volatile compounds and odor traits of dry-cured ham (Prosciutto crudo) irradiated by electron beam and gamma rays. Radiat. Phys. Chem., 130, 265-272.

Lambert, Y., Demazeau, G., Largeteau, A., & Bouvier, J. M. (1999). Changes in aromatic volatile composition of strawberry after high pressure treatment. Food Chem., 67(1), 7-16.

Lee, S. F., Liang, Y. C., & Lin, J. K. (1995). Inhibition of 1, 2, 4-benzenetriol-generated active oxygen species and induction of phase II enzymes by green tea polyphenols. Chem Biol Interact., 98(3), 283-301.

Mahmood, I., Imadi, S.R.; Shazadi, K., Gul, A., & Hakeem, K.R. (2016). Effects of Pesticides on Environment. In Plant, Soil and Microbes, Hakeem, Springer, Cham., Print ISBN. pp. 253-269.

Oyedeji, A. B., Chinma, C. E., Green, E., & Adebo, O. A. (2021). Metabolite data of germinated Bambara groundnut flour and starch extracted with two different solvents. Data in Brief., 38, 107-288.

Oz, A. T., Baktemur, G., Kargi, S. P., & Kafkas, E. (2016). Volatile compounds of strawberry varieties. Chem. Nat. Compd., 52, 507-509.

Park, E. R., Lee, H. J., & Kim, K. S. (2000). Volatile flavor components in Bogyojosaeng and Suhong cultivars of strawberry (*Fragaria ananassa* Duch.). Prev Nutr Food Sci., 5(3), 119-125.

Pereira, S.I., Figueiredo, P.I., Barros, A.S., Dias, M.C., Santos, C., Duarte, I.F., & Gil, A.M. (2014). Changes in the metabolome of lettuce leaves due to exposure to mancozeb pesticide. Food Chemistry, 154, 291-298.

Peris-Felipo, F. J., Benavent-Gil, Y., & Hernández-Apaolaza, L. (2020). Silicon beneficial effects on yield, fruit quality and shelf-life of strawberries grown in different culture substrates under different iron status. Plant Physiol Biochem., 152, 23-31.

Pico, Y., Alfarhan, A. H., & Barcelo, D. (2020). How recent innovations in gas chromatography-mass spectrometry have improved pesticide residue determination: An alternative technique to be in your radar. TrAC, Trends Anal. Chem., 122, 115720.

Prasher, I. B., & Dhanda, R. K. (2017). GC-MS analysis of secondary metabolites of endophytic Nigrospora sphaerica isolated from Parthenium hysterophorus. Int J Pharm Sci Rev Res., 44(1), 217-223.

Qadir, A., Ali, A., Arif, M., Al-Rohaimi, A. H., Singh, S. P., Ahmad, U., Khalid, M. & Kumar, A. (2018). Solvent extraction and GC-MS analysis of sesame seeds for determination of bioactive antioxidant fatty acid/fatty oil components. Drug Research, 68(06), 344-348.

Rangel-Sánchez, G., Castro-Mercado, E., & García-Pineda, E. (2014). Avocado roots treated with salicylic acid produce phenol-2, 4-bis (1, 1-dimethylethyl), a compound with antifungal activity. J. Plant Physiol., 171(3-4), 189-198.

Rho, H. S., Baek, H. S., You, J. W., Kim, S. J., Lee, J. Y., Kim, D. H., & Chang, I. S. (2007). New 5-hydroxy-2-(hydroxymethyl)-4H-pyran-4-one derivative has both tyrosinase inhibitory and antioxidant properties. Bull. Korean Chem. Soc., 28(3), 471-473.

Rohloff, J. (2011). Impact of agricultural and environmental factors on strawberry *(Fragaria* × *ananassa* Duch.) aroma-A review. Eur. J. Plant Sci. Biotechnol, 5(1), 17-34.

Shi, M., Sun, Y., Wang, Z., He, G., Quan, H., & He, H. (2019). Plastic film mulching increased the accumulation and human health risks of phthalate esters in wheat grains. Environ. Pollut., 250, 1-7.

Shiomi, N., and Savitskaya, A. (Eds.). (2022). Current Topics in Functional Food. BoD–Books on Demand.

Simkova, K., Veberic, R., Grohar, M. C., Pelacci, M., Smrke, T., Ivancic, T., ... & Jakopic, J. (2024). Changes in the Aroma Profile and Phenolic Compound Contents of Different Strawberry Cultivars during Ripening. Plants., 13(10), 1419.

Stachniuk, A., Fornal, E. (2016). Liquid Chromatography-Mass Spectrometry in the Analysis of Pesticide Residues in Food. Food Anal. Methods., 9, 1654-1665.

Sun, J., Wu, X., & Gan, J. (2015). Uptake and metabolism of phthalate esters by edible plants. Environ. Sci. Technol., 49(14), 8471-8478.

Susilawati, N. P. A., Suprihatin, I. E., & Adhi, N. G. A. M. D. (2016). Analisi residu pestisida organofosfat pada buah stawberry (Fragaria ananassa Rosalinda) menggunakan kromatografi gas. AnalisI, 4(1).

Tin Leung, K., Campbell, S., Gan, Y.; White, D.C., Lee, H.; Trevors, J.T. (1999). The role of the Sphingomonas species UG30 pentachlorophenol-4-monooxygenase in p-nitrophenol degradation. FEMS Microbiol. Lett., 173, 247-253.

Tudi, M., Daniel Ruan, H., Wang, L., Lyu, J., Sadler, R., Connell, D., Cordia Chu., Chu C., & Phung, D. T. (2021). Agriculture development, pesticide application and its impact on the environment. Int. J. Environ. Res. Public Health., 18(3), 1112.

Vox, G., Loisi, R. V., Blanco, I., Mugnozza, G. S., & Schettini, E. (2016). Mapping of agriculture plastic waste. Agric Agric Sci Procedia., 8, 583-591.

Wadkar, S. S., Shete, C. C., Inamdar, F. R., Wadkar, S. S., Gurav, R. V., Patil, K. S., & Ghosh, J. S. (2017). Phytochemical screening and antibacterial activity of cryptocoryne spiralis var. spiralis and Cryptocoryne retrospiralis (Roxb) Kunth. Med Aromat Plants (Los Angels)., 6(289), 2167-0412.

Wang, Q., Shen, J., Zeng, B., & Wang, H. (2020). Identification and analysis of odor-active compounds from Choerospondias axillaris (Roxb.) Burtt et Hill with different moisture content levels and lacquer treatments. Sci. Rep., 10(1), 14856.

Wang, S. Y., & Lin, H. S. (2000). Antioxidant activity in fruits and leaves of blackberry, raspberry, and strawberry varies with cultivar and developmental stage. J. Agric. Food Chem., 48(2), 140-146.

Wedde, A. E. (2014). Metabolite Profiling of Commercially Important Strawberry (*Fragaria X Ananassa*) Cultivars Throughout Development (Doctoral dissertation, Washington State University).

Youn, K., Kim, J. Y., Yeo, H., Yun, E. Y., Hwang, J. S., & Jun, M. (2012). Fatty acid and volatile oil compositions of Allomyrina dichotoma larvae. Prev Nutr Food Sci., 17(4), 310.

Yuan, M. (2010). Analysis of butylated hydroxytoluene in food with headspace Trap-GC/MS. Food and Nutrition, 20.

Zamorska, I. (2022). Volatile Components of Strawberries. In *Recent Studies on Strawberries*. IntechOpen.

Zhan, X., Khan, R. A. A., Zhang, J., Chen, J., Yin, Y., Tang, Z., ... & Liu, T. (2023). Control of postharvest stem-end rot on mango by antifungal metabolites of Trichoderma pinnatum LS029-3. Sci. Hortic, 310, 111-696.

Zhang, J., Wang, X., Yu, O., Tang, J., Gu, X., Wan, X., & Fang, C. (2011). Metabolic profiling of strawberry (*Fragaria* ×*ananassa* Duch.) during fruit development and maturation. J. Exp. Bot., 62(3), 1103-1118.

Zhang, Q., & Ruan, J. (2016). Tea: Analysis and Tasting. Encyclopedia of Food and Health, 256–267.

Zhao, L., Huang, Y., Zhou, H., Adeleye, A. S., Wang, H., Ortiz, C., Ortiz, C., Mazer, S.J., & Keller, A. A. (2016). GC-TOF-MS based metabolomics and ICP-MS based metallomics of cucumber (*Cucumis sativus)* fruits reveal alteration of metabolites profile and biological pathway disruption induced by nano copper. Environ. Sci. Nano., 3(5), 1114-1123.

Zhou, Y., Zhao, W., Shang, F., & Zhang, D. (2020). Development of bioactive components from Chaenomeles sinensis leaves. Therm. Sci., 24(3 Part A), 1795-1802.