APPLICATION NOTE

Liquid Chromatography/ Mass Spectrometry

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Analysis of Pesticide Residues in Cannabis Regulated by Oregon State Using LC/MS/MS

Introduction

With the legalization of cannabis (marijuana) for medical and recreational applications ever increasing in more States in the US, the demand for clean and safe cannabis and related products has grown significantly. Like many other agricultural products, pesticides, antifungals, as well as performance enhancement reagents have been applied to cannabis to increase yields and reduce attacks from insects and mold. However, many of these chemicals and reagents may have harmful effects on humans, animals and the environment, especially to persons who grow or work with the products for a long time[1, 2]. In addition, when smoking plant materials such as tobacco and cannabis products, highly complex mixtures of compounds can be generated, many of which interact with the chemicals such as pesticides present in the initial product to form more toxic materials[3, 4]. It has been demonstrated that cannabis smoke contains significant amounts of pesticide residues when pesticides are initially present in the product[4]. Therefore, it is important to have a highly sensitive and selective testing method for the analyses of pesticides and other toxic chemicals such as mycotoxins to control the quality of the cannabis products and to evaluate the risk of human exposure. Although gas chromatography-mass spectrometry (GC-MS/MS) has been used for pesticide analysis in cannabis samples, it is not suitable for ionic and polar compounds, especially for compounds that are thermal labile in the GC injection port[5].

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Liquid chromatography-tandem mass spectrometry (LC/MS/MS) has become the method of choice for pesticide analysis due to its high selectivity and sensitivity as well as its suitability for a wide range of compounds in different sample matrices[6-12]. The state of Oregon has issued regulatory limits for 59 pesticide residues in both cannabis flower and concentrates, while other states have come up with their own lists of pesticide residues relating to medical marijuana and cannabis testing[13, 14, 15]. In this study, all 59 pesticides were spiked into cannabis flower samples and analyzed by coupling QuEChERS sample preparation with LC/MS/MS. All the 59 pesticides in Oregon's regulated list were detected using this methodology, with results well below the current action limits specified. Recoveries of pesticides from spiked cannabis flower extracts are shown to be between 70-120%.

Experimental

Hardware/Software

Chromatographic separation was conducted on a PerkinElmer UHPLC System, while detection was achieved using a PerkinElmer QSight™ 220 triple quadrupole mass spec detector with a dual ionization source. All instrument control, data acquisition and data processing was performed using Simplicity 3Q™ software.

Method

Sample Preparation

1 g of cannabis flower was hydrated with 5 mL of water, spiked with pesticide internal standards (and mixed pesticide standards for recovery study and matrix-match calibration standards) and followed by the addition of 5 mL of acetonitrile. To this mixture, QuEChERS salts (3 g of $MgSO_4$ and 0.75 g of sodium acetate) were added, vortexed for 30 min and centrifuged at 7000 rpm for five minutes. The supernatant was then analyzed directly or after further clean-up, using dispersive SPE (dSPE containing 150 mg $MgSO_4$, 50 mg PSA, and 50 mg C18). The samples (both with and without dSPE clean up) were then diluted five-fold in acetonitrile and injected.

LC Method and MS Source Conditions

The LC method and MS source parameters are shown in Table 1. The Multiple Reaction Monitoring mode (MRM) transitions are listed in Table 2.

Table 1. LC Method and MS Source Conditions.

LC Conditions	
LC Column	Restek Raptor ARC-18 (4.6 × 50 mm, 2.7 µm)
Mobile Phase A	2 mM ammonium formate + 0.1% formic acid (in water)
Mobile Phase B	2 mM ammonium formate + 0.1% formic acid (in methanol)
Mobile Phase Gradient	Start at 5% mobile phase B and hold it for one min, then increase B to 95% in 15 mins and keep at 95% B for 4 mins. Finally equilibrate the column at initial condition for 4 mins.
Column Oven Temperature	30 °C
Auto Sampler Temperature	18 °C
Injection Volume	3.0 µL
MS Source Conditions	
ESI Voltage (Positive)	5000 V
ESI Voltage (Negative)	-4000V
Drying Gas	120 arbitrary units
Nebulizer Gas	140 arbitrary units
Source Temperature	450 °C
HSID Temperature	290 °C
Detection Mode	Time-managed MRM™

Table 2. MRM transitions.

Compound Name	Polarity	Q1 Mass	Q2 Mass	CE	EV	CCL2
Chlorantranilprole	Positive	484	452.8	-20	25	-111
Chlorantranilprole-2	Positive	484	285.8	-18	25	-109
Imazalil	Positive	297.1	159.2	-31	25	-63
Imazalil-2	Positive	297.1	201	-25	25	-57
Paclobutrazole	Positive	294	70	-26	25	-40
Paclobutrazole-2	Positive	294	125	-48	25	-62
Spirotetramat	Positive	374.2	330.1	-21	25	-87
Spirotetramat-3	Positive	374.2	302.1	-23	25	-89
Clofentezine	Positive	303	138	-28	25	-56
Clofentezine-2	Positive	303	102	-50	25	-78
Fenoxycarb	Positive	302.2	88	-34	25	-52
Fenoxycarb-2	Positive	302.2	116	-15	25	-33
Spiroxamine-1	Positive	298.3	144.2	-11	25	-34
Spiroxamine-2	Positive	298.3	100.2	-50	25	-79
Azostrobin	Positive	404.1	372.1	-18	25	-92
Azostrobin-2	Positive	404.1	344.1	-34	25	-108
Boscalid	Positive	343	307	-25	25	-86
Boscalid-2	Positive	343	140	-28	25	-89
Malathion	Positive	331.1	99.1	-24	25	-44
Malathion-2	Positive	331.1	127.1	-22	25	-42
Metalaxyl	Positive	280.2	220.2	-18	25	-62
Metalaxyl-2	Positive	280.2	192.2	-24	25	-68

Table 2. MRM transitions *continued.*

Compound Name	Polarity	Q1 Mass	Q2 Mass	CE	EV	CCL2
Myclobutanil-1	Positive	289	70	-22	25	-36
Myclobutanil-2	Positive	289	125	-42	25	-56
Phosmet	Positive	318	160	-15	10	-60
Phosmet-2	Positive	318	76.9	-80	10	-88
Piperonyl butoxide	Positive	356.2	177	-13	25	-48
Piperonyl butoxide-2	Positive	356.2	119	-37	25	-72
Propiconazole	Positive	342.1	69.1	-26	25	-40
Propiconazole-2	Positive	342.1	159.1	-42	25	-56
Bifenzate	Positive	301.1	198	-16	25	-56
Bifenzate-2	Positive	301.1	170	-29	25	-69
Tebuconazole	Positive	308	70	-30	25	-44
Tebuconazole-2	Positive	308	125	-50	25	-64
Methyl parathion	Positive	264	124.9	-27	25	-52
Methyl parathion-2	Positive	264	231.9	-25	25	-50
Trifloxystrobin	Positive	409	186	-26	25	-63
Trifloxystrobin-2	Positive	409	206	-20	25	-57
Diazinon	Positive	305.1	169.2	-26	25	-60
Diazinon-2	Positive	305.1	97	-50	25	-84
Methiocarb	Positive	226.1	169.2	-14	25	-48
Methiocarb-1	Positive	226.1	121.1	-30	25	-64
Prallethrin	Positive	301.1	132.9	-17	10	-60
Prallethrin-2	Positive	301.1	168.9	-12	10	-64
Fipronil	Positive	436.8	254.9	-43	30	-132
Fipronil-2	Positive	436.8	368	-24	30	-104
Ethoprop	Positive	243.1	131	-28	16	-56
Ethoprop-2	Positive	243.1	173	-19	14	-48
Kresoxim-methyl	Positive	314	222	-20	10	-64
Kresoxim-methyl-2	Positive	314	235	-21	10	-72
Dibrom	Positive	379	127	-25	10	-64
Dibrom-2	Positive	379	109	-57	10	-64
Dibrom-3	Positive	381.1	127	-68	22	-80
Pyrethrin-II	Positive	373.1	160.9	-17	10	-72
Pyrethrin-II-2	Positive	373.1	133	-33	10	-44
Diazinon-d10	Positive	315	170.1	-33	10	-68
MGK-264	Positive	276.1	210.1	-17	10	-72
MGK-264-2	Positive	276.1	121.1	-28	13	-108
Chlorpyrifos-1	Positive	350	97	-32	25	-51
Chlorpyrifos-2	Positive	350	198	-32	25	-51
Hexathiazox-1	Positive	353	228	-22	25	-66
Hexathiazox-2	Positive	353	168	-34	25	-80
Acequinocyl-3	Positive	385.3	343.1	-15	10	-60
Acequinocyl-4	Positive	385.3	189.3	-38	10	-88
Spinosad -1	Positive	732.6	142	-42	25	-70
Spinosad -2	Positive	732.6	98.1	-100	25	-128
Atrazine-d5	Positive	221.1	179	-24	10	-60
Chlorafenpyr-1	Positive	409.2	271	-25	29	-100
Chlorafenpyr-2	Positive	409.2	379	-17	20	-100
Acephate-1	Positive	184.1	143	-12	25	-41
Acephate-2	Positive	184.1	125	-25	25	-54
Methomyl-1	Positive	163.1	88.1	-16	25	-34
Methomyl-2	Positive	163.1	106	-14	25	-32
Oxamyl-1	Positive	237.1	72.1	-40	25	-51
Oxamyl-2	Positive	237.1	90.1	-30	25	-44
Flunicamide-1	Positive	230.1	203.1	-20	25	-61
Flunicamide-2	Positive	230.1	174	-20	25	-61

Table 2. MRM transitions *continued.*

Compound Name	Polarity	Q1 Mass	Q2 Mass	CE	EV	CCL2
Diaminozide-1	Positive	161.1	143	-14	10	-40
Diaminozide-2	Positive	161.1	101	-21	10	-52
Thiamethoxam-1	Positive	292	211	-18	25	-60
Thiamethoxam-2	Positive	292	181	-28	25	-70
Dimethoate-d6	Positive	236	205	-12	10	-40
Imidachloprid-1	Positive	256.2	209	-18	25	-60
Imidachloprid-2	Positive	256.2	175.2	-26	25	-68
Acetomiprid-1	Positive	223.2	126	-30	25	-55
Acetomiprid-2	Positive	223.2	99.1	-56	25	-81
Aldicarb-1	Positive	115.9	89	-10	10	-28
Aldicarb-2	Positive	115.9	61	-15	10	-28
Dimethoate-1	Positive	230.1	125	-32	25	-57
Dimethoate-2	Positive	230.1	199	-12	25	-37
Thiachloprid-1	Positive	253.1	126	-26	25	-51
Thiachloprid-2	Positive	253.1	99.1	-60	25	-85
Carbaryl-1	Positive	202.1	145	-38	25	-67
Carbaryl-2	Positive	202.1	127	-42	25	-71
Carbofuran-1	Positive	222.2	165.2	-16	25	-49
Carbofuran-2	Positive	222.2	123.1	-28	25	-61
Propoxur-1	Positive	210.1	111	-20	25	-42
Propoxur-2	Positive	210.1	168.1	-10	25	-32
Dichlorvos-1	Positive	221	109.1	-22	25	-44
Dichlorvos-2	Positive	221	79	-38	25	-60
Dichlorvos-d6	Positive	227	115	-13	10	-44
Carbaryl-d7	Positive	209	151.9	-25	20	-56
Abamectin-1	Positive	895.5	305.1	-35	10	-250
Abamectin-2	Positive	895.5	449.2	-63	10	-250
Abamectin-3	Positive	895.5	327.3	-72	10	-250
Pyridaben-1	Positive	365	147	-36	25	-65
Pyridaben-2	Positive	365	309	-16	25	-45
Bifenthrin-1	Positive	440	181.1	-20	18	-88
Bifenthrin-2	Positive	440	166.1	-70	10	-88
Etofenprox-1	Positive	394.2	177.2	-17	10	-60
Etofenprox-2	Positive	394.2	107.2	-50	10	-100
Permethrin-1	Positive	408	183	-29	14	-84
Permethrin-2	Positive	408	355	-13	10	-60
Cypermethrin-1	Positive	433.2	91.1	-73	17	-88
Cypermethrin-2	Positive	433.2	191.1	-19	14	-68
Cyfluthrin	Positive	451.2	206	-70	10	-104
Cyfluthrin-2	Positive	451.2	434	-10	10	-48
Fenpyroximate-1	Positive	422	366.1	-20	25	-93
Fenpyroximate-2	Positive	422	135.1	-40	25	-113
Pyrethrin-I-1	Positive	329.1	160.9	-17	10	-68
Pyrethrin-I-2	Positive	329.1	132.9	-30	10	-68
Jasmolin-I-1	Positive	331	121	-29	12	-92
Jasmolin-I-2	Positive	331	122	-28	16	-88
Cinerin-I-1	Positive	317	108	-31	20	-128
Cinerin-I-2	Positive	317	150.3	-31	20	-140
Etoxazole-1	Positive	360.1	141	-24	25	-52
Etoxazole-2	Positive	360.1	57.2	-24	25	-52
Spiromesifen-1	Positive	273.1	187.1	-25	25	-76
Spiromesifen-2	Positive	273.1	255	-18	20	-76
Fludioxinil-1	Negative	246.6	125.9	46	-20	88
Fludioxinil-2	Negative	246.6	179.9	39	-20	100

Results and Discussion

Analytical Challenges for Testing Multi-residues of Pesticides from Cannabis Samples

Sample matrix effect remains the main concern for LC/MS/MS, especially for cannabis analysis due to the diversity and complexity of the cannabis samples. To overcome sample matrix effects, numerous tools have been widely applied to LC/MS/MS method development, such as sample dilution, use of stable isotope internal standards, sample matrix-matched standard calibration, standard addition method, sample clean-up, use of high efficiency UHPLC column for better separation, and the use of alternative ionization sources[16]. The most common sample matrix effect is discussed in details in the following section.

Since the pesticides tested in this study include both polar and non-polar compounds, 100% of acetonitrile was used, instead of an aqueous solution, to dissolve all the analytes from sample extracts and to further dilute sample extracts to minimize matrix effects. However, the reverse phase LC method used aqueous mobile phase at the beginning of LC run to help better retain the polar compounds on the column. Injecting an organic solvent such as an acetonitrile sample extract on the LC leads to poor chromatographic peaks for early eluting polar compounds. To overcome this problem, small sample injection volume was used in this study.

Sample Matrix Effect (Ion Suppression)

Sample matrix effect (ion suppression) was evaluated for the cannabis QuEChERS extract (not taken through dSPE), by spiking the same amount of pesticide standard and internal standard mix into the extract solutions that were diluted to different levels with acetonitrile. As shown in Figure 1, there was no significant ion suppression observed for compounds eluting before eight minutes. However, pesticides eluting after nine minutes showed significant ion suppression (~60%) in extract diluted two-fold with acetonitrile as demonstrated in Figures 2 and 3.

The extracts with a 10-fold dilution showed similar response to those of pesticides spiked in pure acetonitrile, suggesting that the dilution helps minimize the effects of ion suppression as shown in Figures 2-3. It is likely that the hydrophobic components, including the cannabinoids that elute in the latter portion of the reversed phase column, are contributing to the ion suppression of the pesticides. A five-fold dilution of the cannabis extract was used for analysis and for making matrix matched standards to minimize ion suppression from sample matrix without losing signal for the early eluting analytes (< eight min) that do not experience much ion suppression. Internal standards eluting at different retention times were used to further compensation for ion suppression of the analytes eluting in different regions of the chromatogram (Figure 4).

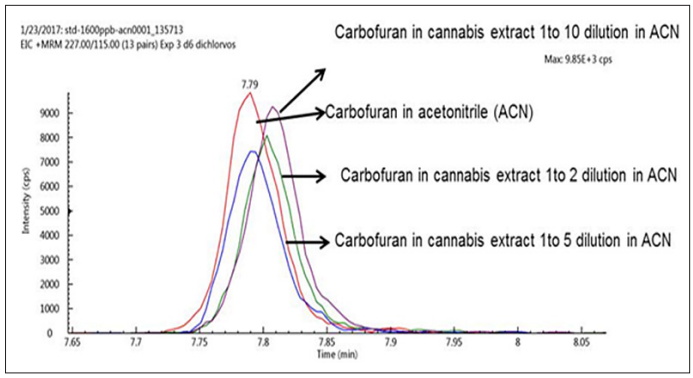

Figure 1. Chromatographic results of testing for ion suppression in ≤ eight min.

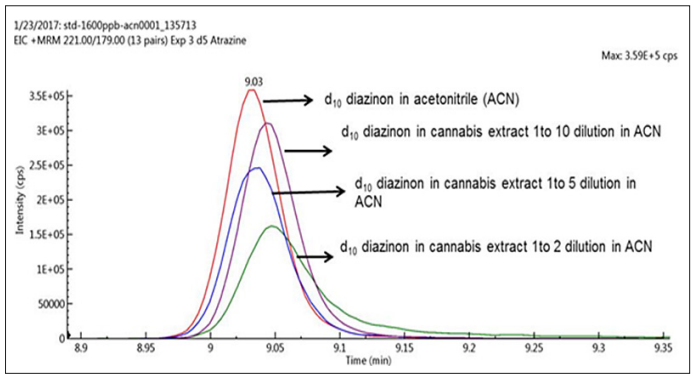

Figure 2. Chromatographic results of testing for ion suppression after nine min.

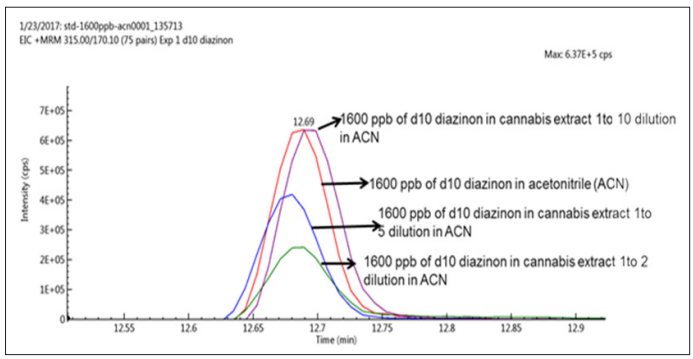

Figure 3. Chromatographic results of testing for ion suppression after 12 min.

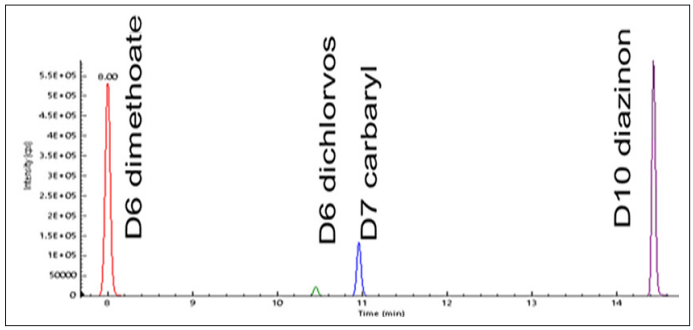

Figure 4. Internal standard chromatographic peaks at different retention times.

Sample Matrix-matched Calibration Standards

As illustrated in Figure 5 by the total ion chromatograms (TICs) of a cannabis flower extract (QuEChERS extract not taken through dSPE), spiked with and without pesticide standard mix (50 ng/g of cannabis), the majority of pesticides well below the regulatory limits set by the state of Oregon can be detected easily by this method. Some pesticides that are normally analyzed by GC-MS can also be analyzed by this LC/MS/MS method and examples of their representative matrix matched calibration curves are shown in Figure 6.

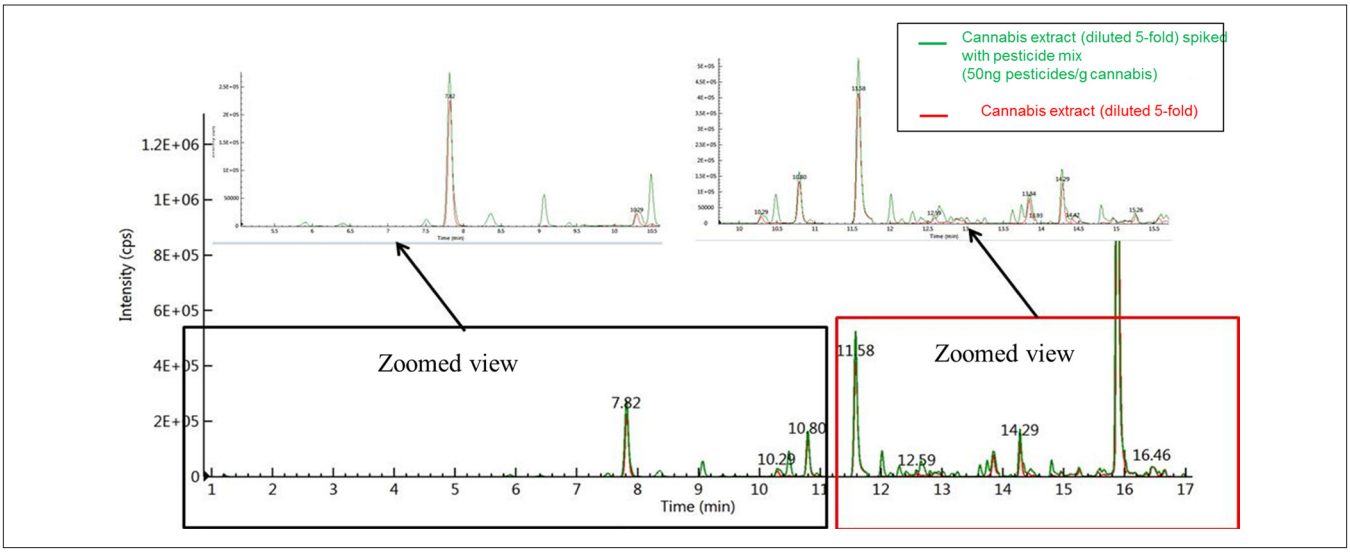

Figure 5. TIC overlays of cannabis flower extract with (green) and without (red) pesticide mix spike.

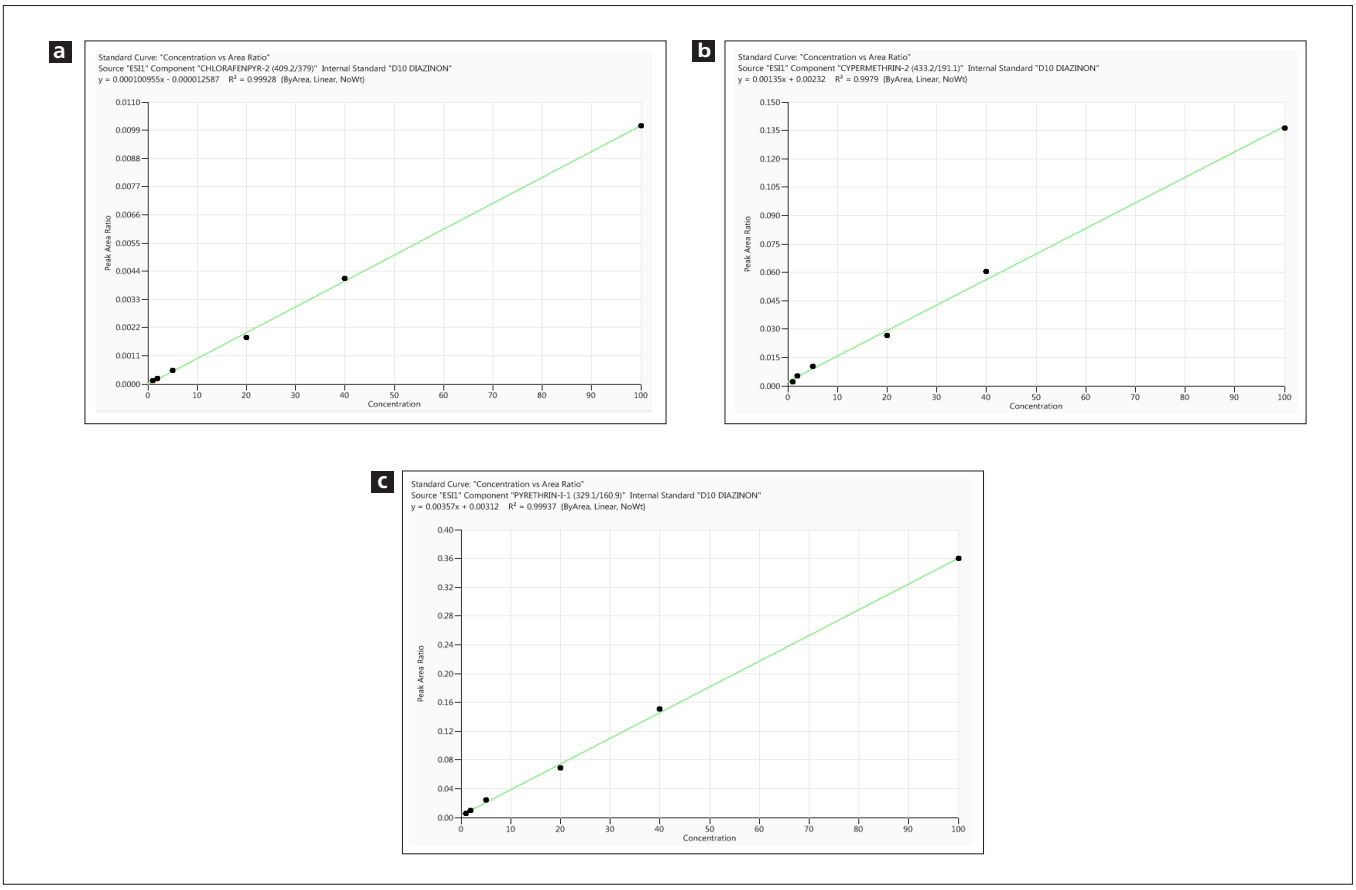

Figure 6. Examples of sample matrix matched calibration curves for (a) Chlorfenapyr, (b) Cypermethrin, and (c) Pyrethrin I.

Limit of Quantification (LOQ)

The limits of quantification (LOQs) were determined by taking into account both the signals of the quantifier and qualifier ions (S/N > 10 for both) and ensuring that the product ion ratios were within the 20% tolerance windows of the expected ratio[17]. As demonstrated in Table 3, the LOQs determined in this study are well below the Oregon Action Limit OR* (1.6 to 40.0 fold lower than OR*) for all the pesticides listed in Oregon regulation. The pesticides highlighted in Table 3 are normally analyzed by GC-MS/MS method.

Analyte Recovery (%)

As shown in Table 4, the recoveries for the majority of the pesticides taken through the QuEChERS extraction, with and without dSPE, are well above 70% (via triplicate analysis). There are no significant differences between the recoveries obtained with dSPE and without the additional dSPE cleaning up step.

Table 3. LOQs of Oregon regulated pesticides determined in this study (dry cannabis flowers based).

Analyte	CAS Registry Number	OR* (ppm)	LOQ (ppm)	Fold Lower Than OR*
Abamectin	71751-41-2	0.5	0.313	1.6
Acephate	30560-19-1	0.4	0.0975	4.1
Acequinocyl	57960-19-1	2.0	1.0	2.0
Acetamiprid	135410-20-7	0.2	0.025	8.0
Aldicarb	116-06-3	0.4	0.025	16.0
Azoxystrobin	131860-33-8	0.2	0.025	8.0
Bifenazate	149877-41-8	0.2	0.025	8.0
Bifenthrin	82657-04-3	0.2	0.025	8.0
Boscalid	188425-85-6	0.4	0.025	16.0
Carbaryl	63-25-2	0.2	0.0487	4.1
Carbofuran	1563-66-2	0.2	0.025	8.0
Chlorantraniliprole	500008-45-7	0.2	0.025	8.0
Chlorfenapyr	122453-73-0	1	0.39	2.6
Chlorpyrifos	2021-88-2	0.2	0.025	8.0
Clofentezine	74115-24-5	0.2	0.025	8.0
Cyfluthrin	68359-37-5	1	0.39	2.6
Cypermethrin	52315-07-8	1	0.39	2.6
Daminozide	1596-84-5	1	0.487	20.5
Diazinon	333-41-5	0.2	0.025	8.0
Dibrom (Naled)	300-76-5	0.5	0.0487	10.3
Dichlorvos (DDVP)	62-73-7	0.1	0.025	4.0
Dimethoate	60-51-5	0.2	0.025	8.0
Ethoprophos or Ethoprop	13194-48-4	0.2	0.0487	4.1
Etofenprox	80844-07-1	0.4	0.025	16.0
Etoxazole	153233-91-1	0.2	0.025	8.0
Fenoxycarb	72490-01-8	0.2	0.025	8.0
Fenpyroximate	134098-61-6	0.4	0.025	16.0
Fipronil	120068-37-3	0.4	0.025	16.0
Flonicamid	158062-67-0	1	0.025	40.0
Fludioxonil	131341-86-1	0.4	0.487	8.2
Hexythiazox	78587-05-0	1	0.025	40.0
Imazalil	35554-44-0	0.2	0.025	8.0
Imidacloprid	138261-41-3	0.4	0.025	16.0
Kresoxim-methyl	134390-89-0	0.4	0.025	16.0
Malathion	121-75-5	0.2	0.097	2.1
Metalaxyl	57837-19-1	0.2	0.025	8.0
Methiocarb	2032-65-7	0.2	0.0487	4.1
Methomyl	16752-77-5	0.4	0.097	4.1
Methyl Parathion	298-00-0	0.2	0.025	8.0
MGK-264	113-48-4	0.2	0.0487	4.1
Myclobutanil	88671-89-0	0.2	0.025	8.0
Oxamyl	23135-22-0	1	0.39	2.6
Paclobutrazol	76738-62-0	0.4	0.0487	8.2
Permethrin	52645-53-1	0.2	0.0487	4.1
Phosmet	732-11-6	0.2	0.025	8.0
Piperonyl Butoxide	51-03-6	2	0.0975	20.5
Prallethrin	23031-36-9	0.2	0.025	8.0
Propiconazole	60207-90-1	0.4	0.195	2.1
Propoxur	114-26-1	0.2	0.025	8.0
Pyrethrins-1	8003-34-7	1	0.195	5.1
Pyrethrins-2	8003-34-7		0.195	
Pyridaben	96489-71-3	0.2	0.025	8.0
Spinosad	168316-95-8	0.2	0.025	8.0
Spiromesifen	283594-90-1	0.2	0.025	8.0
Spirotetramat	203313-25-1	0.2	0.025	8.0
Spiroxamine	118134-30-8	0.4	0.025	16.0
Tebuconazole	80443-41-0	0.4	0.025	16.0
Thiacloprid	111988-49-9	0.2	0.025	8.0
Thiamethoxam	153719-23-4	0.2	0.025	8.0
Trifloxystrobin	141517-21-7	0.2	0.025	8.0

OR - Oregon Action Limits*

Table 4. Recoveries of pesticides in cannabis flower using QuEChERS extraction with (left) or without (right) dSPE.

Analyte	Amount Spiked (ppb)	% Recovery with dSPE	%RSD	% Recovery without dSPE	%RSD
Acetamiprid	16	100.0	7.8	87.0	6.8
Aldicarb	32	109.0	11.0	85.5	15.8
Azoxystrobin	16	98.9	6.3	94.1	3.9
Bifenazate	16	129.7	7.3	105	8.5
Bifenthrin	16	104.6	13.5	112.6	7.2
Boscalid	32	103.0	4.3	100.4	9.8
Carbaryl	16	107.0	20.1	101.0	6.9
Carbofuran	16	101.9	3.3	91.9	4.3
Chlorantraniliprole	16	100.0	1.8	90.9	9.0
Chlorpyrifos	16	112.9	10.6	95.3	26.8
Clofentezine	16	124.5	11.8	130.0	20.0
Cypermethrin	80	111.5	21.9	124.0	10.8
Diazinon	16	107.0	3.3	89.9	9.1
Dibrom (Naled)	40	74.5	6.0	79.1	10.7
Dichlorvos (DDVP)	80	105.0	2.7	99.9	4.9
Dimethoate	16	93.0	4.0	97.0	6.0
Ethoprophos or Ethoprop	16	102.5	3.5	107.0	2.7
Etofenprox	32	98.2	5.0	93.5	6.5
Etoxazole	16	88.6	1.3	81.9	13.9
Fenoxycarb	16	103.9	3.4	88.5	6.7
Fenpyroximate	32	76.2	12.9	72.6	6.4
Fipronil	32	108.1	15.0	93.1	11.0
Flonicamid	80	120.0	0.1	118.0	7.2
Fludioxonil	32	73.4	1.7	93.5	13.5
Hexythiazox	80	97.3	9.4	84.4	10.1
Imazalil	16	93.8	25.0	96.5	5.3
Imidacloprid	32	109.0	3.0	111.0	6.0
Kresoxim-methyl	32	105.3	8.3	99.2	9.1
Malathion	16	98.8	18.0	95.0	12.0
Metalaxyl	16	96.0	3.0	88.6	10.6
Methiocarb	16	99.0	12.0	112.0	8.7
Methyl parathion	16	99.9	12.0	101.3	19.9
Myclobutanil	16	106.7	7.9	91.7	10.8
Paclobutrazol	32	105.0	2.5	97.4	3.0
Phosmet	16	108.7	2.0	106.0	12.0
Piperonyl butoxide	160	106.0	3.6	94.3	12.0
Prallethrin	16	95.1	18.0	112.9	20.0
Propiconazole	32	96.5	16.0	84.3	20.0
Propoxur	16	109.6	9.4	119.6	26.7
Pyridaben	16	78.8	11.3	88.2	15.8
Pyrethrins-1	80	109.8	9.7	110.0	11.0
Pyrethrins-2	80	100.2	2.3	96.8	5.2
Spirotetramat	16	133.9	5.3	111.7	3.8
Spiroxamine	32	72.1	4.3	81.8	18.8
Tebuconazole	32	92.5	2.1	87.6	7.3
Thiacloprid	16	119.0	3.8	104.1	6.8
Thiamethoxam	16	128.0	0.4	129.0	0.1
Trifloxystrobin	16	111.5	6.1	101.7	3.2

Sample Results

For a set of randomly tested cannabis flower samples, the most commonly detected pesticide residues were piperonyl butoxide, bifenthrin, and propiconazole. Table 5 shows the results of some cannabis samples. The TIC chromatograms of sample E are illustrated in Figure 7a and the MRM chromatograms for the three detected pesticides are shown in Figure 7b.

Table 5. Pesticides detected from a set of cannabis samples destined for the commercial market.

Sample	Pesticides Detected
A	No pesticides detected
B	475 ppb propiconazole
C	No pesticides detected
D	No pesticides detected
E	1230 ppb cypermethrin, 147 ppb bifenazate, 5520 ppb bifenthrin
F	No pesticides detected
G	1624 ppb piperonyl butoxide
H	No pesticides detected
I	1210 ppb piperonyl butoxide
J	No pesticides detected

Conclusions

An LC/MS/MS method for multi-residue pesticides analysis in cannabis was developed by coupling a UHPLC system to a QSight 220 triple-quad mass spectrometer. This method can be applied to the determination of pesticides in cannabis flower extract with LOQs well below the limit set by the regulatory board in Oregon State.

The QuEChERS extraction method provides a simple routine sample preparation procedure. Although sample matrix effects (mainly ion suppressions) have been observed in this study, especially for the late eluting analytes, they can be drastically reduced with sample dilution (e.g. five to ten folds dilution) and use of internal standards and matrix-matched calibration standards. Due to the high sensitivity of the LC/MS/MS method, pesticides can be analyzed after dilution of the QuEChERS extracts. These results demonstrated this method's applicability and effectiveness in detecting and quantifying both LC and GC amenable pesticides in cannabis flower and similar samples.

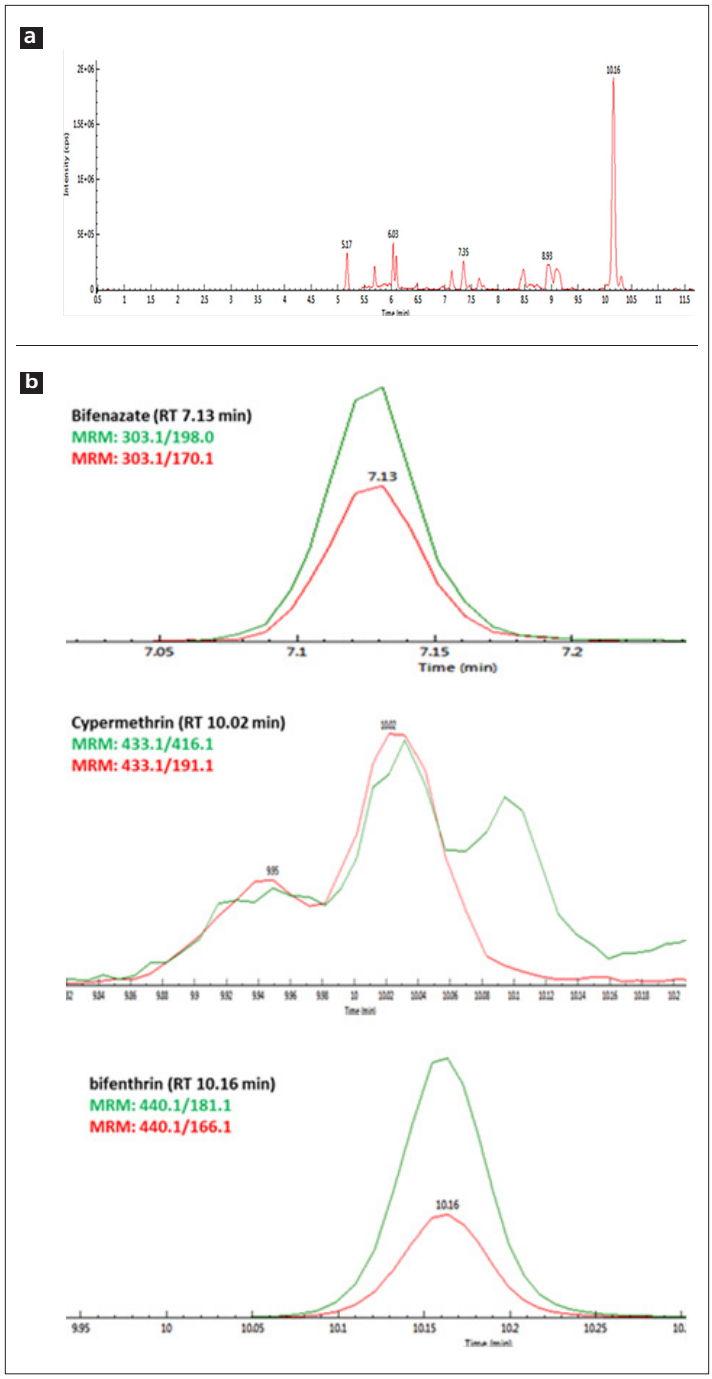

Figure 7. a) TIC Chromatograms for sample E. b) MRM chromatograms of the three pesticides found in sample E with two mass transitions.

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