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Analysis of Illicit and Legal Cannabis Products for a Suite of Chemical and Microbial Contaminants

A Comparative Study

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In 2018 recreational cannabis use was legalized in Canada with the objective to provide a legal framework for the production and sale of cannabis products. As a result, the Cannabis Act[1], Cannabis Regulations[2] and Health Canada's Good Production Practices for Cannabis[3] were established and formed the regulatory backbone of Canada's legal cannabis industry.

Canada's Cannabis Regulations facilitate standardization across the industry while promoting health, safety, consistency, and fairness. Every licensed cannabis producer in Canada must demonstrate compliance with the Cannabis Act, Cannabis Regulations and Health Canada's Good Production Practices.

Regulatory and quality frameworks not only serve to support health, safety and security for all stakeholders, but they also work together to manage risk. Regulations serve as an enabler, standardizing the industry with consistency, fairness, and transparency. Regulatory frameworks also support innovation, productivity, and competition. Moreover, regulations play a vital role in ensuring value for the consumer while also carrying economic benefits for the producer and supply chain.

It is important to address risk pertaining to products we inhale or ingest. Risk management addresses health and safety of consumers and production line workers by considering parameters such as microbial and chemical hazards, misuse of additives, product adulteration and spoilage. Preventative measures introduced by these frameworks benefit the supply chain, as unsuitable products can be identified and removed before additional costs of processing are incurred. Regulatory frameworks enable evidence-based decision-making for stakeholders and regulators. These frameworks also support research, innovation and marketability of the product, provide a sound foundation for trade, and enhance consumer confidence.

Two main cannabis supply chains exist in Canada since the legalization of recreational cannabis; an illicit supply and a legal supply. The illicit market existed in Canada pre-legalization; however, since legalization, the legal market has been gaining ground, with more people accessing cannabis through legal channels.

The legal industry is one in which all components of production and supply are compliant with regulations and policies. Legal entities are inspected and audited routinely by external parties, obtain necessary licenses for production and sale, employ quality management programs, and work in controlled/sterile environments when necessary. Additionally, legal entities implement routine quality assurance and quality control checks in their production/supply processes to ensure a high-quality, safe and consistent product is delivered to consumers. While legal entities bear additional overhead costs associated with regulatory compliance, it is understood by the industry that this is a necessary step toward fostering a safe and prosperous cannabis industry in Canada.

An illicit industry is one that does not comply with one or more policies described in Canada's legal cannabis framework. Storefronts selling cannabis products obtained from unknown sources, or, from known sources not traceable to licensed producers are considered part of the illicit industry.

Surprisingly, a significant proportion of cannabis users in Canada have yet to be influenced by safety and quality when purchasing products. According to Canadian Cannabis Survey results released in 2020, price was the predominant consideration when purchasing cannabis[4]. Moreover, the ability to purchase from a legal source was one of the least influential factors. When asked where recreational users obtained cannabis in the past 12 months, 6% reported obtaining cannabis from an illicit source. Furthermore, 8% of medicinal users reported purchasing cannabis from illicit online sources and 6% reported purchasing from an illicit storefront[4]. Consequently, illicit storefronts continue to be prevalent across the country, posing challenges for progression of the industry.

The number of Canadians consuming illicit cannabis warranted an investigation into whether these products are equivalent to legal products with respect to consistency, safety and quality. Our scientists investigated this via a series of experiments that included analysis of potency, microbial and metal contaminants, pesticides, foreign matter and uniformity of mass. Potency claim accuracies were also evaluated. Data from these experiments are presented herein.

EXPERIMENTAL

All sample analyses were conducted by qualified scientists at the New Brunswick Research and Productivity Council (RPC). RPC is a research and technology organization (RTO) that specializes in a vast array of services, including cannabis testing. RPC is a not-for-profit crown corporation and was established in 1962. The facility is an ISO 17025:2017[5] and ISO 9001:2015[6] accredited organization that holds both analytical testing[7] and cannabis research licenses[8] from Health Canada.

RPC has a rich history in providing cannabis analytical services to industry and was on the forefront of cannabis science well before medicinal or recreational legalization in Canada. The organization's cannabis journey began over 20 years ago via hemp analysis, with expansion of services to accommodate the medicinal sector in 2013 and again in 2018 to service the recreational sector.

RPC's quality system is core to the backbone of the organization, with internal and external audits conducted routinely and over 1100 proficiency tests completed each year. All experimental methods employed were validated and subject to our stringent quality policies.

The Government of New Brunswick states that the only legal source of cannabis in the province of New Brunswick is Cannabis NB[9]. For the purpose of this study, the term 'Illicit' refers to a cannabis product obtained from a storefront other than a legal supplier such as Cannabis NB.

Illicit samples were obtained from multiple storefronts across the province of New Brunswick by personnel legally authorized to obtain and submit illicit cannabis for analytical testing. A total of seven illicit flower types and six illicit edible types (multiple packets of each) were analyzed for potency and a suite of microbial and chemical contaminants. Similarly, a total of four legal flower types and five legal edible types (multiple packets of each) were analyzed for potency and the same suite of contaminants. Legal samples were obtained from Cannabis NB. All samples were stored and handled according to chain of custody protocols managed via a laboratory information management system (LIMS) and quality management system (QMS).

Each flower product submitted in its own package was considered a separate sample and assigned a unique identification. This was the case even if it was suspected that some products may be the same across various packages. For example, two illicit flower samples were submitted in separate packages but believed to be the same product. Lack of lot number and production details made it impossible to confirm whether these products were identical. As a result, the samples were assigned unique identifications and treated as distinct samples. Although packaging details were clearer for the legal flower products, the same approach was taken; a different package was considered a different sample. Edible products were treated in the same manner unless it could be confirmed with certainty via lot number and production details that they were the exact same product. In these cases, the products were given the same identifier across multiple packages. For the data presented, the same sample identifier is used for the same product. For example, "Illicit 1" in Table 1 is the same product as "Illicit 1" in Table 5.

Where possible, all tests were conducted in triplicate. As a result, hundreds of data points were obtained across a variety of test parameters, making this study one of the most comprehensive illicit versus legal studies publicly available. For clarity, description of the product tested, and number of replicates are described throughout.

RESULTS

POTENCY - CANNABIS FLOWER

Cannabinoid analyses were conducted via high performance liquid chromatography equipped with ultraviolet detectors (HPLC-UV). A total of six illicit flower samples and four legal flower samples were analyzed in triplicate. Average results for total THC/CBD and relative standard deviations (% RSD) from replicate measurements are provided in Table 1.

TABLE 1: AVERAGE THC AND CBD RESULTS FOR ILLICIT AND LEGAL CANNABIS FLOWER SAMPLES

Sample ID	Potency Claim (% THC / % CBD)	Average % THC / % RSD	Average % CBD	Accuracy in THC Claim (%) *
Illicit 1	30 / not listed	22 / 2.6	< 0.7	73
Illicit 2	30 / not listed	13 / 2.3	< 0.7	43
Illicit 3	32 / not listed	17 / 0.33	< 0.7	53
Illicit 4	30 / not listed	13 / 2.0	< 0.7	43
Illicit 5	30 / not listed	13 / 1.6	< 0.7	43
Illicit 6**	32 / not listed	18 / 3.3	< 0.7	56
Legal 1	17 / 0.53	16 / 0.62	< 0.7	94
Legal 2	17 / 0.53	15 / 2.6	< 0.7	88
Legal 3	17 / < 0.07	16 / 0.95	< 0.7	94
Legal 4	17 / < 0.07	17 / 1.9	< 0.7	100

** Claim accuracy calculated using mean THC value. CBD accuracy not calculated; all values were below reporting limit.*
***Average of duplicate results, insufficient sample volume for triplicates. Relative percent difference (RPD) reported opposed to % RSD.*

According to the regulations, legal cannabis flower products must have potency claims based on testing results, with certificates of analysis kept on-hand by licensed producers to support those claims.

The data in Table 1 shows that accuracy in THC claims for illicit flower products are low, ranging from 43% to 73%, where that of legal flower products were higher, ranging from 88% to 100%.

POTENCY - CANNABIS EDIBLES

Several edible sample types were analyzed for THC via HPLC-UV. Results are provided in Table 2.

TABLE 2: THC RESULTS FOR ILLICIT AND LEGAL CANNABIS EDIBLE SAMPLES

Sample ID	Description	THC Result (mg)	Average THC (mg) / % RSD	Potency Claim	Accuracy in Potency Claim (%)*
Illicit 7	5 gummies in one pack, each gummy tested once	Gummy 1: 5.80 Gummy 2: 4.56 Gummy 3: 8.20 Gummy 4: 8.48 Gummy 5: 4.71	6.35 / 30	Not determined, see note 1	-
Illicit 8	5 gummies in one pack, each gummy tested once	Gummy 1: 27.9 Gummy 2: 33.9 Gummy 3: 48.7 Gummy 4: 27.2 Gummy 5: 28.4	33.2 / 27	Not determined, see note 2	-
Illicit 9	1 chocolate chip cookie tested in triplicate	Rep 1: 121 Rep 2: 121 Rep 3: 125	122 / 1.9	500 mg	24
Illicit 10	1 chocolate chunk cookie tested in triplicate	Rep 1: 119 Rep 2: 114 Rep 3: 116	116 / 2.2	500 mg	23
Illicit 11	1 cereal bar tested in triplicate	Rep 1: 153 Rep 2: 151 Rep 3: 155	153 / 1.3	400 mg	38
Illicit 12	1 bar tested in triplicate	Rep 1: 134 Rep 2: 137 Rep 3: 134	135 / 1.3	400 mg	34
Legal 5	1 Gummy per pack, three packages tested**	Pack 1: 6.47 Pack 2: 6.42 Pack 3: 7.23	6.7 / 6.8	10 mg per gummy/ pack	67
Legal 6	4 gummies, in one pack, three packs tested Pack 1: Units analyzed individually Packs 2/3:Contents homogenized and tested for total THC**	Pack 1: Gummy 1: 2.15 Gummy 2: 2.19 Gummy 3: 2.07 Gummy 4: 1.95 Pack 2: 8.39 Pack 3: 8.87	Pack 1: 2.09 / 5.1 Packages 2/3: 8.63 / 3.9	2.5 mg per gummy, 10 mg total in pack	Individual Gummies: 84 Packages: 86
Legal 7	5 chocolates in one pack, all 5 tested once	Chocolate 1: 1.97 Chocolate 2: 1.95 Chocolate 3: 1.89 Chocolate 4: 1.90 Chocolate 5: 1.92	1.93 / 1.7	2 mg per chocolate	97
Legal 8	5 chocolates in one pack homogenized and tested once	9.09	NA	10 mg total in pack	91
Legal 9	5 chocolates in one pack homogenized and tested once	10.5	NA	10 mg total in pack	105

** Calculated as percent recovery using average value.*
*** Packets confirmed to be the exact same product via lot number and packaging details.*
Note 1: Package states "68 mg THC per serving" and "68 pieces per pack". Only five pieces in pack, label claim cannot be determined.
Note 2: Package states "About 1 serving per container, serving size 10 pieces, 500 mg THC". Only five gummies in pack, label claim cannot be determined.
NA: Not applicable

With respect to cannabis edibles, the regulations specify different tolerance limits based on the amount claimed to be in the product[2]. An edible cannabis product with a claimed potency between 2 mg and 5 mg of THC must be within 80% - 120% of the claimed amount. For products containing more than 5 mg of THC, the label must be within 85% - 115% of the claimed amount. As seen in Table 2, all illicit edible products would not meet this specification whereas only one legal product (Legal 5) would not meet specifications.

As indicated above, potency claims could not be evaluated for some illicit products due to lack of clarity on the label. For example, the label for Illicit 7 claimed to have 68 mg of THC per serving and 68 pieces per pack, however there were only five pieces in the pack. Moreover, the claim for Illicit 8 was ten pieces and a total of 500 mg THC in the pack, however there were only five pieces. For this reason, accuracy claims for Illicit 7 and Illicit 8 potency could not be determined given it was unclear what the claim was. As a result, accuracy of illicit edible potency claims were either indeterminate or ranged from 23% - 38%.

Accuracy of potency claims for legal products could all be calculated and ranged from 67% - 105%. Interestingly, legal 5, which was least accurate in potency claim (67%) had a package date over a year old by the time it was analyzed. For this reason, it may be beneficial to consider guidelines to address shelf- life/ stability testing of this type of product in the future.

It was also noted that Illicit edible packages were non-compliant with cannabis regulations[2]. They did not have a security feature, were colorful, contained illustrations of well-known cartoon characters and imitated popular brands of candy products. One of the intentions of regulated packaging is to reduce risk of underage Canadians' consumption of cannabis by making the product less enticing. The illicit product packages did not meet these expectations.

Illicit cookie and cereal bar products that claimed to contain high levels of THC contained only a fraction of what was claimed (Table 2, Illicit 9-12). Lack of production details meant it could not be ascertained whether these products originally contained the claimed THC and degraded, or whether the THC was never the amount claimed. Regardless of rationale for the discrepancy, consumers who purchase these products believe they contain these claimed levels of THC. This could prove to be problematic for a consumer who is determining their optimal dosage given they would be applying inaccurate information for this determination.

CONTENT UNIFORMITY AND FOREIGN MATTER

The data presented above (Table 2) also suggests that uniformity of units within the same package is more consistent for legal products compared to illicit products. For example, RSDs from measurements of multiple units in the same package were as high as 27% (Illicit 8) and 30% (Illicit 7) compared to 1.7% (Legal 7) and 5.1% (Legal 6).

Two packets of Illicit 7 were also analyzed for uniformity of mass according to European Pharmacopeia 2.9.40 (EP 2.9.40). Results of this analysis are provided in Table 3.

TABLE 3: UNIFORMITY OF MASS FOR ILLICIT 7

Gummy	Total Weight (mg)	% of Label Claim (4900 mg)
1	4261	87.0
2	4266	87.1
3	4211	85.9
4	3469	70.8
5	4274	87.2
6	3102	63.3
7	3782	77.2
8	3971	81.0
9	3878	79.1
10	4183	85.4
Average	**3940**	**80.4**

Standard deviation: 8.069, Reference value (M): 98.5, Acceptability Constant: 2.4, Acceptance Value: 37.5, Acceptance Criteria: ≤ 15

According to EP 2.9.40, Illicit 7 would not meet the required specifications for uniformity of mass. Moreover, according to an additional document entitled "Tolerance Limits for the Net Weight and Volume Declared on Cannabis Product Labeling"[10], this product would also fail the tolerance specifications with a result greater than 9%.

Illicit and legal flower samples were also tested for foreign matter according to United States Pharmacopeia (USP) 42 <561> specifications. For all samples tested, no foreign matter was detected with the exception of Illicit 5, which contained a 4-inch white/blonde hair as well as three small unidentifiable objects.

MICROBIAL CONTAMINANTS - CANNABIS FLOWER

All microbiological methods employed were validated culture plate methods. Cannabis flower samples were tested in triplicate for bile-tolerant gram-negative bacteria (BTGN), total bacteria, *E. coli, Pseudomonas aeruginosa, Staphylococcus aureus, Salmonella*, total yeasts and total moulds. All flower samples, whether illicit or legal, had no detection of *E. coli, Pseudomonas aeruginosa, Staphylococcus aureus* or *Salmonella*. Results for BTGN, total bacteria, total yeasts and total moulds are provided in Tables 4 - 7 respectively.

TABLE 4: BTGN FOR ILLICIT AND LEGAL FLOWER SAMPLES

Bile Tolerant Gram Negative (MPN/g)*			
Sample ID	**Rep 1**	**Rep 2**	**Rep 3**
Illicit 1	>100 - < 1000	>100 - <1000	<10
Illicit 2	>1000 - <10000	>10 - <100	>100 - <1000
Illicit 3	>100 - <1000	<10	>10 - <100
Illicit 4	>1000 - <10000	>10 - <100	>10000
Illicit 5	<10	>10 - <100	>10000
Illicit 6**	>1000 - <10000	>10 - <100	
Legal 1	<10	<10	<10
Legal 2	<10	<10	<10
Legal 3	<10	<10	<10
Legal 4	<10	<10	<10

** MPN/g: Most probable number per gram*
*** Sample analyzed in duplicate, insufficient sample volume for triplicates*

The Cannabis Regulations state that acceptance limits used for impurities of microbiological contaminants must be for the intended use of the product. As a result, there are a variety of tolerance limits depending on the intended use.

For cannabis flower intended for inhalation, Health Canada specifies that the limits in chapter 5.1.8 of the EP on herbal medicinal products for oral use are acceptable. Some licensed producers, however, are opting to use more stringent limits such as those specified in EP 5.1.4 or USP <IIII> for nonsterile products intended for inhalation use.

The acceptance criterion for BTGN specified in EP 5.1.8 (Table B) is 100 CFU/g, or comparably, 100 MPN/g. All illicit samples contained at least one replicate result that would not meet these specifications. In contrast, all legal sample replicates yielded BTGN results less than the test method reporting limit and would meet specifications.

TABLE 5: TOTAL BACTERIA RESULTS FOR ILLICIT AND LEGAL FLOWER SAMPLES

Total Bacteria (CFU/g)*			
Sample ID	**Rep 1**	**Rep 2**	**Rep 3**
Illicit 1	59000	30000	33000
Illicit 2	180000	100000	110000
Illicit 3	35	820	570
Illicit 4	1000000	65000	420000
Illicit 5	28000	72000	45000
Illicit 6**	300	840	
Legal 1	<10	<10	<10
Legal 2	<10	<10	<10
Legal 3	<10	<10	<10
Legal 4	<10	<10	<10

** Colony forming units per gram*
*** Sample analyzed in duplicate, insufficient sample volume for triplicates*

Section 5.1.8 of the EP (Table B) states the acceptance criterion for total bacteria is 50,000 CFU/g. The data in Table 5 shows that four of the six illicit flower samples would not meet this specification for at least one replicate. All replicates for legal samples yielded results less than the test method reporting limit and would meet specifications.

TABLE 6: TOTAL YEAST RESULTS FOR ILLICIT AND LEGAL FLOWER SAMPLES

Total Yeasts (CFU/g)*			
Sample ID	**Rep 1**	**Rep 2**	**Rep 3**
Illicit 1	800	<100	<100
Illicit 2	260000	160000	150000
Illicit 3	<10	55	10
Illicit 4	1300000	98000	580000
Illicit 5	31000	66000	46000
Illicit 6**	130	15	
Legal 1	<10	<10	<10
Legal 2	<10	<10	<10
Legal 3	<10	<10	<10
Legal 4	<10	<10	<10

** Colony forming units per gram*
*** Sample analyzed in duplicate, insufficient sample volume for triplicates*

The EP 5.1.8 (Table B) states that the acceptance criterion for total yeasts is 500 CFU/g. As the data shows, four of the six illicit samples would not meet this specification for at least one replicate. All replicates for legal samples contained total yeast values less than the test method reporting limit and would meet specifications.

TABLE 7: TOTAL MOULD RESULTS FOR ILLICIT AND LEGAL FLOWER SAMPLES

Total Moulds (CFU/g)*			
Sample ID	**Rep 1**	**Rep 2**	**Rep 3**
Illicit 1	430000	840000	520000
Illicit 2	25000	36000	29000
Illicit 3	300	180	390
Illicit 4	5500	4900	6500
Illicit 5	17000	32000	17000
Illicit 6**	490	230	
Legal 1	<10	<10	<10
Legal 2	<10	<10	<10
Legal 3	<10	<10	<10
Legal 4	<10	<10	<10

** Colony forming units per gram*
*** Sample analyzed in duplicate, insufficient sample volume for triplicates*

Section 5.1.8 of the EP (Table B) states that the acceptance criterion for total moulds is 500 CFU/g. Four of the six illicit samples tested would not meet this specification where all legal samples would.

MICROBIAL CONTAMINANTS - CANNABIS EDIBLES

The Cannabis Regulations state that edible cannabis products must not contain any substance that would cause it to be prohibited under the Food and Drugs Act. Specifically, the product must not:

1. Have in it or on it any poisonous or harmful substance
2. Be unfit for human consumption
3. Consist in whole or in part of any filthy, putrid, disgusting, rotten, decomposed or diseased animal or vegetable substance, or;
4. Be adulterated

Furthermore, the input cannabis used must be below the limits set out in one of the pharmacopoeias and be appropriate for an ingested product. In the case of the edibles reported below (Tables 8-10), the input cannabis was not tested as a part of this study given the edibles were received as final products. As a result, it cannot be determined whether the input product would have met regulatory specifications. Albeit, it was deemed beneficial to analyze the edible samples for microbial contaminants to shed light on whether these products contained any detectable microbes.

Cannabis edibles were analyzed in triplicate for total bacteria, *E. coli,* coliforms*, Enterobactericae, Staphylococcus aureus, Salmonella*, total yeasts and total moulds. For all edible products tested, whether illicit or legal, there was no detection of *E. coli,* coliforms*, Enterobactericae, Staphylococcus aureus,* or *Salmonella*. Results for total bacteria, total yeasts and total moulds in edible cannabis products are provided in Tables 8-10 respectively.

TABLE 8: TOTAL BACTERIA RESULTS FOR ILLICIT AND LEGAL EDIBLE SAMPLES

Total Bacteria (CFU/g)*			
Sample ID	**Rep 1**	**Rep 2**	**Rep 3**
Illicit 7	10	<10	<10
Illicit 8	<10	25	<10
Illicit 9	15	45	40
Illicit 11	220	<10	35
Illicit 12	<10	10	10
Legal 5	<10	<10	<10
Legal 6	<10	<10	<10
Legal 7	<10	<10	<10
Legal 9	<10	<10	<10
Legal 10	<10	<10	<10

** Colony forming units per gram*

TABLE 9: TOTAL YEAST RESULTS FOR ILLICIT AND LEGAL EDIBLE SAMPLES

Total Yeasts (CFU/g)*			
Sample ID	**Rep 1**	**Rep 2**	**Rep 3**
Illicit 7	<10	<10	<10
Illicit 8	<10	<10	<10
Illicit 9	<10	<10	<10
Illicit 11	<10	<10	<100
Illicit 12	<10	<10	<10
Legal 5	<10	<10	<10
Legal 6	<10	<10	<10
Legal 7	<10	<10	<10
Legal 9	<10	<10	<10
Legal 10	<10	<10	<10

** Colony forming units per gram*

TABLE 10: TOTAL MOULD RESULTS FOR ILLICIT AND LEGAL EDIBLE SAMPLES

Total Moulds (CFU/g)*			
Sample ID	**Rep 1**	**Rep 2**	**Rep 3**
Illicit 7	<10	<10	<10
Illicit 8	<10	<10	<10
Illicit 9	<10	<10	<10
Illicit 11	<10	10	10
Illicit 12	<10	<10	<10
Legal 5	<10	<10	<10
Legal 6	<10	<10	<10
Legal 7	<10	<10	<10
Legal 9	<10	<10	<10
Legal 10	<10	<10	<10

** Colony forming units per gram*

As seen in Tables 8 - 10, several microbial contaminants were detected in illicit edible samples whereas no microbial contaminants were detected in legal equivalents. Although speculative, a rationale for this may be that licensed producers operate in sterile, controlled environments deemed compliant with regulatory standards.

METAL CONTAMINANTS - CANNABIS FLOWER

Analyses of cadmium, arsenic and lead were conducted via inductively coupled plasma mass spectrometry (ICP-MS). Mercury was also analyzed via cold vapour atomic absorption spectrometry (CVAAS). For all samples tested, there was no detection of arsenic or mercury. Results for cadmium and lead detected in flower samples are provided in Tables 11 and 12 respectively. Similar results for edibles are provided in Tables 13 and 14.

TABLE 11: CADMIUM RESULTS FOR ILLICIT AND LEGAL FLOWER SAMPLES

Cadmium (µg/g)			
Sample ID	**Rep 1**	**Rep 2**	**Rep 3**
Illicit 1	0.091	0.094	0.092
Illicit 2	0.081	0.084	0.087
Illicit 3	0.050	0.054	0.050
Illicit 4	0.097	0.100	0.089
Illicit 5	0.082	0.084	0.083
Illicit 6*	0.061	0.071	
Illicit 13**	0.083		
Legal 1	0.004	0.003	0.004
Legal 2	0.006	0.005	0.006
Legal 3	0.005	0.005	0.005
Legal 4	0.004	0.004	0.005

** Insufficient sample volume for triplicate analysis*
***Sample was a pre-rolled cannabis cigarette analyzed once*

TABLE 12: LEAD RESULTS FOR ILLICIT AND LEGAL FLOWER SAMPLES

Lead (µg/g)			
Sample ID	**Rep 1**	**Rep 2**	**Rep 3**
Illicit 1	< 0.02	< 0.02	< 0.02
Illicit 2	0.03	0.27	0.03
Illicit 3	< 0.02	< 0.02	< 0.02
Illicit 4	0.03	0.02	0.02
Illicit 5	0.02	0.02	0.02
Illicit 6*	< 0.02	< 0.02	
Illicit 13**	0.13		
Legal 1	< 0.02	< 0.02	< 0.02
Legal 2	< 0.02	< 0.02	< 0.02
Legal 3	< 0.02	< 0.02	< 0.02
Legal 4	< 0.02	< 0.02	< 0.02

** Insufficient sample volume for triplicate analysis*
***Sample was a pre-rolled cannabis cigarette analyzed once*

TABLE 13: CADMIUM RESULTS FOR ILLICIT AND LEGAL EDIBLE SAMPLES

Cadmium (µg/g)			
Sample ID	**Rep 1**	**Rep 2**	**Rep 3**
Illicit 7	< 0.002	< 0.002	< 0.002
Illicit 8	< 0.002	< 0.002	< 0.002
Illicit 9	0.017	0.017	0.018
Illicit 11	0.005	0.005	0.004
Illicit 12	0.007	0.007	0.007
Legal 5	< 0.002	< 0.002	< 0.002
Legal 6	< 0.002	< 0.002	< 0.002
Legal 7*	0.070		
Legal 9*	0.041	0.041	

** Insufficient sample volume for triplicate analysis*

TABLE 14: LEAD RESULTS FOR ILLICIT AND LEGAL EDIBLE SAMPLES

Lead (µg/g)			
Sample ID	**Rep 1**	**Rep 2**	**Rep 3**
Illicit 7	< 0.02	< 0.02	< 0.02
Illicit 8	< 0.02	< 0.02	< 0.02
Illicit 9	< 0.02	< 0.02	< 0.02
Illicit 11	< 0.02	< 0.02	< 0.02
Illicit 12	< 0.02	< 0.02	< 0.02
Legal 5	0.03	0.02	0.02
Legal 6	< 0.02	< 0.02	0.02
Legal 7*	0.02		
Legal 9*	0.03	0.03	

** Insufficient sample volume for triplicate analysis*

For inhalable products with a maximum dose of 10 g/day, the acceptable limits (USP <232> and EP 5.20) are as follows: Cadmium: 0.3 µg/g, Arsenic: 0.2 µg/g, Mercury: 0.1 µg/g and Lead: 0.5 µg/g. For edible products, oral limits are as follows: Cadmium: 0.5 µg/g, Arsenic: 1.5 µg/g, Mercury: 3 µg/g and Lead: 0.5 µg/g.

All samples tested, whether illicit or legal, meet specifications for metal contaminants.

PESTICIDES - CANNABIS FLOWER

Illicit and legal cannabis flower samples were analyzed for the suite of 96 pesticides specified in Health Canada's Mandatory Cannabis Testing for Pesticide Active Ingredients list[11]. Pesticide analyses were conducted via a combination of liquid chromatography-tandem mass spectrometry (LC-MS/MS) and atmospheric pressure gas chromatography-tandem mass spectrometry (APGC-MS/MS).

There were no pesticides detected in any of the legal flower samples. All illicit flower samples had multiple pesticides detected from the suite of 96 investigated (Table 15).

TABLE 15: PESTICIDE RESULTS FOR ILLICIT FLOWER SAMPLES

Pesticide (mg/kg)	Illicit 1	Illicit 2	Illicit 3	Illicit 4	Illicit 5	Illicit 6
Daminozide		0.38 0.35 0.34		0.52 0.52 0.50	0.43 0.40 0.39	
Fenvalerate	0.01 <0.01 0.02					
Imidacloprid	<0.01 <0.01 0.01					
Myclobutanil		9.4 11 9.4	4.2 4.5 3.7	6.8 8.2 6.9	11 10 9.5	9.2 7.4
Paclobutrazol		6.7 6.8 6.9	0.19 0.19 0.19	4.0 4.3 4.9	10 9.9 7.3	0.46 0.47
Piperonyl butoxide		1.1 1.2 1.1		0.76 0.75 0.76	1.1 1.1 0.89	0.04 0.03
Pyrethrins		0.28 0.30 0.27	0.19 0.18 0.17	0.18 0.19 0.19	0.19 0.14 0.17	0.22 0.30
Spiromesifen			0.06 0.06 0.05			0.03 0.05

** Insufficient sample volume for triplicate analysis*

To meet the mandatory testing requirements for pesticides, license holders under the Cannabis Regulations must demonstrate that none of the unauthorized pesticide active ingredients[12] have been used to treat cannabis and that the cannabis is free from contamination.

All illicit flower samples tested would not meet these pesticide requirements.

CONCLUDING REMARKS

Considerable differences were observed in this study between illicit and legal cannabis products with respect to accuracy of label claims, consistency of product, and level of contaminants.

More specifically, the data resulting from this study provides evidence that:

1. Legal product packaging and labeling meets the Health Canada requirements whereas illicit products do not
2. Legal products are free of contaminants such as microbials and pesticides where illicit products are not
3. Legal products are traceable to batch and source whereas illicit products are not
4. Legal product potency claims are more accurate than that of illicit products

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