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Author(s): Carl E. Wolf

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Final Report

Agency: National Institute of Justice

Federal Award number: 2017-R2-CX-0029

Project Title: Development of Matrix Matched Quality Control Materials and Sample Preparation Techniques for the Analysis of Marijuana Infused Products and their Application to Edible Testing.

PI: Carl E. Wolf
Assistant Professor
carl.wolf@vcuhealth.org
Box 980165, Richmond, VA 23298-0165
804-828-4420

Recipient Organization: Virginia Commonwealth University
Box 980568, Richmond, VA 23298-0568

Award Period: 01/01/2018 to 12/31/2019

Award Amount: \$215,830.00

Summary of the project

◦ Major goals and objectives

Aim 1: Develop and optimize sample preparation technique for the analysis of cannabinoids in edible matrices (brownies, chocolate, and gummies) using a previously optimized Ultrahigh Pressure Liquid Chromatography System with Tandem Mass Spectrometer detector (UPLC-MS/MS), following Scientific Working Group for Forensic Toxicology (SWGTOX) standard practices for method validation in forensic toxicology guidelines

Aim 2: Develop Quality Control materials for 3 common edible matrices to determine cannabinoid stability in these materials.

Aim 3: Determine cannabinoid stability in Quality Controls materials under various storage and time conditions.

◦ Research questions

1. Is there a sample preparation technique that can be used for the analysis of cannabinoids in edible matrices (brownies, chocolate, and gummies)?
2. What is the optimal storage condition for cannabinoid infused edibles and how long are the cannabinoids stable?
3. What is the optimal storage condition for cannabinoid acid infused edibles and how long are the cannabinoid acids stable?
4. Is there a sample preparation technique that can be used for the analysis of cannabinoids in edible matrices (brownies, chocolate, and gummies)?

◦ Research design, methods, analytical and data analysis techniques

1. Evaluate sample preparation techniques to determine their ability to reduce ion enhancement/suppression matrix effect, increase absolute recovery, and overall process efficiency of the cannabinoids from the edible and beverage matrices using SWGTOX guidelines. Then using the optimum method to validate quantitation of the cannabinoids in the matrices using a previously published method for the analysis of cannabinoids.

Sample preparation techniques included liquid-liquid, supported-liquid, solid phase, filtration, and hybrid extraction methods. Ultimately, over 25 sample preparation

techniques were evaluated for edible matrices before the sample preparation technique was validated. Over 40 sample preparation techniques were evaluated for beverage matrices before the sample preparation technique was validated.

Ideal extraction technique would have a ME ~ 0%, RE ~100%, and PE ~100%. Acceptable results would be within 15% across the 3 matrices of each edible or beverage.

2. Evaluate stability of cannabinoids in matrix, storage temperature and storage time, to determine optimal storage temperature and storage time for each matrix.

Four storage temperatures were evaluated (room temperature, refrigerator (5 °C), freezer (-15 °C), and ultra-freezer (-80 °C). Storage time was evaluated at 9 different time points (1 day, 1 & 2 weeks, 1, 2, 3, 6, 9 and 12-months) in at each temperature.

◦ **Expected applicability of the research**

The legalization of marijuana in the United States for both medicinal and recreational use has increased in the past few years. Marijuana is classified as a Schedule 1 substance by the US Drug Enforcement Administration. Federally, the US Food and Drug Administration (FDA) does not regulate nor enforce manufacturing restrictions on formulations of THC as Marinol® and cannabidiol (CBD) as Epidiolex®, which have limited approved therapeutic uses. In 2018, the Agriculture Improvement Act (Farm Bill) legalized hemp. However, this legislation and the approved pharmaceutical preparations do not address the formulation of beverages, nor do they address the standardization of methods for potency analysis of cannabinoids in edibles and beverages.

Forensic laboratories are receiving an ever-increasing workload of cannabinoid products for analysis. The analysis of these products may come into question, as there are limited published methods for analysis, and no known publications of storage and stability of cannabinoids in various edible and beverage matrices.

This research is very relevant to the current status of marijuana in the United States and the world, as it will attempt to provide valuable techniques and information.

PARTICIPANTS

Participants and other collaborating organizations

The following individuals were involved in the project.

Carl E. Wolf – Principle Investigator
Justin L. Poklis – Co-Investigator
Kathryn Orton – Student Analyst
Heidi Brightman – Student Analyst
Casey M. Spencer – Student Analyst
Jean A. Heneks – Student Analyst
Rachael B. Fielden – Statistician

No other organizations have been involved as partners.

Other individual collaborators or contacts involved.

Rhea Ramnarine
Hubert H. Humphrey Fellow
Scientific Officer I
Trinidad and Tobago Forensic Science Centre
Port of Spain, Trinidad & Tobago

CHANGES/PROBLEMS

1) Changes in approach and reasons for change

Restarted Aim 3 due to inconsistencies in results obtained from matrices analysis.

2) Actual or anticipated problems or delays and actions or plans to resolve them

Restarting of Aim 3 due to inconsistencies in results has resulted in the need to extend the end date for the project, but this will not incur any additional cost or expenditures.

3) Changes that have a significant impact on expenditures

None

4) Change of Scope or Project Period Extension GANs submitted

An addition to the project scope that is very relevant to current trend in cannabinoids was submitted. The addition was not that different from the current project, without the necessity of additional funding. The addition was to determine appropriate methods for the determination of cannabinoids in beverages.

Since Aim 3 had to be restarted due to homogeneity issues, a no additional cost extension to the project was granted until June 30, 2020.

4. Outcomes

Accomplishment of goals.

Aim 1: Method validation was completed in September 2018.

Aim 2: The Cannabinoid Quality Control materials were prepared in September 2018 and then again in January 2019 because of some initial homogeneity and stability issues. The Degradation Quality Control materials to evaluate degradation of the carboxylic acid forms of CBD and THC were prepared in March 2019. This will allow us to follow their potential degradation at each temperature point for up to one year.

Aim 3. The Cannabinoid Quality Control matrices were analyzed at 1 day, 1 & 2 weeks, 1, 2, 3, 6, 9 and 12-month storage temperatures. The Degradation Quality Control matrices were analyzed at 1 day, 1 & 2 weeks, 1, 2, 3, 6, 9 and 12-month storage temperatures in September and December 2019, respectively. The observed results were more consistent as previously observed from the pilot projects and the results within each matrix were more consistent.

Results and findings

The optimum medible sample preparation technique involved a modification of Phenomenex's roQ QuEChERS extraction technique.

Phenomenex roQ QuEChERS Extraction

- 25 mg sample
- Cannabinoid mix
- 1.5 mL H₂O
- 1.5 mL Acetonitrile
- Equilibrate 1 hr.
- 20 mcL ISTD (10 mcg/mL, THC-d₃, CBD-d₃)
- Vortex
- 0.65 g roQ salt
- Shake 0.5 min. at 5.3 m/s in BeadRuptor
- Centrifuge 5 min. @ 5000 g
- Transfer 1 mL ACN layer to roQ dSPE tube
- Vortex 1 min.
- Centrifuge 5 min.
- Transfer supernatant to glass insert autosampler plate for analysis.

The optimum beverage sample preparation technique was developed using United Chemical Technologies' (UCT) Clean Screen FAST[®] THC Extraction column.

UCT Clean Screen FAST[®] THC Extraction

- 250 mcL Diluted Sample
 - (25 mcL Beverage + 225 mcL of Water)
- 20 mcL ISTD (10 mcg/mL, THC-d₃, CBD-d₃)
- 250 mcL Acetonitrile
- Vortex
- Centrifuge if necessary
- Add to UCT Clean Screen FAST[®] THC column
- Apply pressure (80 psi)
- Collect eluate
- Transfer supernatant to glass insert autosampler plate for analysis.

Matrix Effect, recovery, and process efficiency of techniques – See Appendix A

Stability at storage temperatures and time points – See Appendix B

Generally, medibles were more stable when stored at room temperature or the refrigerator (5 °C), and were less stable when stored in the freezer (-15 °C), or ultra-freezer (-80 °C). Storage time stability ranged from 6 – 12 months, depending on the storage temperature.

5. Artifacts

List of products

1. Ramnarine RS, Poklis JL, Wolf CE. Determination of Cannabinoids in Breast Milk using QuEChERS and Ultra-Performance Liquid Chromatography and Tandem Mass Spectrometry (UPLC-MSMS). J Anal. Toxicol. 10.1093/jat/bkz072.
2. Wolf CE. Just Science Podcast: Just Analyzing Beverages for Cannabinoids. Forensic Technology, Center of Excellence, February 2020, <https://forensiccoe.org/2020-nij-rd-e3/>

Dissemination activities

1. Bishop-Fielden, R., Brownies, Gummies, and Chocolates Oh My: A Conversation about Medical Marijuana Edibles (“Medibles”), VCU Pathology Grand Rounds, Richmond, VA. June 2018.
2. Spencer CM, Orton KL, Heneks, JA, Poklis JL, Wolf CE, Getting Fat Out of Fat: The Extraction of Cannabinoids from Chocolate, SOFT Meeting, Minneapolis, MN. October 2018.
3. Orton KL, Spencer CM, Heneks JA, Fielden RB, Poklis JL, Wolf CE. Medible Testing: Preparation of Matrix-Matched Calibrators and Controls for Forensic Analysis. American Academy of Forensic Sciences’ 7th Annual Scientific Meeting, Baltimore MD, Feb 2019.
4. Ramnarine RS, Poklis JL, Wolf CE. Evaluation of Extraction Methods for the Determination of Cannabinoids in Breast Milk. 2019 NIDA International Forum, San Antonio, Texas. June 2019.
5. Webinar, Emerging Research in Toxicology & Drugs. Center for Forensic Sciences, Forensic Technology Center of Excellence. RTI International April 2019
6. Wolf, CE. Marijuana infused edible (medible) testing:” Chewzing” your technique. 2019 Triangle Chromatography Spring Symposium. Durham, North Carolina. May 2019.
7. Wolf CE. Webinar, Development of matrix matched quality control materials and sample preparation techniques for the analysis of marijuana infused products. Emerging Research in Toxicology & Drugs. Center for Forensic Sciences, Forensic Technology Center of Excellence. RTI International, April 2019.
8. Orton KL, Spencer CM, Heneks JA, Fielden RB, Poklis JL, Wolf CE. Medible Testing: Preparation of Matrix-Matched Calibrators and Controls for Forensic Analysis. American Academy of Forensic Sciences’ 7th Annual Scientific Meeting, Baltimore MD, Feb 2019.

9. Wolf, CE. The Highs & Lows of Marijuana Infused Edible (Medible) Testing: Whole New Matrices. Virginia Department of Forensic Science, Richmond, Virginia, July 2019.
10. Orton KL, Spencer CM, Vest (Heneks) JA, Fielden RB, Poklis JL, Wolf CE. Havoc in the Kitchen: Making to do some Baking, the Preparation of Matrix-Matched Cannabinoid Calibrators and Controls SOFT Meeting, San Antonio, TX, October 2019.
11. Wolf CE, Brightman HL, Poklis JL, Korzun WJ. Forty plus ways not to analyze beverages for cannabinoids, National Institute of Justice, Forensic Science Research and Development Symposium, American Academy of Forensic Sciences' 72th Annual Scientific Meeting, Anaheim, CA, February 2020.
12. Wolf CE, Orton KL, Spencer CM, Vest (Heneks) JA, Fielden RB, Poklis JL. Evaluation of 25+ techniques for the determination of cannabinoids in marijuana infused edibles. National Institute of Justice, Forensic Science Research and Development Symposium, Pittsburg Conference (Pittcon), Chicago, IL, March 2020.
13. Wolf CE. Cannabinoids in Foodstuffs. Ohio Department of Public Safety. Skype Meeting. July 2020.
14. Brightman HL, Poklis JL, Korzun WJ, Wolf CE. Evaluation of multiple methods for the analysis of cannabinoid infused beverages. SOFTember, Society of Forensic Toxicologists Inc. Virtual Meeting, September 2020.

Appendix

Appendix A. Matrix Effect (ME), Recovery (RE), and Process Efficiency (PE) of techniques

1. Medibles

Brownies	CBD-d3	CBD	THC-d3	THC
ME	8.2	16.9	5.1	18.6
RE	98.7	81.6	96.1	83.8
PE	106.8	95.3	101.0	99.4
Gummies	CBD-d3	CBD	THC-d3	THC
ME	28.8	-4.1	-11.0	-0.6
RE	72.9	90.5	111.4	90.4
PE	93.8	86.8	99.2	89.8
Chocolate	CBD-d3	CBD	THC-d3	THC
ME	58.6	31.8	35.6	34.0
RE	69.3	79.0	78.0	73.3
PE	110.0	104.1	105.7	98.2

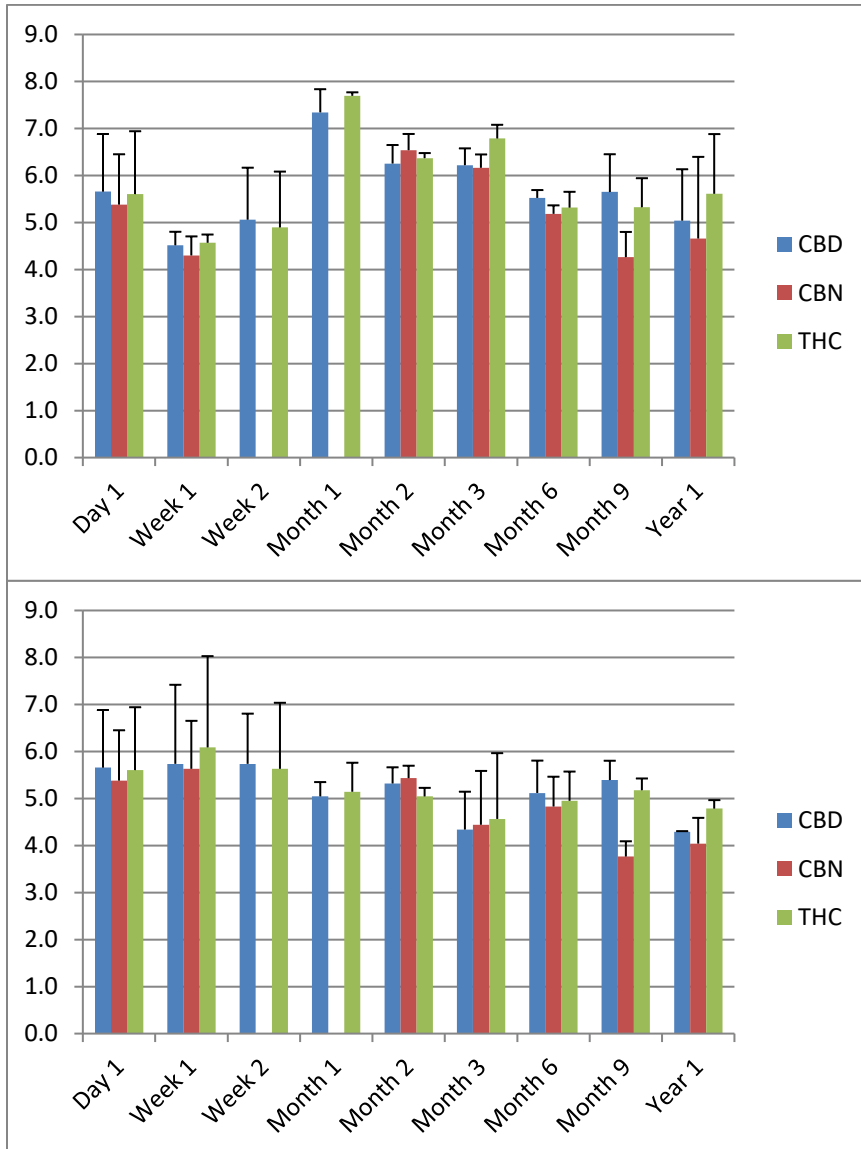
2. Beverages, Overall PE was evaluated in order to equally compare all techniques.

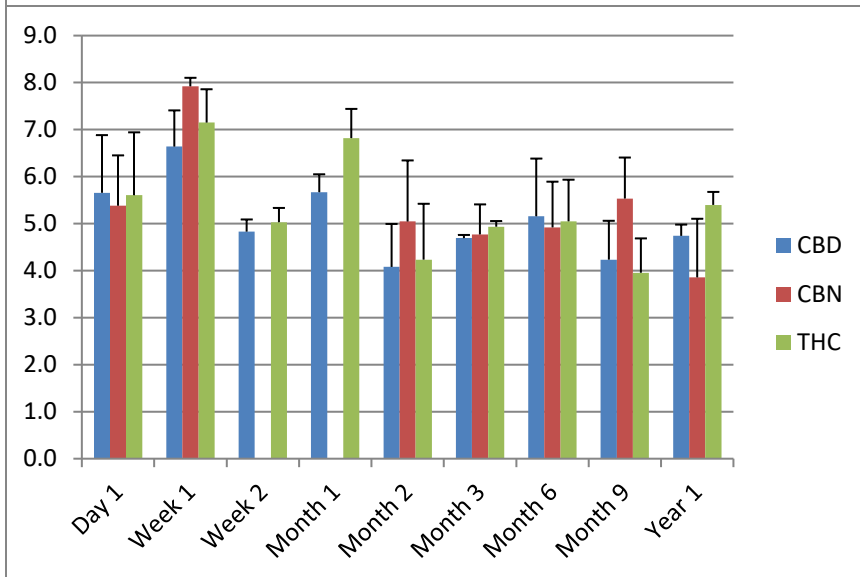
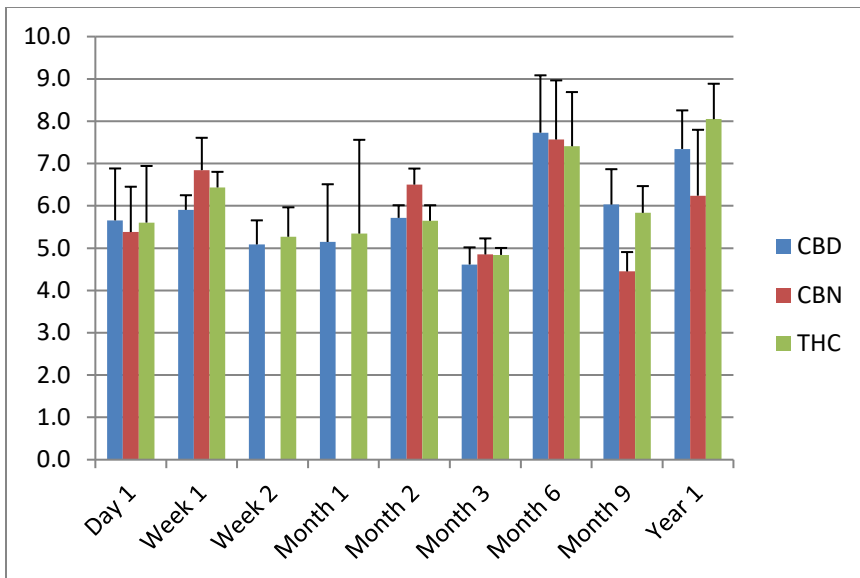
PE	UCT Clean Screen FAST[®] THC		
	Fermented	Brewed	Sugar
CBD	65	65	71
CBN	50	56	67
THC	40	45	54

Appendix B. Medible Storage Temperature and Time Point Results

1. THC, CBD & CBN Stability in Brownies

5 mg Quality Control





5 mg/ Brownie			
Room Temp	CBD	CBN	THC
Day 1	5.7	5.4	5.6
Week 1	4.5	4.3	4.6
Week 2	5.1		4.9
Month 1	7.3		7.7
Month 2	6.3	6.5	6.4
Month 3	6.2	6.2	6.8
Month 6	5.5	5.2	5.3
Month 9	5.6	4.3	5.3
1 Year	5.0	4.7	5.6

5 mg/ Brownie			
5 °C	CBD	CBN	THC
Day 1	5.7	5.4	5.6
Week 1	5.7	5.6	6.1
Week 2	5.7		5.6
Month 1	5.0		5.1
Month 2	5.3	5.4	5.0
Month 3	4.3	4.4	4.6
Month 6	5.1	4.8	5.0
Month 9	5.4	3.8	5.2
1 Year	4.3	4.0	4.8

5 mg/ Brownie			
(-)15°C	CBD	CBN	THC
Day 1	5.7	5.4	5.6
Week 1	5.9	6.8	6.4
Week 2	5.1		5.3
Month 1	5.1		5.3
Month 2	5.7	6.5	5.6
Month 3	4.6	4.9	4.8
Month 6	7.7	7.6	7.4
Month 9	6.0	4.4	5.8
1 Year	7.3	6.2	8.0

5 mg/ Brownie			
(-)70°C	CBD	CBN	THC
Day 1	5.7	5.4	5.6
Week 1	6.6	7.9	7.2
Week 2	4.8		5.0
Month 1	5.7		6.8
Month 2	4.1	5.0	4.2
Month 3	4.7	4.8	4.9
Month 6	5.2	4.9	5.1
Month 9	4.2	5.5	4.0
1 Year	4.7	3.9	5.4

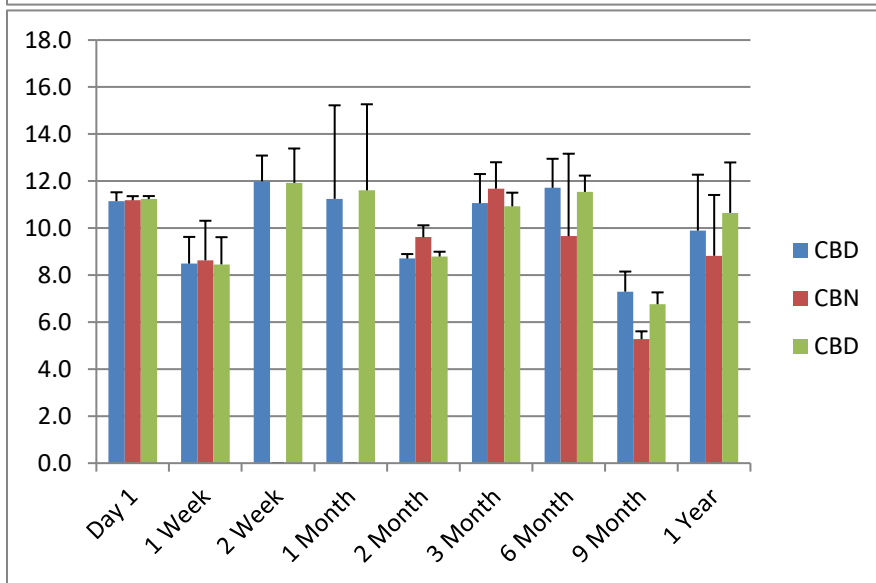
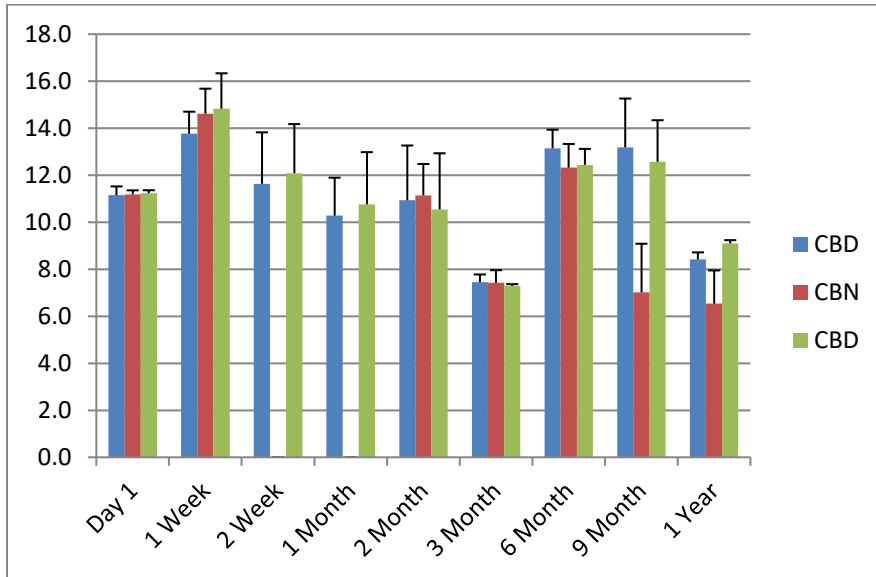
Standard Deviation 5 mg Brownies Room			
Temp	CBD	CBN	THC
Day 1	1.2	1.1	1.3
Week 1	0.3	0.4	0.2
Week 2	1.1		1.2
Month 1	0.5		0.1
Month 2	0.4	0.3	0.1
Month 3	0.4	0.3	0.3
Month 6	0.2	0.2	0.3
Month 9	0.8	0.5	0.6
1 Year	1.1	1.7	1.3

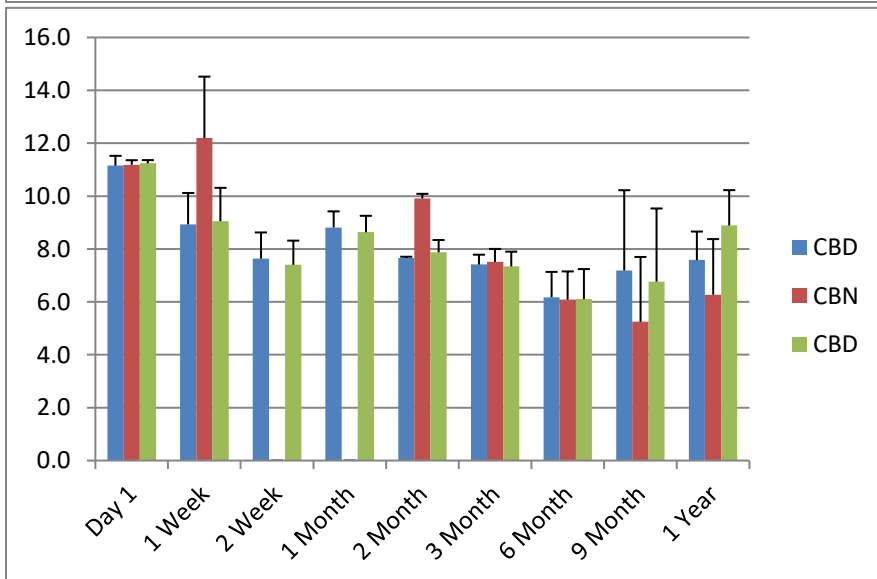
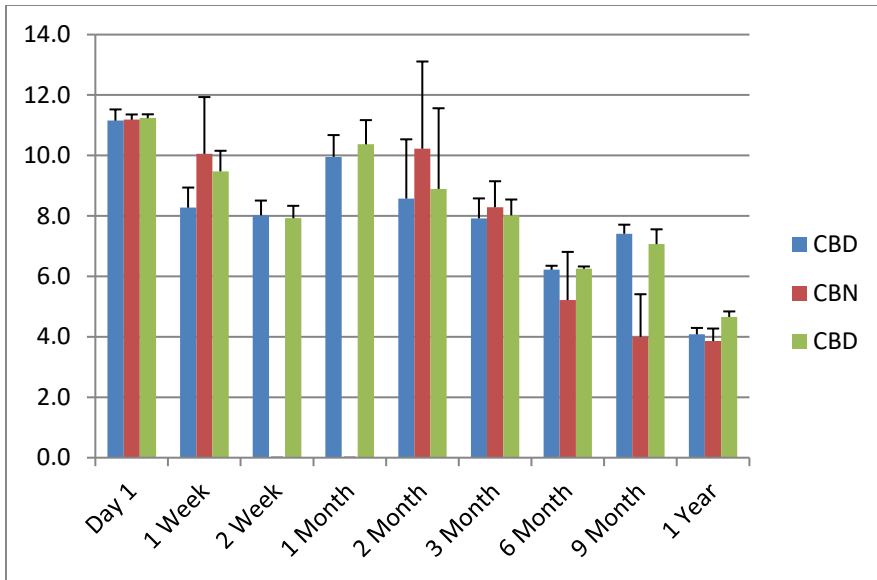
Standard Deviation 5 mg Brownies 5 °C			
Temp	CBD	CBN	THC
Day 1	1.2	1.1	1.3
Week 1	1.7	1.0	1.9
Week 2	1.1		1.4
Month 1	0.3		0.6
Month 2	0.3	0.3	0.2
Month 3	0.8	1.1	1.4
Month 6	0.7	0.6	0.6
Month 9	0.4	0.3	0.2
1 Year	0.0	0.5	0.2

Standard Deviation 5 mg Brownies (-)15°C			
Temp	CBD	CBN	THC
Day 1	1.2	1.1	1.3
Week 1	0.3	0.8	0.4
Week 2	0.6	0.0	0.7
Month 1	1.4	0.0	2.2
Month 2	0.3	0.4	0.4
Month 3	0.4	0.4	0.2
Month 6	1.4	1.4	1.3
Month 9	0.8	0.5	0.6
1 Year	0.9	1.6	0.8

Standard Deviation 5 mg Brownies (-)70°C			
Temp	CBD	CBN	THC
Day 1	1.2	1.1	1.3
Week 1	0.8	0.2	0.7
Week 2	0.3	0.0	0.3
Month 1	0.4	0.0	0.6
Month 2	0.9	1.3	1.2
Month 3	0.1	0.6	0.1
Month 6	1.2	1.0	0.9
Month 9	0.8	0.9	0.7
1 Year	0.2	1.2	0.3

10 mg Quality Control





10 mg/ Brownie			
Room Temp	CBD	CBN	THC
Day 1	11.2	11.2	11.2
Week 1	13.8	14.6	14.8
Week 2	11.6	0.0	12.1
Month 1	10.3	0.0	10.8
Month 2	10.9	11.1	10.5
Month 3	7.5	7.4	7.3
Month 6	13.1	12.3	12.4
Month 9	13.2	7.0	12.6
1 Year	8.4	6.5	9.1

10 mg/ Brownie			
5 °C	CBD	CBN	THC
Day 1	11.2	11.2	11.2
Week 1	8.5	8.6	8.5
Week 2	12.0	0.0	11.9
Month 1	11.2	0.0	11.6
Month 2	8.7	9.6	8.8
Month 3	11.1	11.7	10.9
Month 6	11.7	9.7	11.5
Month 9	7.3	5.3	6.8
1 Year	9.9	8.8	10.6

10 mg/ Brownie			
(-)15°C	CBD	CBN	THC
Day 1	11.2	11.2	11.2
Week 1	8.3	10.1	9.5
Week 2	8.0	0.0	7.9
Month 1	10.0	0.0	10.4
Month 2	8.6	10.2	8.9
Month 3	7.9	8.3	8.0
Month 6	6.2	5.2	6.3
Month 9	7.4	4.0	7.1
1 Year	4.1	3.9	4.7

10 mg/ Brownie			
(-)70°C	CBD	CBN	THC
Day 1	11.2	11.2	11.2
Week 1	8.9	12.2	9.1
Week 2	7.6	0.0	7.4
Month 1	8.8	0.0	8.6
Month 2	7.7	9.9	7.9
Month 3	7.4	7.5	7.3
Month 6	6.2	6.1	6.1
Month 9	7.2	5.2	6.8
1 Year	7.6	6.3	8.9

Standard Deviation 10 mg Gummies

Room	CBD	CBN	THC
Temp			
Day 1	1.1	0.9	1.2
Week 1	0.7	0.0	0.4
Week 2	0.4	0.0	0.3
Month 1	0.2	0.0	0.6
Month 2	1.1	0.9	1.3
Month 3	0.9	0.2	0.5
Month 6	0.8	0.9	0.6
Month 9	0.4	0.4	0.3
1 Year	0.5	3.2	0.4

Standard Deviation 10 mg Gummies

5 °C	CBD	CBN	THC
Day 1	1.1	0.9	1.2
Week 1	0.8	0.0	0.8
Week 2	2.0	0.0	2.2
Month 1	0.5	0.0	1.3
Month 2	0.9	0.6	0.9
Month 3	2.1	1.6	1.5
Month 6	0.6	0.8	0.6
Month 9	0.9	0.6	0.5
1 Year	0.9	3.4	1.0

Standard Deviation 10 mg Gummies

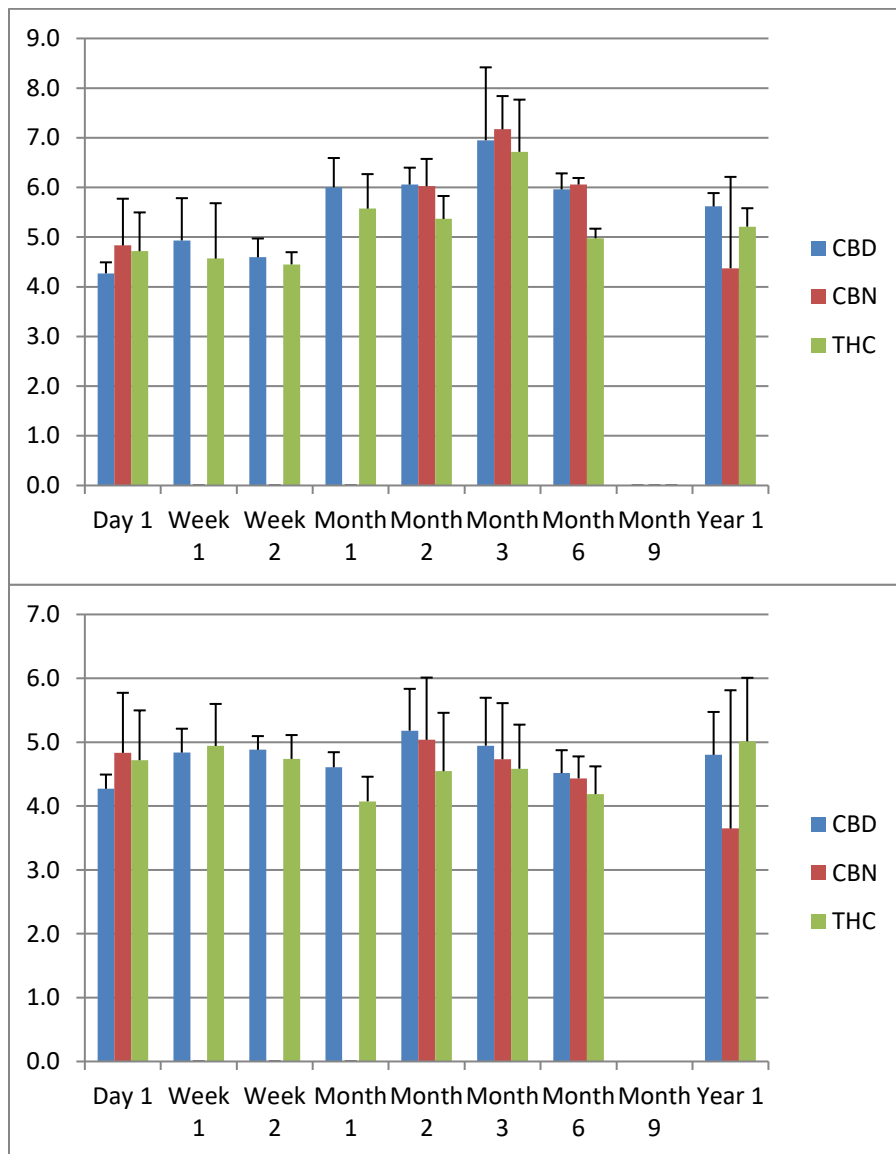
(-)15°C	CBD	CBN	THC
Day 1	1.1	0.9	1.2
Week 1	0.1	0.0	0.3
Week 2	0.9	0.0	0.8
Month 1	0.2	0.0	1.0
Month 2	0.2	0.3	0.2
Month 3	1.6	1.1	1.4
Month 6	0.4	0.4	0.0
Month 9	0.2	2.2	0.3
1 Year	0.2	1.0	0.4

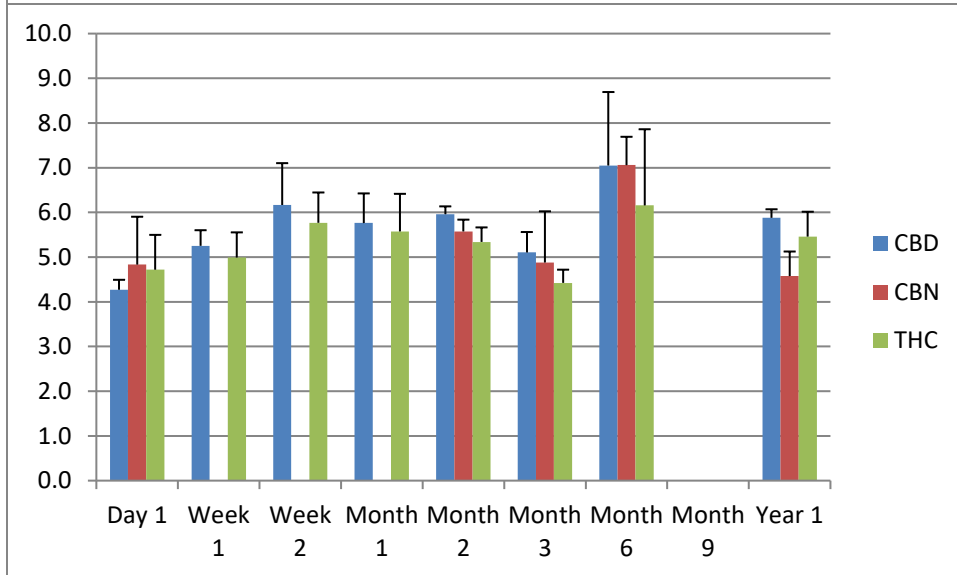
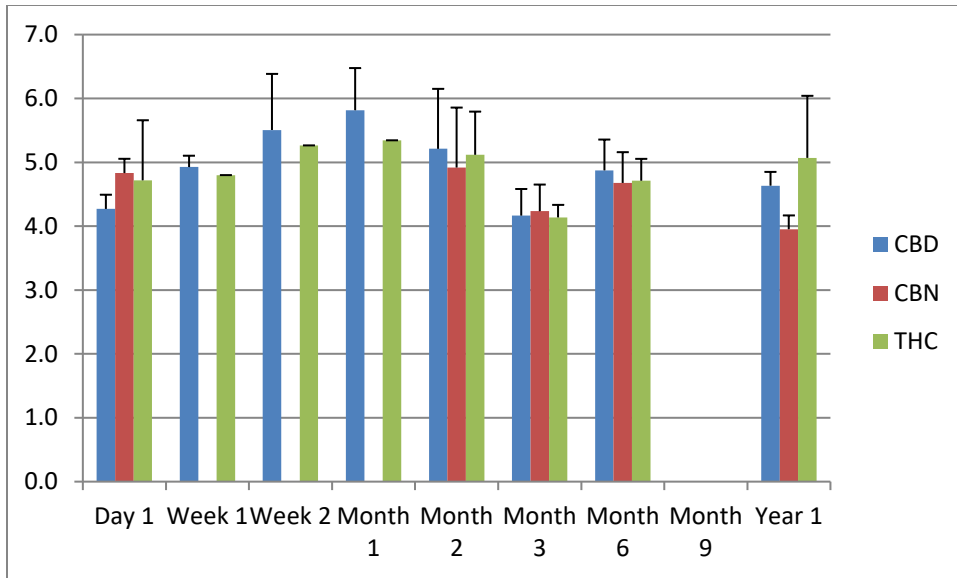
Standard Deviation 10 mg Gummies

(-)70°C	CBD	CBN	THC
Day 1	1.1	0.9	1.2
Week 1	1.8	0.0	1.6
Week 2	1.3	0.0	1.9
Month 1	1.7	0.0	0.9
Month 2	0.4	0.2	0.3
Month 3	0.5	0.3	0.6
Month 6	0.6	0.6	0.6
Month 9	2.6	2.1	2.2
1 Year	0.5	2.7	0.7

2. THC, CBD & CBN Stability in Gummies

5 mg Quality Control





5 mg/ Gummies			
Room Temp	CBD	CBN	THC
Day 1	4.3	4.8	4.7
Week 1	4.9	0.0	4.6
Week 2	4.6	0.0	4.5
Month 1	6.0	0.0	5.6
Month 2	6.1	6.0	5.4
Month 3	6.9	7.2	6.7
Month 6	6.0	6.1	5.0
Month 9			
1 Year	5.6	4.4	5.2

5 mg/ Gummies			
5 °C	CBD	CBN	THC
Day 1	4.3	4.8	4.7
Week 1	5.3		5.0
Week 2	6.2		5.8
Month 1	5.8		5.6
Month 2	6.0	5.6	5.3
Month 3	5.1	4.9	4.4
Month 6	7.0	7.1	6.2
Month 9			
1 Year	5.9	4.6	5.5

5 mg/ Gummies			
(-)15°C	CBD	CBN	THC
Day 1	4.3	4.8	4.7
Week 1	4.8		4.9
Week 2	4.9		4.7
Month 1	4.6		4.1
Month 2	5.2	5.0	4.5
Month 3	4.9	4.7	4.6
Month 6	4.5	4.4	4.2
Month 9			
1 Year	4.8	3.6	5.0

5 mg/ Gummies			
(-)70°C	CBD	CBN	THC
Day 1	4.3	4.8	4.7
Week 1	4.9		4.8
Week 2	5.5		5.3
Month 1	5.8		5.3
Month 2	5.2	4.9	5.1
Month 3	4.2	4.2	4.1
Month 6	4.9	4.7	4.7
Month 9			
1 Year	4.6	4.0	5.1

Standard Deviation 5 mg Gummies

Room Temp	CBD	CBN	THC
Day 1	0.2	0.9	0.8
Week 1	0.8		1.1
Week 2	0.4		0.2
Month 1	0.6		0.7
Month 2	0.3	0.5	0.5
Month 3	1.5	0.7	1.1
Month 6	0.3	0.1	0.2
Month 9			
1 Year	0.3	1.8	0.4

Standard Deviation 5 mg Gummies

5 °C	CBD	CBN	THC
Day 1	0.2	0.9	0.8
Week 1	0.3		0.6
Week 2	0.9		0.7
Month 1	0.7		0.8
Month 2	0.2	0.1	0.3
Month 3	0.5	0.5	0.3
Month 6	1.6	1.6	1.7
Month 9			
1 Year	0.2	2.5	0.6

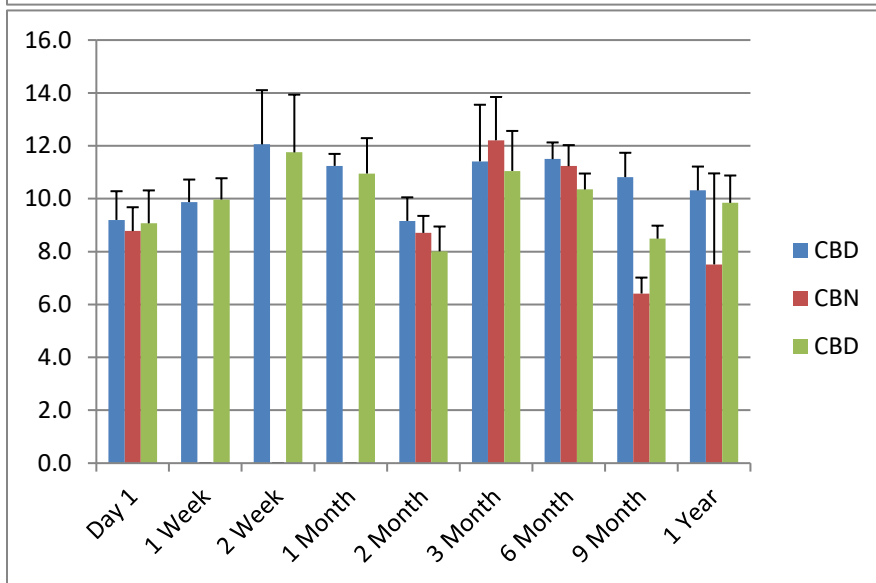
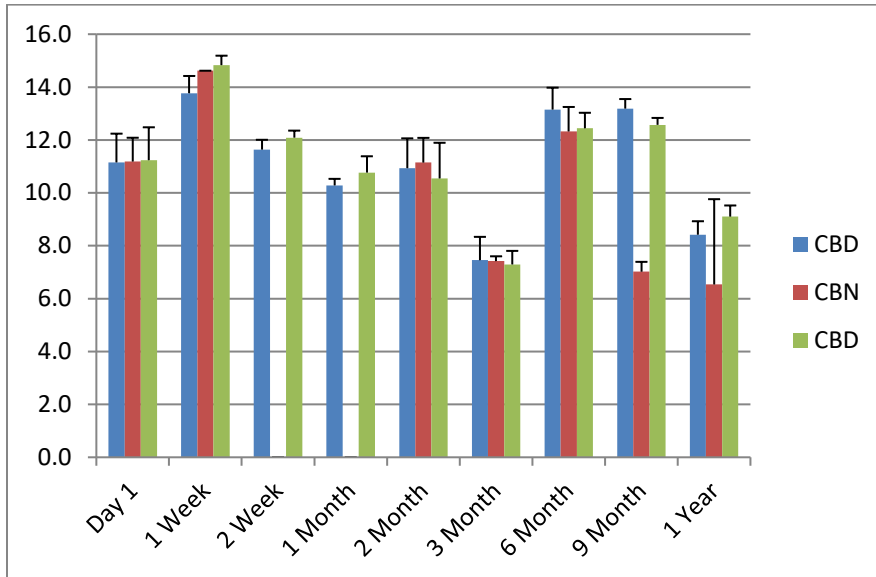
Standard Deviation 5 mg Gummies

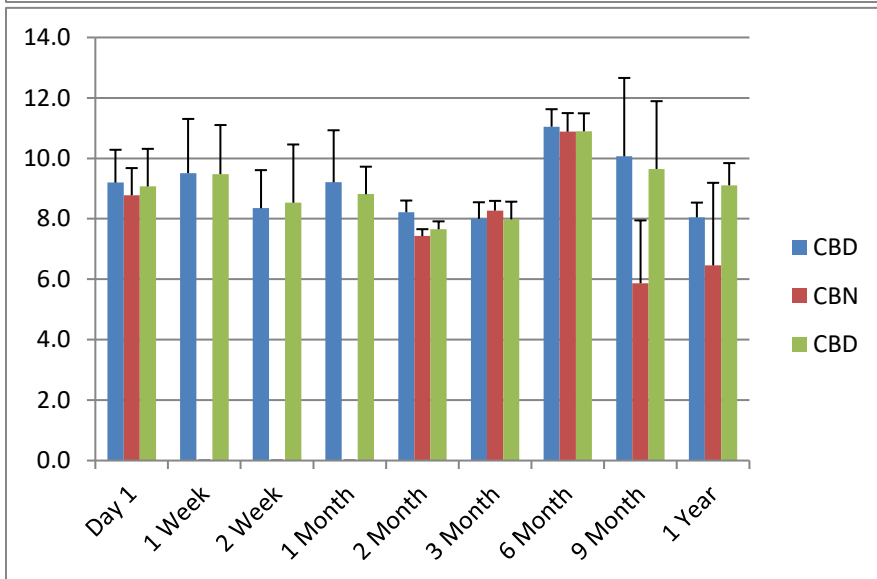
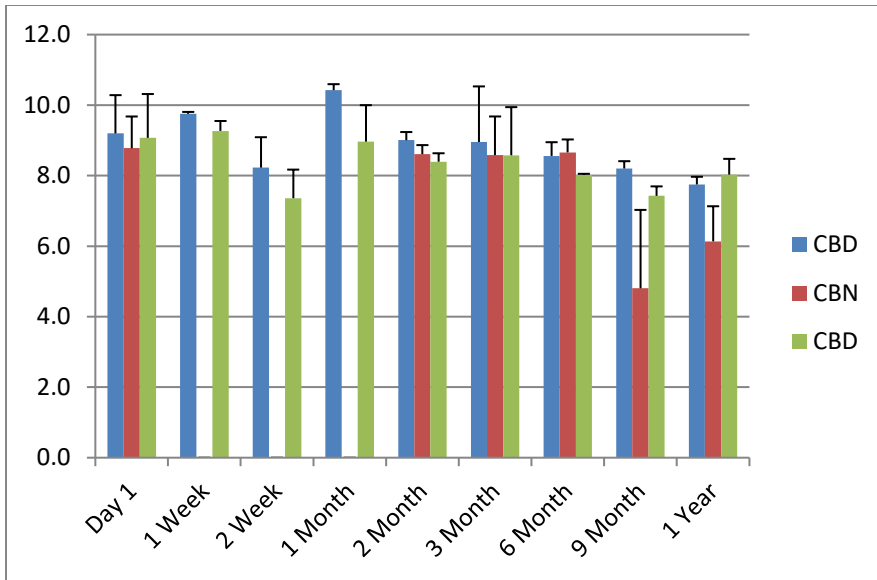
(-)15°C	CBD	CBN	THC
Day 1	0.2	0.9	0.8
Week 1	0.4		0.7
Week 2	0.2		0.4
Month 1	0.2		0.4
Month 2	0.7	1.0	0.9
Month 3	0.7	0.9	0.7
Month 6	0.4	0.3	0.4
Month 9			
1 Year	0.7	2.2	1.0

Standard Deviation 5 mg Gummies

(-)70°C	CBD	CBN	THC
Day 1	0.2	0.9	0.8
Week 1	0.2		0.0
Week 2	0.9		1.4
Month 1	0.7		0.8
Month 2	0.9	0.7	0.5
Month 3	0.4	0.2	0.2
Month 6	0.5	0.3	0.4
Month 9			
1 Year	0.2	1.0	0.3

10 mg Quality Control





10 mg/ Gummies			
Room Temp	CBD	CBN	THC
Day 1	9.2	8.8	9.1
Week 1	9.1	0.0	8.6
Week 2	9.7	0.0	8.9
Month 1	10.9	0.0	10.0
Month 2	12.1	11.9	11.7
Month 3	9.5	10.0	9.9
Month 6	11.3	11.6	9.9
Month 9	10.8	7.6	8.9
1 Year	8.5	4.5	7.6

10 mg/ Gummies			
5 °C	CBD	CBN	THC
Day 1	9.2	8.8	9.1
Week 1	9.9	0.0	10.0
Week 2	12.1	0.0	11.8
Month 1	11.2	0.0	11.0
Month 2	9.2	8.7	8.0
Month 3	11.4	12.2	11.1
Month 6	11.5	11.2	10.4
Month 9	10.8	6.4	8.5
1 Year	10.3	7.5	9.8

10 mg/ Gummies			
(-)15°C	CBD	CBN	THC
Day 1	9.2	8.8	9.1
Week 1	9.8	0.0	9.3
Week 2	8.2	0.0	7.4
Month 1	10.4	0.0	9.0
Month 2	9.0	8.6	8.4
Month 3	9.0	8.6	8.6
Month 6	8.6	8.7	8.0
Month 9	8.2	4.8	7.4
1 Year	7.8	6.1	8.0

10 mg/ Gummies			
(-)70°C	CBD	CBN	THC
Day 1	9.2	8.8	9.1
Week 1	9.5	0.0	9.5
Week 2	8.3	0.0	8.5
Month 1	9.2	0.0	8.8
Month 2	8.2	7.4	7.7
Month 3	8.0	8.3	8.0
Month 6	11.0	10.9	10.9
Month 9	10.1	5.9	9.6
1 Year	8.0	6.5	9.1

Standard Deviation 10 mg Gummies

Room	CBD	CBN	THC
Temp			
Day 1	1.1	0.9	1.2
Week 1	0.7	0.0	0.4
Week 2	0.4	0.0	0.3
Month 1	0.2	0.0	0.6
Month 2	1.1	0.9	1.3
Month 3	0.9	0.2	0.5
Month 6	0.8	0.9	0.6
Month 9	0.4	0.4	0.3
1 Year	0.5	3.2	0.4

Standard Deviation 10 mg Gummies

5 °C	CBD	CBN	THC
Day 1	1.1	0.9	1.2
Week 1	0.8	0.0	0.8
Week 2	2.0	0.0	2.2
Month 1	0.5	0.0	1.3
Month 2	0.9	0.6	0.9
Month 3	2.1	1.6	1.5
Month 6	0.6	0.8	0.6
Month 9	0.9	0.6	0.5
1 Year	0.9	3.4	1.0

Standard Deviation 10 mg Gummies

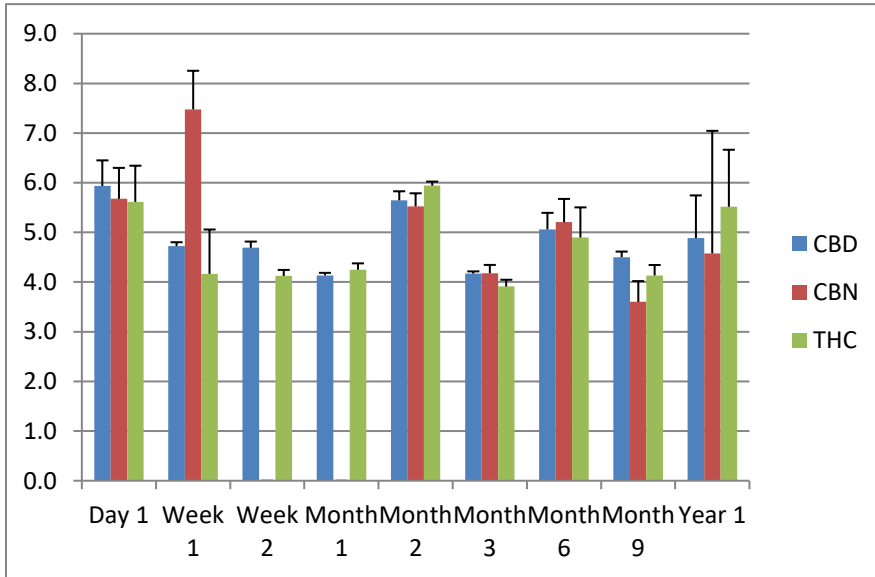
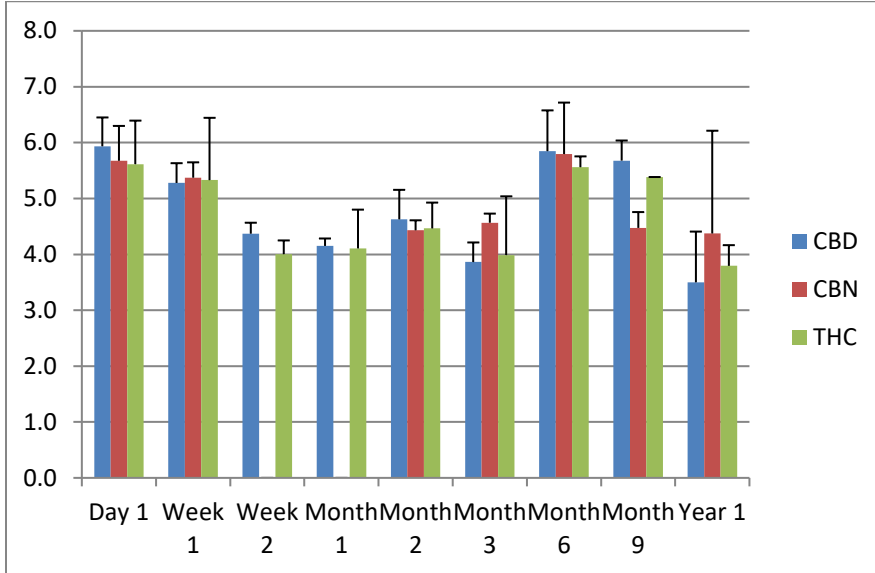
(-)15°C	CBD	CBN	THC
Day 1	1.1	0.9	1.2
Week 1	0.1	0.0	0.3
Week 2	0.9	0.0	0.8
Month 1	0.2	0.0	1.0
Month 2	0.2	0.3	0.2
Month 3	1.6	1.1	1.4
Month 6	0.4	0.4	0.0
Month 9	0.2	2.2	0.3
1 Year	0.2	1.0	0.4

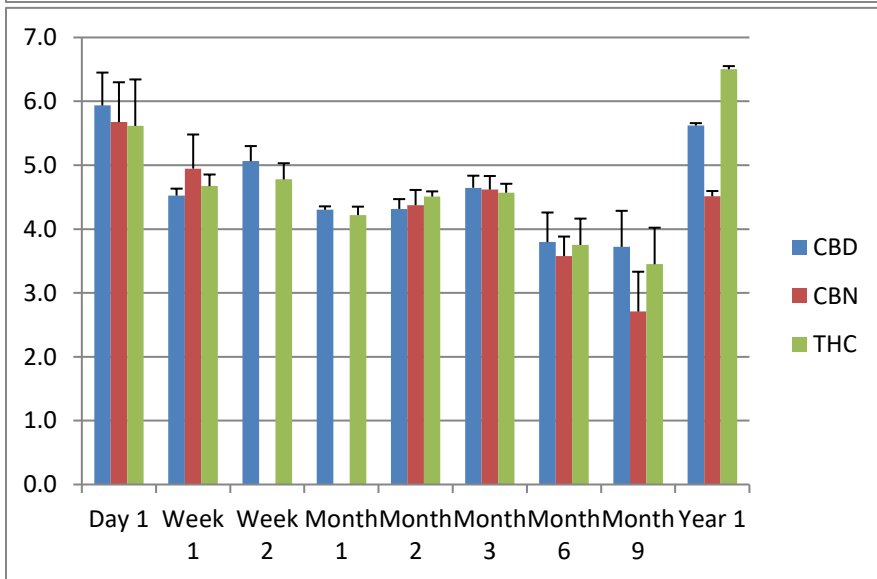
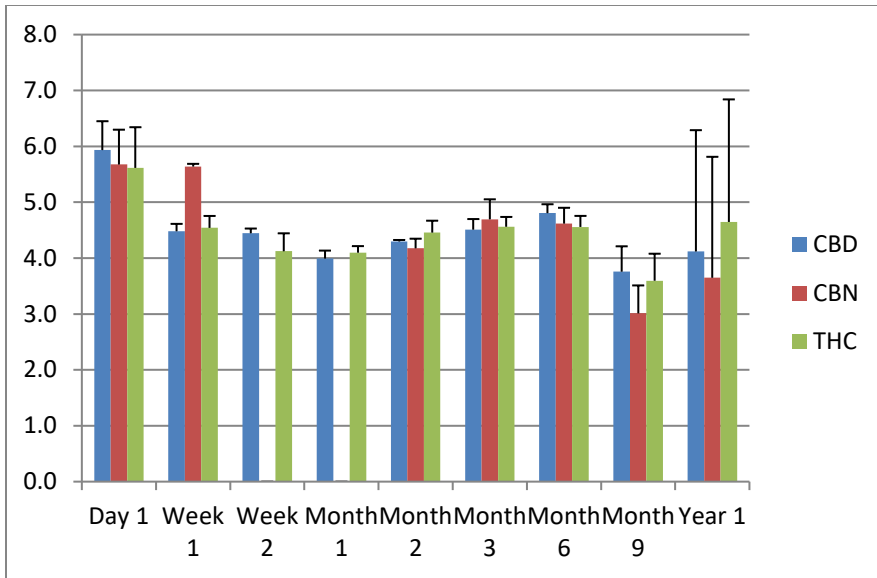
Standard Deviation 10 mg Gummies

(-)70°C	CBD	CBN	THC
Day 1	1.1	0.9	1.2
Week 1	1.8	0.0	1.6
Week 2	1.3	0.0	1.9
Month 1	1.7	0.0	0.9
Month 2	0.4	0.2	0.3
Month 3	0.5	0.3	0.6
Month 6	0.6	0.6	0.6
Month 9	2.6	2.1	2.2
1 Year	0.5	2.7	0.7

3. THC, CBD & CBN Stability in Dark Chocolate

5 mg Quality Control





5 mg/ Chocolate			
Room			
Temp	CBD	CBN	THC
Day 1	5.9	5.7	5.6
Week 1	5.3	5.4	5.3
Week 2	4.4		4.0
Month 1	4.2		4.1
Month 2	4.6	4.4	4.5
Month 3	3.9	4.6	4.0
Month 6	5.8	5.8	5.6
Month 9	5.7	4.5	5.4
1 Year	3.5	4.4	3.8

5 mg/ Chocolate			
5 °C	CBD	CBN	THC
Day 1	5.9	5.7	5.6
Week 1	4.7	7.5	4.2
Week 2	4.7		4.1
Month 1	4.1		4.2
Month 2	5.6	5.5	5.9
Month 3	4.2	4.2	3.9
Month 6	5.1	5.2	4.9
Month 9	4.5	3.6	4.1
1 Year	4.9	4.6	5.5

5 mg/ Chocolate			
(-)15°C	CBD	CBN	THC
Day 1	5.9	5.7	5.6
Week 1	4.5	5.6	4.5
Week 2	4.4		4.1
Month 1	4.0		4.1
Month 2	4.3	4.2	4.5
Month 3	4.5	4.7	4.6
Month 6	4.8	4.6	4.6
Month 9	3.8	3.0	3.6
1 Year	4.1	3.6	4.6

5 mg/ Chocolate			
(-)70°C	CBD	CBN	THC
Day 1	5.9	5.7	5.6
Week 1	4.5	4.9	4.7
Week 2	5.1		4.8
Month 1	4.3		4.2
Month 2	4.3	4.4	4.5
Month 3	4.6	4.6	4.6
Month 6	3.8	3.6	3.8
Month 9	3.7	2.7	3.5
1 Year	5.6	4.5	6.5

Standard Deviation 5 mg Chocolate

Room	CBD	CBN	THC
Day 1	0.5	0.6	0.7
Week 1	0.4	0.3	0.2
Week 2	0.2		0.1
Month 1	0.1		0.1
Month 2	0.5	0.2	0.2
Month 3	0.3	0.2	0.2
Month 6	0.7	0.9	0.7
Month 9	0.4	0.3	0.1
1 Year	0.9	1.8	1.2

Standard Deviation 5 mg Chocolate

5 °C	CBD	CBN	THC
Day 1	0.5	0.6	0.7
Week 1	0.1	0.8	0.9
Week 2	0.1		0.1
Month 1	0.1		0.1
Month 2	0.2	0.3	0.1
Month 3	0.0	0.2	0.1
Month 6	0.3	0.5	0.6
Month 9	0.1	0.4	0.2
1 Year	0.9	2.5	1.1

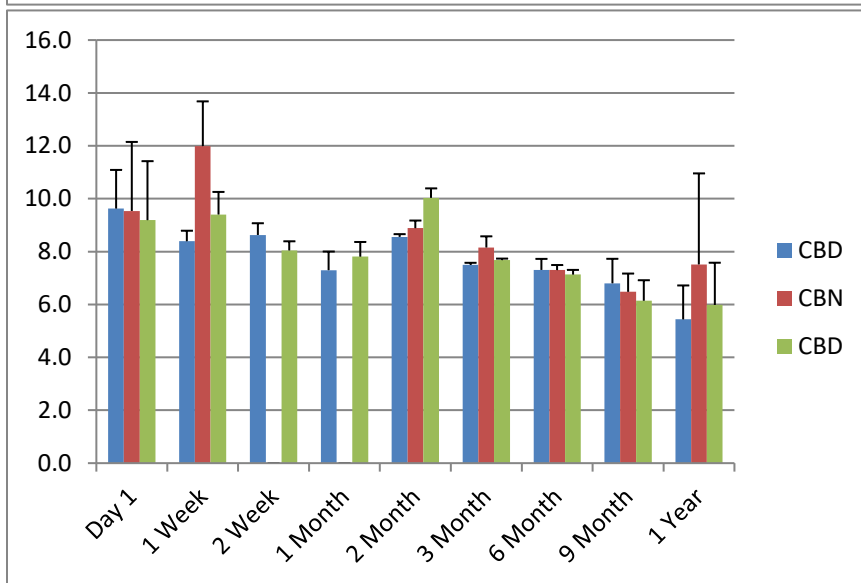
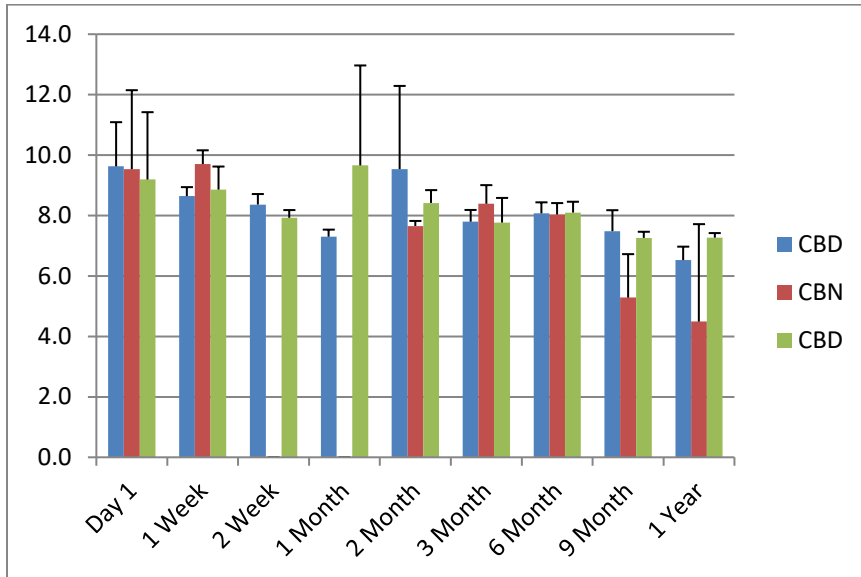
Standard Deviation 5 mg Chocolate

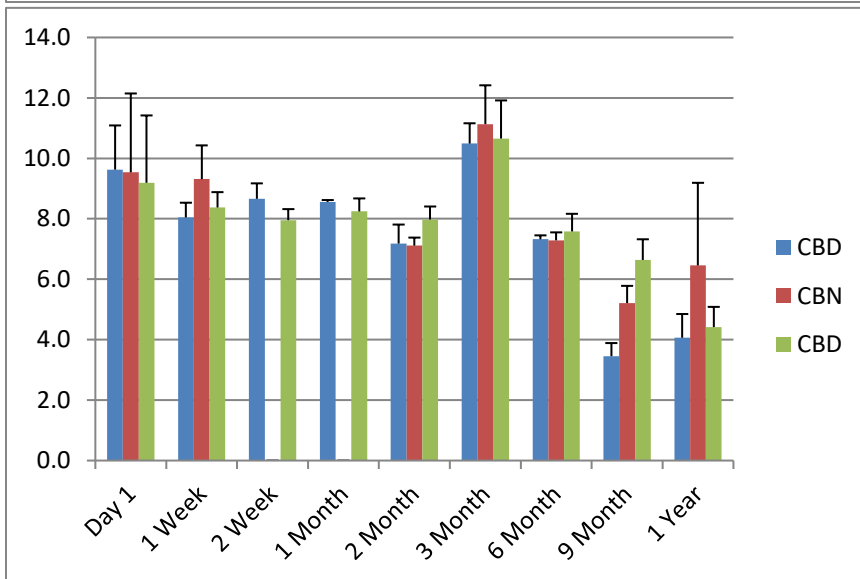
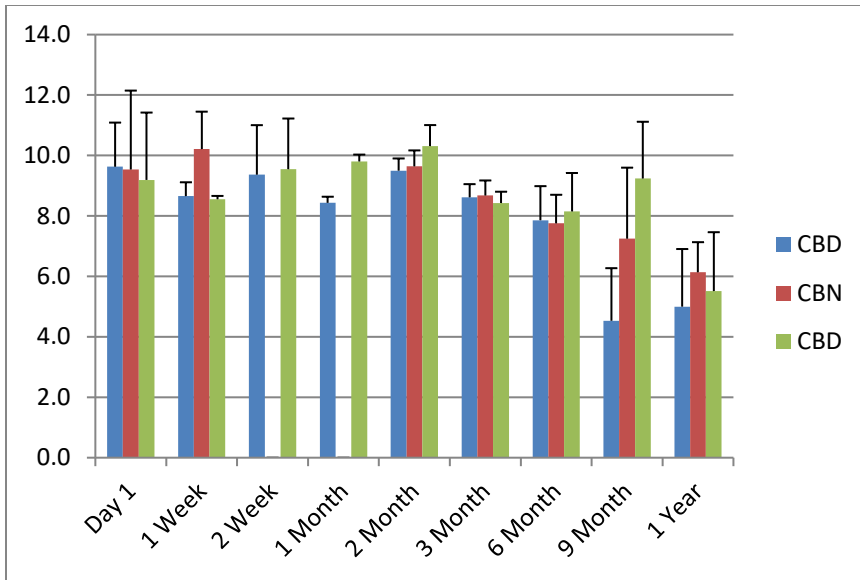
(-)15°C	CBD	CBN	THC
Day 1	0.5	0.6	0.7
Week 1	0.1	0.1	0.2
Week 2	0.1		0.3
Month 1	0.1		0.1
Month 2	0.0	0.2	0.2
Month 3	0.2	0.4	0.2
Month 6	0.2	0.3	0.2
Month 9	0.5	0.5	0.5
1 Year	2.2	2.2	2.2

Standard Deviation 5 mg Chocolate

(-)70°C	CBD	CBN	THC
Day 1	0.5	0.6	0.7
Week 1	0.1	0.5	0.2
Week 2	0.2		0.3
Month 1	0.1		0.1
Month 2	0.2	0.2	0.1
Month 3	0.2	0.2	0.1
Month 6	0.5	0.3	0.4
Month 9	0.6	0.6	0.6
1 Year	0.0	0.1	0.0

10 mg Quality Control





10 mg/ Chocolate			
Room Temp	CBD	CBN	THC
Day 1	9.6	9.5	9.2
Week 1	8.6	9.7	8.9
Week 2	8.4		7.9
Month 1	7.3		9.7
Month 2	9.5	7.7	8.4
Month 3	7.8	8.4	7.8
Month 6	8.1	8.0	8.1
Month 9	7.5	5.3	7.3
1 Year	6.5	4.5	7.3

10 mg/ Chocolate			
5 °C	CBD	CBN	THC
Day 1	9.6	9.5	9.2
Week 1	8.4	12.0	9.4
Week 2	8.6		8.0
Month 1	7.3		7.8
Month 2	8.6	8.9	10.0
Month 3	7.5	8.2	7.7
Month 6	7.3	7.3	7.1
Month 9	6.8	6.5	6.1
1 Year	5.4	7.5	6.0

10 mg/ Chocolate			
(-)15°C	CBD	CBN	THC
Day 1	9.6	9.5	9.2
Week 1	8.7	10.2	8.6
Week 2	9.4		9.5
Month 1	8.4		9.8
Month 2	9.5	9.6	10.3
Month 3	8.6	8.7	8.4
Month 6	7.9	7.8	8.1
Month 9	4.5	7.2	9.2
1 Year	5.0	6.1	5.5

10 mg/ Chocolate			
(-)70°C	CBD	CBN	THC
Day 1	9.6	9.5	9.2
Week 1	8.0	9.3	8.4
Week 2	8.7		8.0
Month 1	8.6		8.2
Month 2	7.2	7.1	8.0
Month 3	10.5	11.1	10.7
Month 6	7.3	7.3	7.6
Month 9	3.5	5.2	6.6
1 Year	4.1	6.5	4.4

Standard Deviation 10 mg Chocolate

Room	CBD	CBN	THC
Temp			
Day 1	1.5	2.6	2.2
Week 1	0.3	0.5	0.8
Week 2	0.3		0.3
Month 1	0.2		3.3
Month 2	2.8	0.2	0.4
Month 3	0.4	0.6	0.8
Month 6	0.4	0.4	0.4
Month 9	0.7	1.4	0.2
1 Year	0.4	3.2	0.1

Standard Deviation 10 mg Chocolate

5 °C	CBD	CBN	THC
Day 1	1.5	2.6	2.2
Week 1	0.4	1.7	0.9
Week 2	0.4		0.3
Month 1	0.7		0.6
Month 2	0.1	0.3	0.4
Month 3	0.1	0.4	0.1
Month 6	0.4	0.2	0.2
Month 9	0.9	0.7	0.8
1 Year	1.3	3.4	1.6

Standard Deviation 10 mg Chocolate

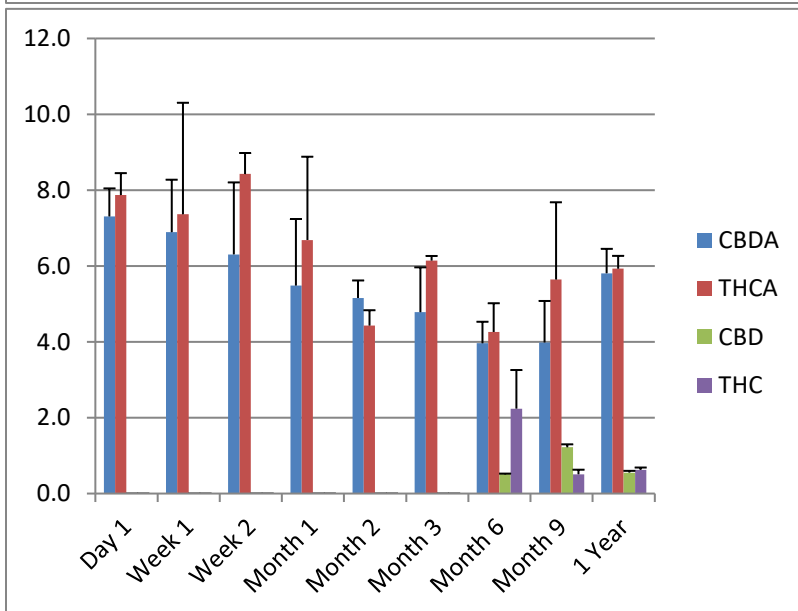
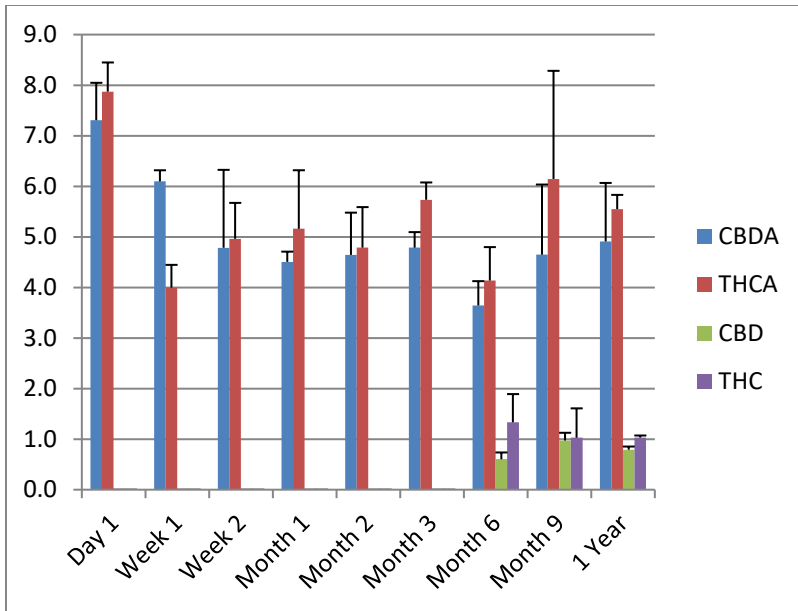
(-)15°C	CBD	CBN	THC
Day 1	1.5	2.6	2.2
Week 1	0.5	1.2	0.1
Week 2	1.6		1.7
Month 1	0.2		0.2
Month 2	0.4	0.5	0.7
Month 3	0.4	0.5	0.4
Month 6	1.1	0.9	1.3
Month 9	1.7	2.3	1.9
1 Year	1.9	1.0	1.9

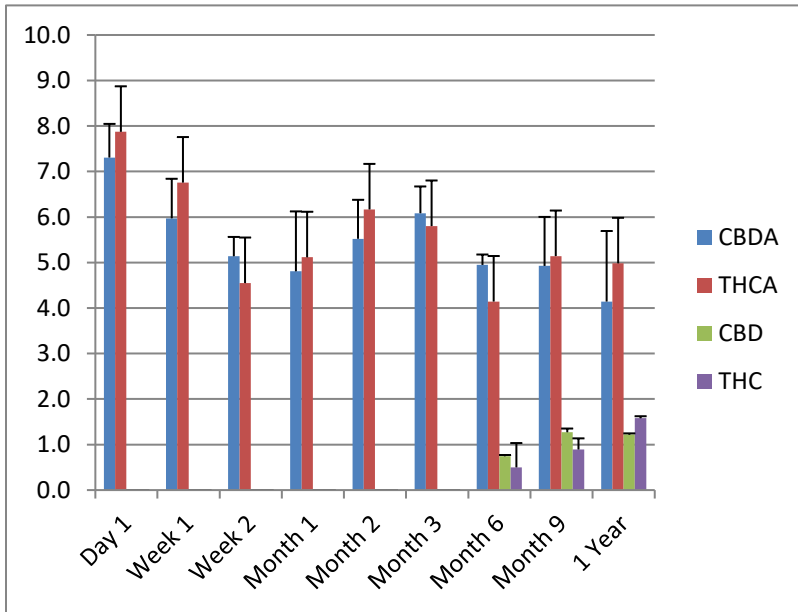
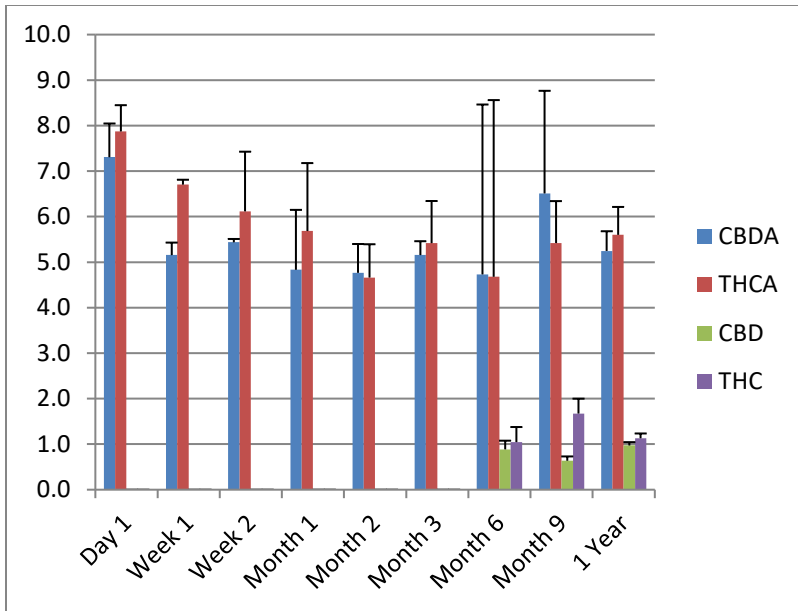
Standard Deviation 10 mg Chocolate

(-)70°C	CBD	CBN	THC
Day 1	1.5	2.6	2.2
Week 1	0.5	1.1	0.5
Week 2	0.5		0.4
Month 1	0.1		0.4
Month 2	0.6	0.3	0.4
Month 3	0.7	1.3	1.3
Month 6	0.1	0.3	0.6
Month 9	0.4	0.6	0.7
1 Year	0.8	2.7	0.7

4. THCA & CBDA Stability in Brownies

5 mg Quality Control





Room Temp	mg/ Brownie			
	CBDA	THCA	CBD	THC
Day 1	7.3	7.9	ND	ND
Week 1	6.0	6.8	ND	ND
Week 2	5.1	4.5	ND	ND
Month 1	4.8	5.1	ND	ND
Month 2	5.5	6.2	ND	ND
Month 3	6.1	5.8	ND	ND
Month 6	4.9	4.1	0.7	0.5
Month 9	4.9	5.1	1.3	0.9
1 Year	4.1	5.0	1.2	1.6

5 °C	mg/ Brownie			
	CBDA	THCA	CBD	THC
Day 1	7.3	7.9	ND	ND
Week 1	5.2	6.7	ND	ND
Week 2	5.4	6.1	ND	ND
Month 1	4.8	5.7	ND	ND
Month 2	4.8	4.7	ND	ND
Month 3	5.2	5.4	ND	ND
Month 6	4.7	4.7	0.9	1.0
Month 9	6.5	5.4	0.6	1.7
1 Year	5.2	5.6	1.0	1.1

(-)15°C	mg/ Brownie			
	CBDA	THCA	CBD	THC
Day 1	7.3	7.9	ND	ND
Week 1	6.9	7.4	ND	ND
Week 2	6.3	8.4	ND	ND
Month 1	5.5	6.7	ND	ND
Month 2	5.2	4.4	ND	ND
Month 3	4.8	6.1	ND	ND
Month 6	4.0	4.3	0.5	2.2
Month 9	4.0	5.6	1.2	0.5
1 Year	5.8	5.9	0.6	0.6

(-)70°C	mg/ Brownie			
	CBDA	THCA	CBD	THC
Day 1	7.3	7.9	ND	ND
Week 1	6.1	4.0	ND	ND
Week 2	4.8	5.0	ND	ND
Month 1	4.5	5.2	ND	ND
Month 2	4.6	4.8	ND	ND
Month 3	4.8	5.7	ND	ND
Month 6	3.6	4.1	0.6	1.3
Month 9	4.6	6.1	1.0	1.0
1 Year	4.9	5.5	0.8	1.0

mg/ Brownie				
Room Temp	CBDA	THCA	CBD	THC
Day 1	7.3	7.9	ND	ND
Week 1	6.0	6.8	ND	ND
Week 2	5.1	4.5	ND	ND
Month 1	4.8	5.1	ND	ND
Month 2	5.5	6.2	ND	ND
Month 3	6.1	5.8	ND	ND
Month 6	4.9	4.1	0.7	0.5
Month 9	4.9	5.1	1.3	0.9
1 Year	4.1	5.0	1.2	1.6

mg/ Brownie				
5 °C	CBDA	THCA	CBD	THC
Day 1	7.3	7.9	ND	ND
Week 1	5.2	6.7	ND	ND
Week 2	5.4	6.1	ND	ND
Month 1	4.8	5.7	ND	ND
Month 2	4.8	4.7	ND	ND
Month 3	5.2	5.4	ND	ND
Month 6	4.7	4.7	0.9	1.0
Month 9	6.5	5.4	0.6	1.7
1 Year	5.2	5.6	1.0	1.1

mg/ Brownie				
(-)15°C	CBDA	THCA	CBD	THC
Day 1	7.3	7.9	ND	ND
Week 1	6.9	7.4	ND	ND
Week 2	6.3	8.4	ND	ND
Month 1	5.5	6.7	ND	ND
Month 2	5.2	4.4	ND	ND
Month 3	4.8	6.1	ND	ND
Month 6	4.0	4.3	0.5	2.2
Month 9	4.0	5.6	1.2	0.5
1 Year	5.8	5.9	0.6	0.6

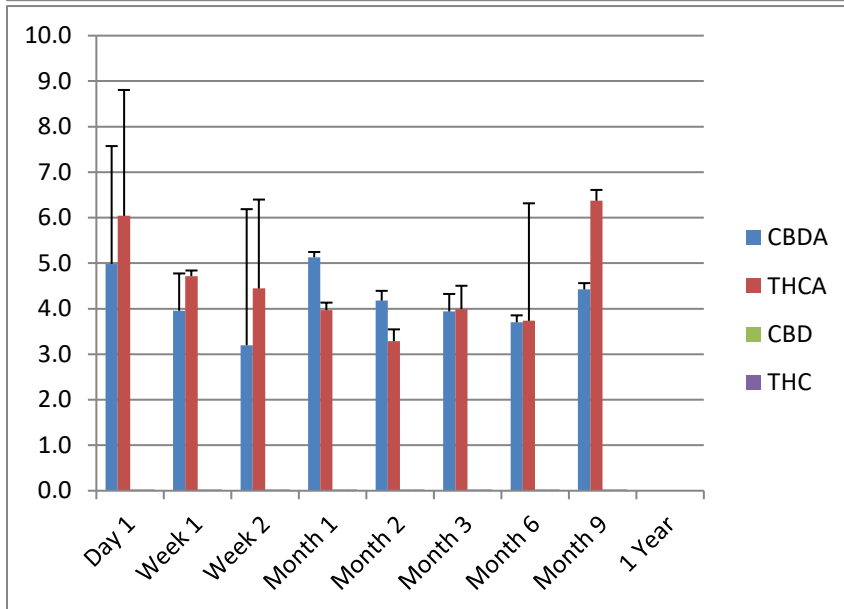
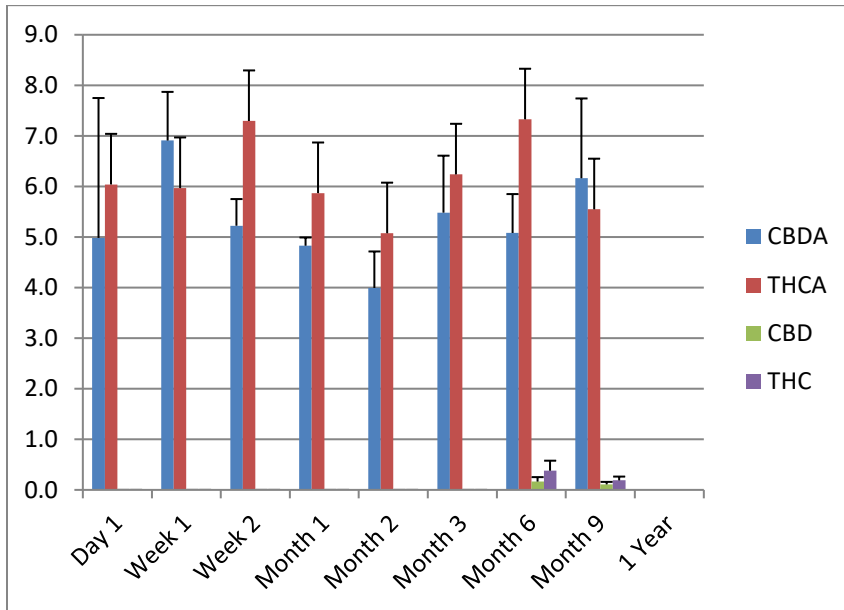
mg/ Brownie				
(-)70°C	CBDA	THCA	CBD	THC
Day 1	7.3	7.9	ND	ND
Week 1	6.1	4.0	ND	ND
Week 2	4.8	5.0	ND	ND
Month 1	4.5	5.2	ND	ND
Month 2	4.6	4.8	ND	ND
Month 3	4.8	5.7	ND	ND
Month 6	3.6	4.1	0.6	1.3
Month 9	4.6	6.1	1.0	1.0
1 Year	4.9	5.5	0.8	1.0

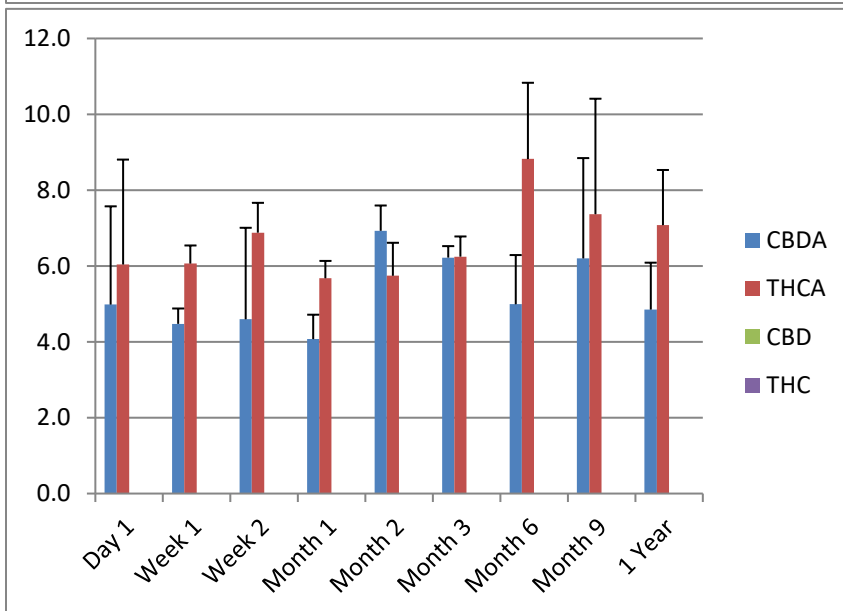
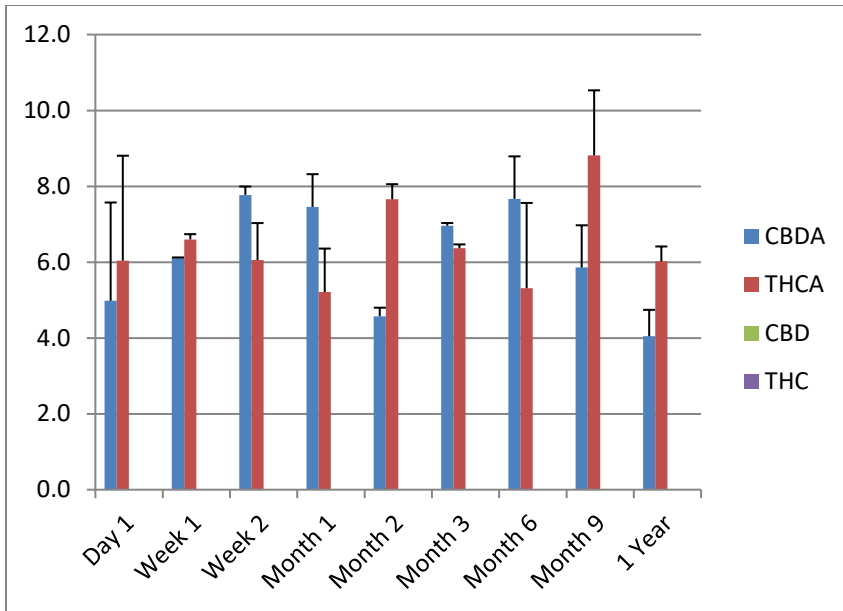
5. THCA & CBDA Stability in Gummies

Data Not Available

6. THCA & CBDA Stability in Dark Chocolate

5 mg Quality Control





mg/ Chocolate				
Room Temp	CBDA	THCA	CBD	THC
Day 1	5.0	6.0	ND	ND
Week 1	6.9	6.0	ND	ND
Week 2	5.2	7.3	ND	ND
Month 1	4.8	5.9	ND	ND
Month 2	4.0	5.1	ND	ND
Month 3	5.5	6.2	ND	ND
Month 6	5.1	7.3	0.2	0.4
Month 9	6.2	5.5	0.1	0.2
1 Year				

mg/ Chocolate				
5 °C	CBDA	THCA	CBD	THC
Day 1	5.0	6.0	ND	ND
Week 1	4.0	4.7	ND	ND
Week 2	3.2	4.4	ND	ND
Month 1	5.1	4.0	ND	ND
Month 2	4.2	3.3	ND	ND
Month 3	3.9	4.0	ND	ND
Month 6	3.7	3.7	ND	ND
Month 9	4.4	6.4	ND	ND
1 Year				

mg/ Chocolate				
(-)15°C	CBDA	THCA	CBD	THC
Day 1	5.0	6.0	ND	ND
Week 1	6.1	6.6	ND	ND
Week 2	7.8	6.1	ND	ND
Month 1	7.5	5.2	ND	ND
Month 2	4.6	7.7	ND	ND
Month 3	7.0	6.4	ND	ND
Month 6	7.7	5.3	ND	ND
Month 9	5.9	8.8	ND	ND
1 Year	4.0	6.0	ND	ND

mg/ Chocolate				
(-)70°C	CBDA	THCA	CBD	THC
Day 1	5.0	6.0	ND	ND
Week 1	4.5	6.1	ND	ND
Week 2	4.6	6.9	ND	ND
Month 1	4.1	5.7	ND	ND
Month 2	6.9	5.7	ND	ND
Month 3	6.2	6.2	ND	ND
Month 6	5.0	8.8	ND	ND
Month 9	6.2	7.4	ND	ND
1 Year	4.9	7.1	ND	ND

Standard Deviation Chocolate				
Room Temp	CBDA	THCA	CBD	THC
Day 1	2.6	2.8		
Week 1	1.8	1.0		
Week 2	0.1	0.5		
Month 1	0.1	0.2		
Month 2	0.7	0.7		
Month 3	0.8	1.1		
Month 6	0.6	0.8	0.1	0.2
Month 9	1.3	1.6	0.0	0.1
1 Year				

Standard Deviation Chocolate				
5 °C	CBDA	THCA	CBD	THC
Day 1	2.6	2.8		
Week 1	0.8	0.1		
Week 2	3.0	2.0		
Month 1	0.1	0.2		
Month 2	0.2	0.3		
Month 3	0.4	0.5		
Month 6	0.2	2.6		
Month 9	0.1	0.2		
1 Year				

Standard Deviation Chocolate				
(-)15°C	CBDA	THCA	CBD	THC
Day 1	2.6	2.8		
Week 1	0.0	0.1		
Week 2	0.2	1.0		
Month 1	0.9	1.1		
Month 2	0.2	0.4		
Month 3	0.1	0.1		
Month 6	1.1	2.2		
Month 9	1.1	1.7		
1 Year	0.7	0.4		

Standard Deviation Chocolate				
(-)70°C	CBDA	THCA	CBD	THC
Day 1	2.6	2.8		
Week 1	0.4	0.5		
Week 2	2.4	0.8		
Month 1	0.6	0.5		
Month 2	0.7	0.9		
Month 3	0.3	0.5		
Month 6	1.3	2.0		
Month 9	2.6	3.0		
1 Year	1.2	1.5		