VERTOSA

IN PARTNERSHIP WITH

PENN COLOR®

CASE STUDY

DETERMINING COMPATIBILITY OF CANNABINOIDS WITH PET

Above: Solid color and additive masterbatches have been the industry wide best practice for coloring polymers throughout the globe.

Introduction

Vertosa has partnered with Penn Color to evaluate if packaging absorption occurs when beverages containing cannabidiol (CBD) and Δ– 9 tetrahydrocannabidiol (THC) come in contact with polyethylene terephthalate (PET) packaging. Various additives were added to the PET to determine if they offer protection to the cannabinoids.

Penn Color is a 3rd generation, family owned, industry leader in color masterbatch, functional additives and material science. Their ability to serve both the thermoplastics and inks & coating sides of the market is unique, and allows them to work with a wide variety of industries ranging from consumer goods to automotive to electronics to building/construction and packaging. They leverage technology cross-pollination between thermoplastics and inks & coatings to sustain the highest product vitality index in the industry, with mainly custom-designed solutions. The Penn Color experience is built around technical expertise, world-class quality, and accelerating their customer's brands.

Background

CBD and THC beverages are storming the marketplace. They make up 19% of the cannabis edibles market which is estimated to reach $10 billion in annual sales by 2025 (Brightfield Group). Yet most of the packaging formats have been limited to glass and cans. This not only limits brands from distinguishing themselves with unique packaging, but limits the number of co-manufacturers available to get cannabis beverages to market. This study was designed to understand if and what type of PET bottles would be best suited for cannabinoid infused beverages.

Objectives of Study

01 Determine if a reduction in cannabinoid concentration occurs in PET bottles due to packaging absorption.

02 Determine if any of the additives within the polymer offer protection to the cannabinoids.

Experimental Design

In this 20-week real time shelf life study, seven different 680 mL PET bottles with non-lined aluminum and polypropylene caps were provided to Vertosa by Penn Color. The colorants and additives in the bottles were specifically formulated to make the set of bottles, representative of the typical applications, specifications and performance of PET bottles on the market They were filled with dilute emulsion at a concentration of 20 mg per 12 oz. and filled high, leaving only a small headspace for expansion.

Bottle application	Formula
Water	0.80 IV bottle grade PET
Beer	Amber color, UV protection, O_2 scavenger
Milk	Light barrier
Soft Drinks	Green color, CO_2 barrier, Slip additive
Juice, Tea	UV protection, O_2 scavenger
Recycled Bottles	Color neutralizer
Flavored and UHT Dairy	Light barrier, O_2 barrier, no TiO_2

Emulsions prepared included the Natural 1 (N1) and Conventional 6 (C6) with both CBD and THC.

Bottle application	N1 CBD	N1 THC	C6 CBD	C6 THC
Water	pH = 7.0	pH = 7.0	pH = 7.0	pH = 7.0
Beer	pH = 3.5	pH = 3.5	pH = 3.5	pH = 3.5
Milk	pH = 7.0	pH = 7.0	pH = 7.0	pH = 7.0
Soft Drinks	pH = 3.5	pH = 3.5	pH = 3.5	pH = 3.5
Juice, Tea	pH = 3.5	pH = 3.5	pH = 3.5	pH = 3.5
Recycled Bottles	pH = 3.5	pH = 3.5	pH = 3.5	pH = 3.5
Flavored and UHT Dairy	pH = 7.0	pH = 7.0	pH = 7.0	pH = 7.0

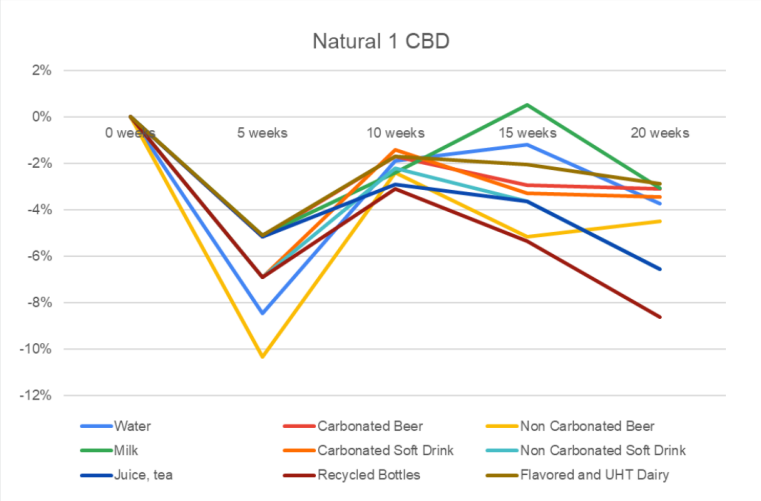
- All emulsions were made at a neutral pH, and half were subsequently adjusted to low pH to simulate that of acidic beverages using citric acid. pH of the emulsion used was chosen based on the expected pH of the finished beverage in the specific bottle type.
- All emulsions contain a preservative to inhibit the growth of microbes.
- Both carbonated & non-carbonated beverages were evaluated for beer and soft drink containers. Carbonation was performed with a SodaStream© so it is not fully representative of carbonation levels achievable in production.
- All samples were bottled at atmospheric oxygen (~21% O2) and no nitrogen flushing or head space was added.

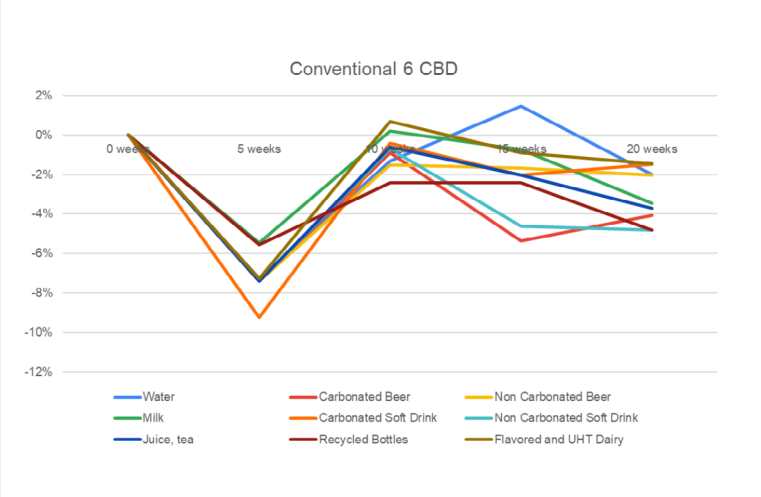
Analysis of the samples

All samples were evaluated on the same instrument by the same technician at a third party laboratory partner, Anresco Laboratories, in this 20 week study.

Results by Cannabinoid: CBD

Both Natural 1 and Conventional 6 graphs show similar behavior. An initial decrease is observed at 5 weeks which then increases at week 10 where variance at later time points is more gradual. The variance observed may be leveling out or be within standard deviation of replicate measurements. The total concentration loss of CBD is <10% for all bottle types across all timepoints. No other cannabinoids were detected in the samples that would indicate the CBD had been broken down into other compounds.





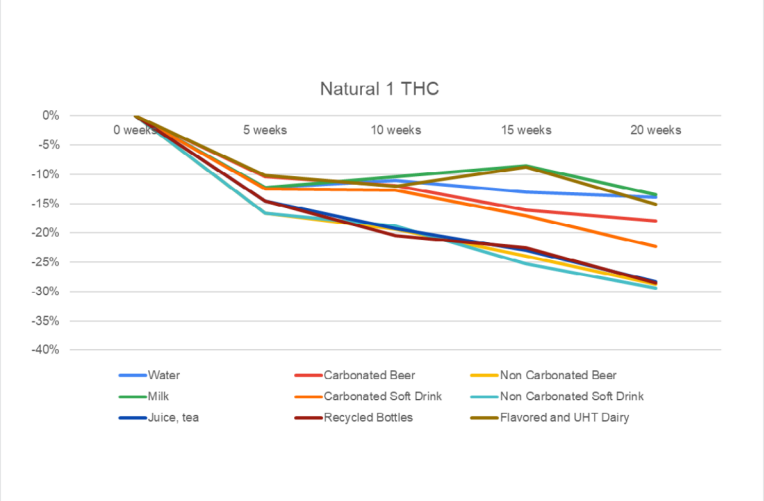
NOTE: The legend in the charts refers to the type of application each bottle is formulated for, and in some cases, whether the bottle was carbonated or not

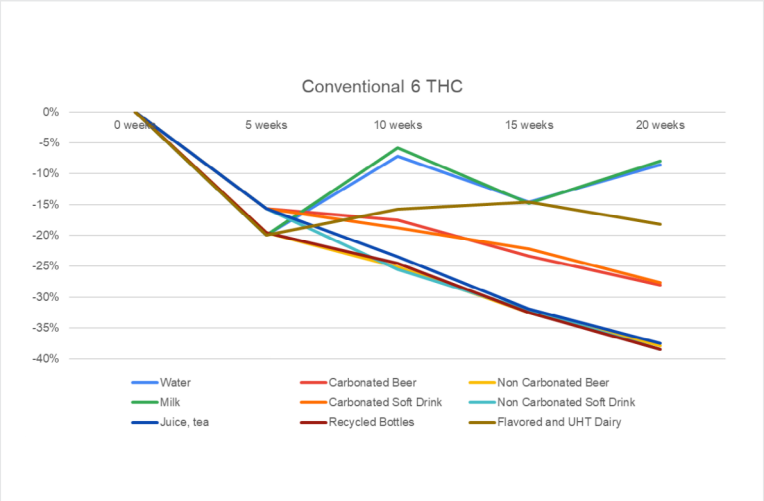
Results by Cannabinoid: THC

Observations

- Natural 1, with average loss of 22.0%, has less cannabinoid potency loss in all packaging types than Conventional 6 with average loss of 27.0%
    - Loss levels are relatively high, see section on Oxidation for what happened.
- We observed clustering of the package types where the pH Neutral liquids: in Milk, Flavored/UHT Dairy and Water perform the best with THC. Therefore, it's expected that pH is a contributing factor in the degradation rate of THC.

Avg loss by pH & active	pH 3.5 CBD	pH 7 CBD	pH 3.5 THC	pH 7 THC
	-4.5%	-2.8%	-30.3%	-12.9%

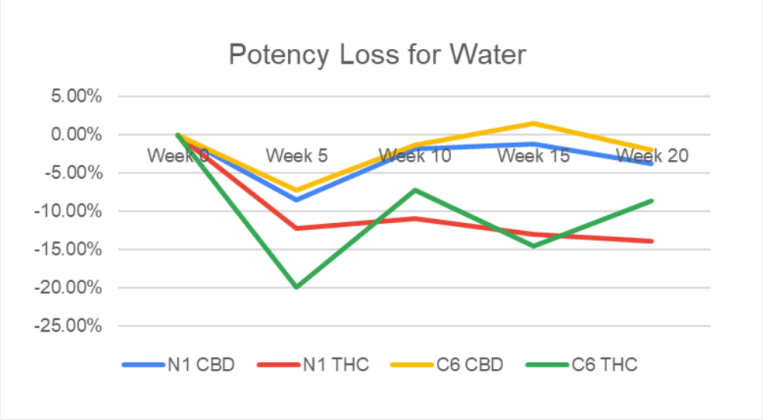


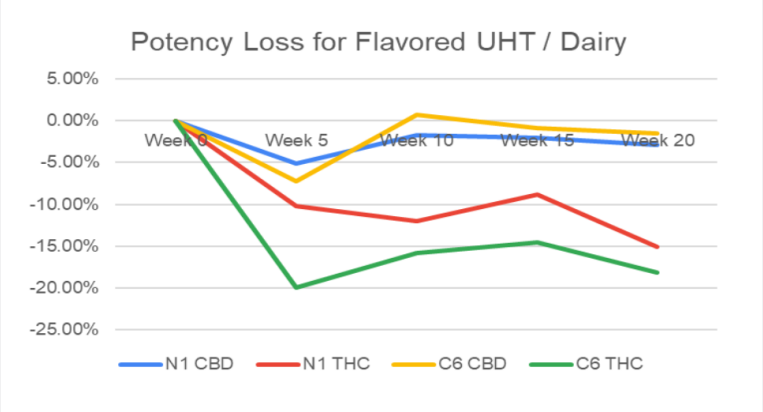


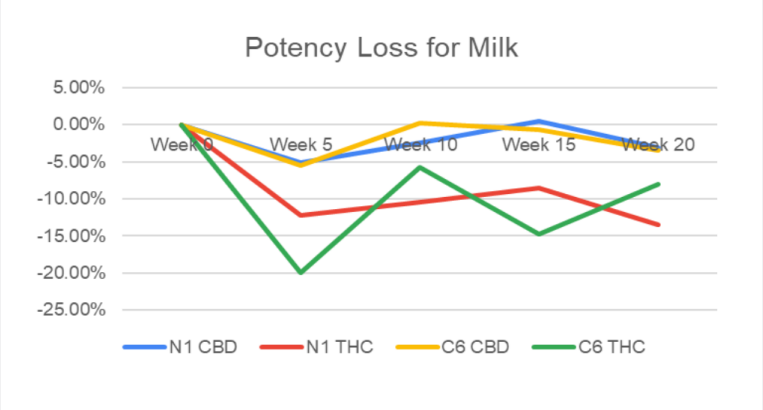
NOTE: The legend in the charts refers to the type of application each bottle is formulated for, and in some cases, whether the bottle was carbonated or not

Results by Packaging Type: low acid, pH ~ 7.0

Immaterial difference in the cannabinoid potency loss between between Natural 1 CBD and Conventional 6 CBD emulsion systems.







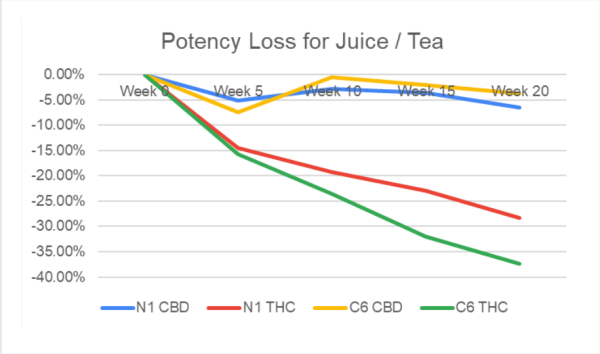
NOTE: The legend in the charts refers to the type of application each bottle is formulated for, and in some cases, whether the bottle was carbonated or not

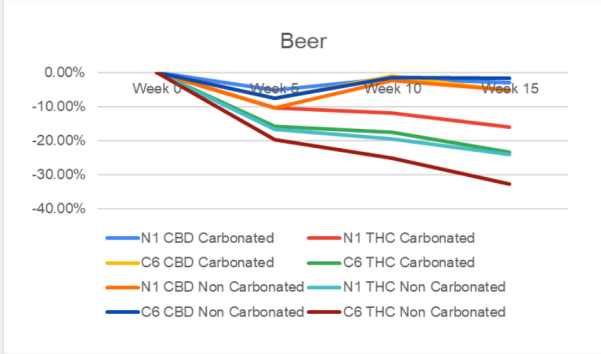
Results by Packaging Type: high acid, pH ~ 3.5

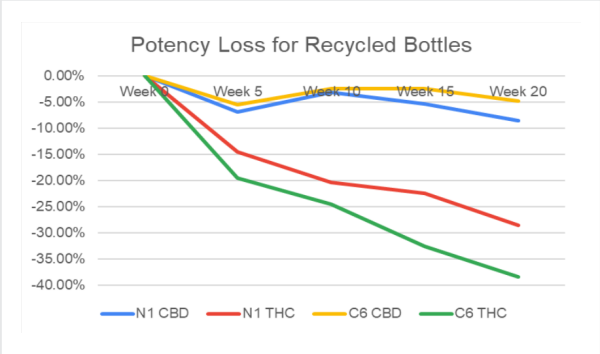
Observations

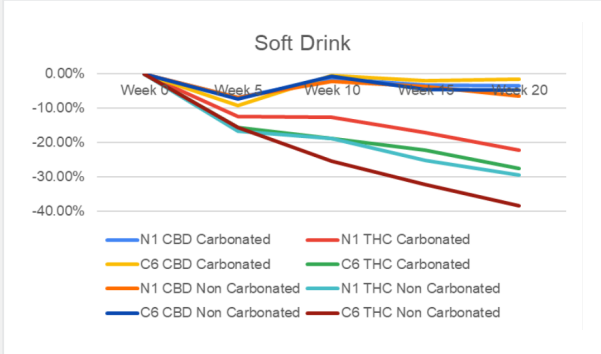
- Immaterial difference in the cannabinoid potency loss between between Natural 1 CBD and Conventional 6 CBD
- Natural 1 emulsion system maintains potency better than Conventional 6 for THC in all package types.
- Carbonation offers a significant reduction in loss of THC concentration by displacing oxygen and causing a positive pressure in the bottle.

Potency Loss		N1 CBD	N1 THC	C6 CBD	C6 THC
Beer	Carbonated	-3.10%	-17.92%	-4.07%	-28.0%
	Non-carbonated	-4.48%	-28.75%	-2.04%	-37.8%
Soft Drink	Carbonated	-3.4%	-22.3%	-1.5%	-27.6%
	Non-carbonated	-6.6%	-29.4%	-4.8%	-38.4%









NOTE: The legend in the charts refers to the type of application each bottle is formulated for, and in some cases, whether the bottle was carbonated or not

So what happened to all the THC?

Packaging Absorption

No cannabinoids were detected on any of the PET packages. This indicates that all cannabinoid loss is due to something other than absorption onto the packaging. The packaging was rinsed with water then 200 ml of Acetonitrile was used to rinse the PET bottles over 24 hours.

Oxidation

First recognized at 15 weeks, we can see cannabinoids in the THC samples that were not present previously. These are indicative of oxidation being detected. Below are the week 20 results. We theorize that the carbonation is displacing oxygen in the system thereby reducing oxidation.

WERE CANNABINOIDS NOT PREVIOUSLY PRESENT DETECTED AT 20 WEEKS?

Other Cannabinoids		N1 CBD	N1 THC	C6 CBD	C6 THC
Water		No	CBD, CBC, CBG	No	CBG
Beer	Carbonated	No	CBN, CBD, CBG, CBC	No	CBN, CBG, THCVA
	Non-carb	No	CBN, CBD, CBG, CBC	No	CBN, CBG
Milk		No	CBD, CBC, CBG	No	CBN, CBG
Soft Drink	Carbonated	No	CBN, CBD, CBG, CBC	No	CBN, CBG, THCA
	Non-carb	No	CBN, CBD, CBG, CBC	No	CBN, CBG, THCV
Juice, tea		No	CBN, CBD, CBG, CBC	No	CBN, CBG
Recycled Bottles		No	CBN, CBD, CBG, CBC	No	CBN, CBG, CBC, THCA
Flavored and UHT Dairy		No	CBD, CBC, CBG	No	CBN, CBG, THCV

What is oxidation and why should I care?

Oxidation is a chemical reaction where a compound gains oxygen and loses an electron. In the case of THC, when in a system with high oxygen levels, the THC could be oxidized and thereby lose concentration of the active over time. Oxidation can also cause the flavor of a beverage to change.

What causes oxidation to occur?

There are several drivers that can catalyze (start) an oxidation reaction. This includes water with metal ions, light, heat and high amounts of oxygen in manufacturing or oxygen ingress into the packaging. This reaction appears to be more deleterious in high acid (pH = 3.5) systems than low acid (pH = 7) systems based on the sample collected in this study.

Above: Solid color and additive masterbatches have been the industry wide best practice for coloring polymers throughout the globe.

Conclusions

- Immaterial difference in the cannabinoid potency loss between between Natural 1 CBD and Conventional 6 CBD
- Natural 1, with average loss of 22.0% THC, has less cannabinoid potency loss in all packaging types than Conventional 6 with average loss of 27.0% THC.
- We observe that pH neutral liquids such as Milk, Flavored/UHT Dairy and Water bottles perform the best with THC. Therefore, it's expected that pH is a contributing factor in the degradation rate of THC with neutral pH beverages having less THC loss than high acid beverages.
- THC potentcy retention is improved under carbonated conditions as carbonation displaces oxygen in the bottle, reducing oxidation. Additionally carbonation creates a positive pressure limiting oxygen ingress.

Were the objectives met?

01 Determine if any changes in cannabinoid concentration (loss) occur in PET bottles due to packaging absorption. ✓

> No cannabinoids were detected absorbed onto the PET packages at 20 weeks.

02 Determine if any of the additives within the polymer offer protection to the cannabinoids. ✗

> Oxidation due to high level of O_2 dissolved in the beverage and O_2 in the headspace, was so overwhelmingthat any advantages offered by various additives were not able to be observed.

Above: The name "Highwater" appearing on the depicted bottle is for illustration purposes only for the purposes of this presentation. Penn Color does not claim ownership of or any rights in the name "Highwater", and does not intend to use the name "Highwater" on or in connection with a commercial brand for bottled water.

What does this mean for cannabinoids in PET?

CBD oxidizes very slowly and can withstand environments with high levels of oxygen significantly better than THC, which is easier to oxidize.

To avoid oxidation and design a beverage in a PET bottle we recommend the following:

- Use filtered water to prevent metal ions from catalyzing the oxidation reaction.
- Avoid high heat thermal processes in beverage manufacturing.
- Use a PET package with appropriate barrier to light.
- Remove oxygen by de-aerating water, nitrogen flushing or carbonating the beverage to displace oxygen prior infusion with THC emulsion. Oxygen levels need to be measured throughout the manufacturing process as well as immediately after bottling. (Contact Anton Paar for equipment to perform these measurements)
- Avoid oxygen ingress by using a cap that fits firmly on the package. Consider a cap with enhanced barrier to gas.
- Avoid oxygen ingress by choosing a PET bottle with a low oxygen transmission rate and add an active oxygen scavenger additive to the packaging.
- Add antioxidants to the beverage to protect the THC over the course of its shelf life.
- Use a filling technology that helps reduce oxygen in the headspace.

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