Potential Risks from Cannabis-Infused Beverages: A Critical Review

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ABSTRACT

Although Canada legalized cannabis beverages in 2019, most available research on acute cannabis intoxication derives from dried flower and edible products. The distinct bioavailability and pharmacokinetic properties of phytocannabinoids ingested from beverages, however, contribute to significantly different acute and long-term effects that need to be better understood to ensure consumer safety. **Objective:** This review investigates existing cannabis beverage literature, with a particular focus on acute intoxication effects. **Method:** *PubMed, PsycINFO* and *Web of Science* databases were systematically searched. A structured search generated 29 eligible studies, comprising studies of consumption patterns and beliefs, advertisements and marketing, acute effects in human models, and drink composition. **Results:** Human studies report aversive acute subjective and physiological effects induced by cannabis beverages in healthy, infrequent users. Beverages also showed inaccurate cannabinoid labeling, posing potential risks to consumers. This review highlights the paucity and inconsistency of available research, further exacerbated by the sheer diversity of formulations investigated, while beginning to address some questions surrounding the safety and risks associated with cannabis beverages. **Conclusions:** Given the extensive differences in effects across cannabis-infused beverages, and the growing 'drinkables' market, it is essential that more studies directly examine both acute and long-term impacts of cannabis beverage consumption.

Key words: = cannabis beverages; cannabis; acute intoxication; cannabinoids; systematic review

Canada legalized recreational cannabis in October 2018 to improve safety regulations and reduce associated health risks (Health Canada, 2022a). By October 2019, the Canadian government expanded the provision of quality-controlled cannabis products to include both edible and concentrate products such as topicals, extracts, and beverages (Department of Justice, 2021; Rubin-Kahana et al., 2022). Recent amendments to the *Cannabis Act* now allow adults to possess up to 17.1L of cannabis-infused beverages for recreational purposes while maintaining controls to prevent overconsumption (Health Canada 2022a). Other regulations implemented for the sale of cannabis edibles include child-resistant packaging, prominent

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health warning labels, serving size, and nutritional information (Ventresca & Elliott, 2022). Improved manufacturing standards are critical to ensure consistent phytocannabinoid content labeling and consistent dosing for consumers (Miller et al., 2022).

The onset and duration of Δ^9-tetrahydrocannabinol (THC), the primary psychotropic phytocannabinoid constituent with affinity to bind to cannabinoid receptor 1 (Kendall & Yudowski, 2017), effects differ across cannabis products. For instance, THC bioavailability and pharmacokinetics are highly dependent on the route of administration and vehicle composition, with edible products often metabolising more slowly than inhaled smoked or vaporised cannabis (Thayer et al., 2019; Vandrey et al., 2017). Thus, despite single drinkable cannabis beverages maintaining a 10 mg THC limit (Health Canada, 2022a), the neurocognitive effects resulting from their consumption will differ from dried flower or non-beverage edibles (Thayer et al., 2019; Vandrey et al., 2017). Individuals consuming cannabis edibles, including beverages, can experience delayed intoxication relative to smoking/vaping due to slower delivery and bioactivation, increasing overdose risk (Russel et al., 2018). Effects on cognition, memory, and driving performance are modulated by variable amounts of cannabidiol (CBD) and THC:CBD ratios (Arkell et al., 2020), and memory deficits may be further exacerbated by psychotropic constituents in cannabis-infused energy drinks, such as caffeine (Panlilio et al., 2012).

However, despite the growing popularity of cannabis beverages in Canada, most acute cannabis effects research derives from dry cannabis flower inhalation or non-beverage edibles (Russel et al., 2018). Considering the novelty of cannabis beverages as a consumable product, a broader examination of research pertaining to their consumer reach, acute effects, and composition is necessary to address potential risks for consumers and guide future research avenues. Thus, the current review provides a critical review of empirical findings on cannabis-infused beverages across the aforementioned domains.

METHODS

Search Strategy

Table 1. *Search Phrases Employed for PsycINFO, PubMed and WoS Article Search*

Database	Boolean Search Phrase	Number of Results
PsycINFO (via OVID)	*(DE "Cannabis Infused Drink" OR DE "Cannabinoid Infused Drink" OR DE "Cannabis Drink" OR DE "Cannabinoid Drink" OR DE "CBD Drink" OR DE "Tetrahydrocannabinol Infused Drink" OR DE "THC Infused drink" OR DE "Weed Drink" OR DE "Weed Infused Drink" OR DE "Marijuana Drink" OR DE "Marijauna Infused Drink" OR DE "Cannabis Infused Beverage" OR DE "Cannabinoid Infused Beverage" OR DE "Cannabis Beverage" OR DE "Cannabinoid Beverage" OR DE "CBD Beverage" OR DE "Tetrahydrocannabinol Infused Beverage" OR DE "THC Infused Beverage" OR DE "Weed Beverage" OR DE "Weed Infused Beverage" OR DE "Marijuana Beverage" OR DE "Marijauna Infused Beverage")*	884
PubMed	*("Cannabis Infused Drink" OR "Cannabinoid Infused Drink" OR "Cannabis Drink" OR "Cannabinoid Drink" OR "CBD Drink" OR "Tetrahydrocannabinol Infused Drink" OR "THC Infused drink" OR "Weed Drink" OR "Weed Infused Drink" OR "Marijuana Drink" OR "Marijauna Infused Drink" OR "Cannabis Infused Beverage" OR "Cannabinoid Infused Beverage" OR "Cannabis Beverage" OR "Cannabinoid Beverage" OR "CBD Beverage" OR "Tetrahydrocannabinol Infused Beverage" OR "THC Infused Beverage" OR "Weed Beverage" OR "Weed Infused Beverage" OR "Marijuana Beverage" OR "Marijauna Infused Beverage")*	5523

Web of Science (Core collection)	*TS=((cannabis* OR cannabinoid* OR CBD OR infused OR tetrahydrocannabinol OR tetra-hydrocannabinol OR marihuana* OR marijuana* OR THC OR weed) NEAR/3 (beverage* OR drink*))* *TI=((cannabis* OR cannabinoid* OR CBD OR infused OR tetrahydrocannabinol OR tetra-hydrocannabinol OR marihuana* OR marijuana* OR THC OR weed) NEAR/3 (beverage* OR drink*))* *AB=((cannabis* OR cannabinoid* OR CBD OR infused OR tetrahydrocannabinol OR tetra-hydrocannabinol OR marihuana* OR marijuana* OR THC OR weed) NEAR/3 (beverage* OR drink*))*	925

Table 2. *Search Phrases Employed for PsycINFO, MEDLINE and WoS Article Search*

Database	Boolean Search Phrase	Number of Results
PsycINFO (via OVID)	*((Cannabis/ OR exp Cannabinoids/) AND exp Beverages/) use medall* *(exp Cannabis/ AND exp "Beverages (Nonalcoholic)"/) use psyh* *((bhang? OR cannabi* OR ganja? OR hashish? OR hemp? OR marihuana? OR marijuana? OR txid1302822 OR txid3482 OR txid3483 OR CBD OR THC) AND (beverage* OR drink OR drinks OR thandai OR lassi)).ti.* *((bhang? OR cannabi* OR ganja? OR hashish? OR hemp? OR marihuana? OR marijuana? OR txid1302822 OR txid3482 OR txid3483 OR CBD OR THC) ADJ5 (beverage* OR drink OR drinks OR thandai OR lassi)).ab,kf,kw,id.* *((bhang-infus* OR cannabis-infus*) AND (beverage* OR drink OR drinks OR thandai OR lassi)).tw,kf,kw,id.* *or/1-5*	42
MEDLINE (via OVID)	*((Cannabis/ OR exp Cannabinoids/) AND exp Beverages/) use medall* *(exp Cannabis/ AND exp "Beverages (Nonalcoholic)"/) use psyh* *((bhang? OR cannabi* OR ganja? OR hashish? OR hemp? OR marihuana? OR marijuana? OR txid1302822 OR txid3482 OR txid3483 OR CBD OR THC) AND (beverage* OR drink OR drinks OR thandai OR lassi)).ti.* *((bhang? OR cannabi* OR ganja? OR hashish? OR hemp? OR marihuana? OR marijuana? OR txid1302822 OR txid3482 OR txid3483 OR CBD OR THC) ADJ5 (beverage* OR drink OR drinks OR thandai OR lassi)).ab,kf,kw,id.* *((bhang-infus* OR cannabis-infus*) AND (beverage* OR drink OR drinks OR thandai OR lassi)).tw,kf,kw,id.* *or/1-5*	309
Web of Science (Core collection)	*TI=(((bhang? OR cannabi* OR ganja? OR hashish? OR hemp? OR marihuana? OR marijuana? OR txid1302822 OR txid3482 OR txid3483 OR CBD OR THC) AND (beverage* OR drink OR drinks OR thandai OR lassi)))* *AK=(((bhang? OR cannabi* OR ganja? OR hashish? OR hemp? OR marihuana? OR marijuana? OR txid1302822 OR txid3482 OR txid3483 OR CBD OR THC) AND (beverage* OR drink OR drinks OR thandai OR lassi)))* *TS=(((bhang? OR cannabi* OR ganja? OR hashish? OR hemp? OR marihuana? OR marijuana? OR txid1302822 OR txid3482 OR txid3483 OR CBD OR THC) NEAR/2 (beverage* OR drink OR drinks OR thandai OR lassi)))* *ALL=(((bhang-infus* OR cannabis-infus*) AND (beverage* OR drink OR drinks OR thandai OR lassi)))* *#4 OR #3 OR #2 OR #1*	319

A systematic literature search was conducted in September 2022 using *PsycINFO, PubMed*, and *Web of Science*, resulting in 7,332 articles (Table 1). An additional search of the beverage 'Bhang' was conducted in May 2023 using the same databases (Table 2), producing 670 results. Title and abstract screening identified articles meeting inclusion criteria; full-text review determined their eligibility.

Our inclusion criteria comprised English-written, peer-reviewed primary research articles examining cannabis, hemp, or Bhang beverages. Acute effect articles in animal models were included, so long as the cannabis beverages were consumed by choice and not injected. There was no limit on age, sex, or the presence of comorbid disorders. Meta-analyses and review articles were excluded; however, their reference lists were screened to identify other relevant articles.

RESULTS

This review broadly explores the current state of available cannabis beverage literature. Our search identified 8,002 articles, with 29 meeting inclusion criteria (Figures 1 and 2). Results describe studies examining consumption patterns and beliefs (n = 11), marketing tactics (n = 1), acute effects in humans (n = 6), and compositional aspects of cannabis and hemp beverages (n = 11).

Figure 1. *Inclusion Flowchart from Initial Search*

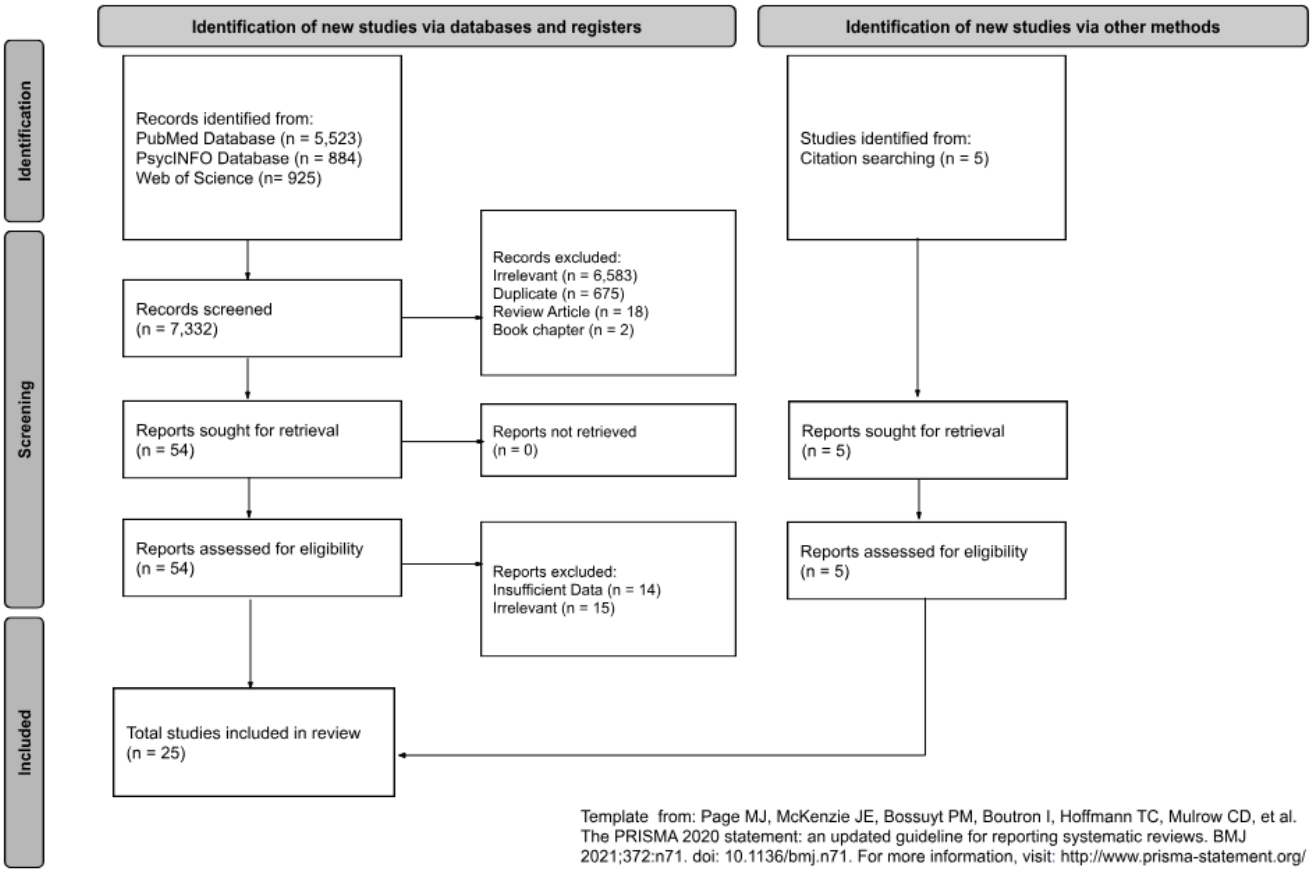
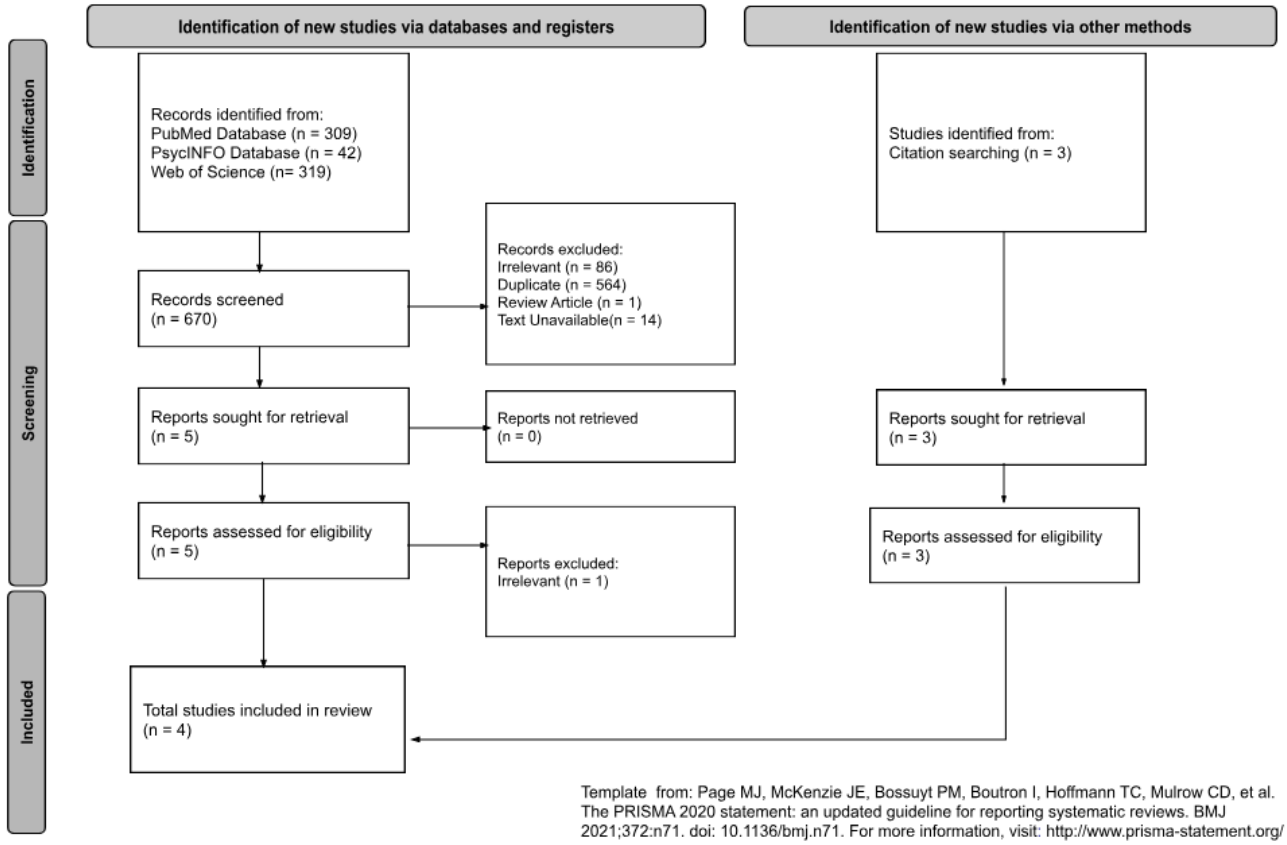


Figure 2. *Inclusion Flowchart from Secondary Search*



Consumption Patterns and Beliefs

Studies exploring consumption patterns are summarized in Table 3. Although cannabis drinks were consistently chosen less often than smokeable or edible cannabis products (Donovan et al., 2022; Dowd et al., 2023; Dunbar et al., 2022; Fedorova et al., 2021; Goodman et al., 2020; Kerr et al., 2019; Schauer et al., 2020; Sikorski et al., 2021; Sullivan et al., 2022), use rates varied significantly. Consumption of cannabis beverages was particularly low among youth, observed in less than 0.1% of participants over four years (Sullivan et al., 2022). Adult past-month cannabis users reported greater beverage use in a Canadian study, where 27.3% reported lifetime consumption and 14.3% reported past-year consumption (Sikorski et al., 2021). Among past-year consumers (Sikorski et al., 2021), 51.8% reported monthly use, averaging 2.8 drinks monthly, and 19.1% consumed beverages weekly, with drinks primarily being sourced from family or friends (25.7%). Still, only 13.8% and 10% could accurately estimate the amount of THC and CBD present in their products, respectively. In US populations, 4.3% of adult past-month users reported consuming beverages (Schauer et al., 2020). Legal beverage purchasing grew from 71.4% in 2020 to 81.6% in 2021 (Wadsworth et al., 2023), and purchasing was 1.5-2.5X higher in legal compared to illegal markets (Goodman et al., 2020). Legal sourcing did vary by sex, however, as males had significantly greater odds of sourcing "some" drinks illegally (Wadsworth et al., 2023). Clinical populations in the US reported low consumption of cannabis beverages; 1.1% of cancer patients endorsing past-year cannabis use consumed beverages and 0.8% of lifetime users consumed beverages (Donovan et al., 2022). Among epilepsy patients, cannabis beverages were consumed less than all other modalities (7.7%), but were the most prevalent method consumed by patients 51-60 years old (Kerr et al. 2019).

Among CBD-only consumers (Dunbar et al., 2022), 10.2% reported past-year beverage use, 8.6% reported lifetime use, and 9.8% reported past-month use, 14.7% of which exclusively used

CBD beverages and 8.4% combined other cannabis products. Alternatively, 2.6% consumed alcoholic CBD beverages in their lifetime, and 3.1% reported past-year consumption.

Preferences for major cannabinoids were reportedly inconsistent across studies. Cannabis consumers from one study reported a preference for CBD-dominant (endorsed by n = 18 participants) over THC-dominant beverages (endorsed by n = 6 participants; Fedorova et al., 2021). The opposite has been observed in other research; among n = 38 cannabis beverage consumers, 34% were more likely to use THC-dominant products, while 18% preferred CBD-dominant products (Dowd et al., 2023). Users noted "enjoyment" and "wanting something to do" as primary motivations for consumption on the Comprehensive Marijuana Motives Questionnaire (CMMQ; Lee et al., 2009) Short Form, and reported that beverages took an average of 19 minutes for acute effects to onset – significantly quicker than edibles. Interest in replacing alcohol with a cannabis beverage dropped to 15.8% from 26.6% in 2017 (Charlebois et al., 2020), and substitution motivations were attributed to therapeutic reasons (31.8%), curiosity (25.8%), and psychoactive effects (17.9%)

Table 3. *Summary of Findings on Cannabis Beverage Consumption Patterns and Beliefs*

Author(s) Year	Purpose	Subjects	Protocol	Summary of Results
Charlebois et al. 2020	Measure perceptions surrounding edible use in Canada.	General Canadian population - *N* = 1051 participants received the survey, and 94% responded - Age range ≥18 years old	- An online survey was administered to randomly selected individuals in 2019 to measure aspects of cannabis use, including: perception of legalisation, legal consumption patterns, social stigma, and perceptions of cannabis edibles.	- 15.8% of respondents would replace an alcoholic drink with a cannabis-infused drink (dropping from 26.6% in 2017). - 14.8% of respondents would be willing to substitute a conventional alcoholic drink with cannabis. - Reasons for substituting alcohol with cannabis beverages included therapeutic reasons (31.8%), curiosity (25.8%), and psychoactive effects (17.9%).
Donovan et al. 2022[a]	Measure cannabis use patterns in a population of young adults with cancer.	Cancer patients -Age range = 18–39 years old - *n* = 144 males; *n* = 328 females; *n* = 4 unspecified gender	- An online questionnaire was administered to patients to measure aspects of cannabis use, including: motives, consumption methods, effectiveness, side effects, source of products, and medical licence status.	- Among weekly cannabis users, 49% reported eating or drinking cannabis. - Of past-year cannabis consumers (*n* = 352), four indicated they were using cannabis beverages purchased from a legal storefront. - Of the patients endorsing cannabis use prior to the last year (*n* = 127), one reported consuming cannabis beverages.
Dowd et al. 2023	Examine various factors related to oral cannabis use.	Cannabis users in the US - Mean age=32 years old - *n* = 174 males; *n* = 185 females	Administered online survey program to participants measuring aspects of cannabis use, including: prevalence, motives, formulation, THC/CBD dose, perceived subjective effects, co-use (alcohol), and advice received about reducing use symptoms.	- *n* = 38 (10%) of users consumed cannabis beverages, making it the second least prevalence mode reported. - Beverages, baked goods, gummies, hard and chocolate candy users reported significantly greater "enjoyment" motives compared to oils/tinctures. - Beverages, baked goods, and chocolate candy users reported significantly greater "wanting something to do" motives compared to oils/tinctures. - Beverage users displayed a trend toward the highest scores for using "to replace the use of another drug/medicine", though this was not significant.

				- 34% (n =13) of cannabis beverage consumers used THC-dominant products, 24% (n = 9) used a 1:1 ratio of THC:CBD, 18% (n = 7) used CBD-dominant products, and 24% (n = 9) were unsure about the cannabinoid composition. - Using only data from 35 cannabis beverage consumers, participants reported that beverages took approximately 19 minutes (SD = 15) for their effects to onset, which was a significantly lower onset duration compared to baked-good and gummy candy consumers.
Dunbar et al. 2022	Explore patterns and correlates of cannabidiol product and marijuana co-use in a sample of young US adults.	Young adults in the US - Mean age(SD) = 22.6(0.8) years old - N = 2534 males and females	- Examined cross-sectional survey data collected from wave 12 of the CHOICE-STRATA cohort study. - The survey assessed for lifetime, past-year, and past-month frequency, as well as the type of CBD products used, frequency and amount of cannabis consumed, and indicators of problematic cannabis use. - Differences in CBD use between participants reporting past-month use of CBD but not marijuana products ("CBD-only") and those who co-use both CBD and marijuana products.	**Alcohol Containing Cannabis Beverages** - 2.6% reported lifetime use of CBD beverages - 3.1% reported past-year use of CBD beverages - 3.1% reported past-month CBD beverages - 1.5% reported past-month use of CBD-only beverages - 3.6% reported past-month CBD and marijuana use - No significant differences in rates of use between past-month CBD-only and past-month CBD and marijuana groups for those who consumed alcoholic cannabis beverages. **Alcohol-free Cannabis Beverages** - 8.6% reported lifetime use of CBD beverages - 10.2% reported past-year use of CBD beverages - 9.8% reported past-month CBD beverages - 14.7% reported past-month use of CBD-only beverages

				- 8.4% reported past-month CBD and marijuana use - No significant differences in rates of use between past-month CBD-only and past-month CBD and marijuana groups for those who consumed alcohol-free cannabis beverages.
Fedorova et al. 2021	Measure cannabis use patterns and cannabinoid preferences.	Recent cannabis users (past 90 days) - Mean age(*SD*) = 25.3(2.5) years old - *n* = 147 males; *n* = 92 females	Data from year 5 of a longitudinal quantitative survey was analysed which measured aspects of cannabis use, including: CBD versus THC-dominant use frequency, mode of administration, general use frequency, and motives. - Cannabis users were classified as either CBD dominant users or THC dominant users. These groups were further divided into four subgroups: (1) (CBD dominant): CBD-only (2) (CBD dominant): Mostly CBD (3) (CBD dominant): Half CBD/half THC (4) (THC dominant): Some CBD	The following rates of cannabis beverage consumption were recorded in each subgroup: - CBD-only: *n* = 11 (19.3%) - Mostly CBD: *n* = 0 (0%) - Half CBD/half THC: *n* = 7 (26.9%) - Some CBD: *n* = 6 (8.7%) - Therefore, the CBD-only users had the largest number of people using cannabis beverages (*n* = 11), but the half CBD/THC subgroup had the greatest proportion of beverage consumers (26.9%). - Drinks and edibles were tied for highest overall prevalence in the half CBD/THC subgroup, compared to all other modes of use.
Goodman et al. 2020	Examine associations between the legal status of non-medical cannabis and patterns of consumption in Canada and legal and illegal regions of the US.	Male and Female participants from Canada and the US - Age range = 16-65 years old - *N* = 27,042 Canada (*n* = 9976) Illegal US states (*n* = 9686)	- Data was collected using self-completed web-based surveys assessing aspects of cannabis use, including: measurement windows (lifetime, most recent and current use), frequency and prevalence of cannabis use, type of cannabis products used, and age of first using cannabis.	**Prevalence of use of cannabis beverages % (n)** - Canada: 8.1% (224), - Illegal US states: 8.7% (201) - Legal US states: 17.0% (430) **Regular (daily and weekly) use of cannabis beverages among past 12-month cannabis users** - Canada: 38.4% - Illegal US states: 58.9% - Legal US states: 30.0%

		Legal US states (n = 7362)		**Frequency of use and prevalence of regular cannabis beverage use among past 12-month users % (n)** **<Once a month:** - Canada: 33.7% (71) - Illegal US states: 17.3% (33) - Legal US states: 41.6% (171) **Monthly:** - Canada: 28.0% (59) - Illegal US states: 24.2% (46) - Legal US states: 28.4% (117) **Weekly:** - Canada: 29.1% (61) - Illegal US states: 41.7% (79) - Legal US states: 18.9% (78) **Daily:** - Canada: 9.3% (20) - Illegal US states: 16.8% (32) - Legal US states: 11.1% (46)
Kerr et al. 2019	Measure cannabis use patterns among individuals who received treatment for epilepsy.	Patients receiving treatment for epilepsy - Mean age(*SD*) = 38(12.4) years old - n = 19 males; n = 20 females	Patients were administered a survey measuring aspects of cannabis use, including: consumption method, source of purchase, use frequency, and cannabinoid content.	- Cannabis beverages were the least used mode of cannabis, with 7.7% of patients reporting use. - Cannabis beverages were a preferred mode of cannabis consumption for patients between 51–60 years old.
Schauer et al. 2020	Identify cannabis use patterns and prevalence of multimodal consumption.	Recent cannabis users (past 30 days) - N = 6174 males and females - Age range≥18 years old	Administered the 2016 BRFSS survey via telephone to measure prevalence of different consumption methods, multimodal use, and demographic correlates.	- 4.3% of the sample reported cannabis beverage consumption, compared to 90.7% of participants reporting smoking cannabis. - 0.2% of cannabis beverage users reported it as their only mode of consumption.
Sikorski et al. 2021	Measure cannabis use patterns and rates.	Recent cannabis users (past 30 days) - Mean age (*SD*) = 23.9(4.3) years old - n = 110 males; n = 75 females	Administered the online CPCT survey to measure aspects of cannabis use, including: mode of consumption, purchase source, price, average consumption rate, and cannabinoid content.	- 27.3% had used beverages at least once in their lifetime. - 14.3% had used beverages within the past year, 51.8% of which used monthly and 19.1% used weekly.

- Participants reported using an average of 2.8 beverages (range: 0.3–21.8) per month.
- 13.8% provided a valid response about how much THC might be present in their cannabis beverages.
- 3.2% of users reported an invalid response (i.e., an unrealistic possible amount).
- 10% provided a valid response of how much CBD is present in their cannabis beverages.
- Overall, individuals who used beverages, concentrates, tinctures, and edibles were more likely to report a valid range of THC and CBD in their products than individuals who used other modes of consumption.

Source of purchasing a cannabis beverage:

Social Category:
- Shared around a group of friends = 7.8%
- From a family member or friend = 25.7%
- From someone else I know = 16.2%

Dealer Category:
- In person = 2.3%
- Mail delivery = N/A

Retail Category:
- Medical marijuana from a store (e.g. dispensary) = 20.5%
- Medical marijuana mailed from a licensed producer = 4.7%
- Non-medical marijuana from a store = N/A
- Ordered it online (not from a licensed producer) = 6.6%

Grown/Made Category:
- On my own = 19.9%
- For me = 20.4%

				Therefore, the most likely source of cannabis beverages amongst past-month users was from a family member or friend.
Sullivan et al. 2022	Identify the associations between previously identified common risk factors of early substance use experimentation and initiation from the ABCD study.	Male and female participants (N = 11,876 at baseline) Mean age = 9.5 years old at baseline	- Data from the 11,876 participants enrolled in the ABCD study at baseline (Y0), with all available yearly follow-ups (Y1, Y2, Y3) - Biological measures and behavioural modules of substance use were collected.	**Proportion of participants reporting lifetime (Y0) or past-year (Y1–3) cannabis beverage use** - Both male and female participants from baseline and follow-up periods (Y0-Y3): <0.1% - Males at follow-up periods Y0, Y2, AND Y3: <0.1% - Males at Y1: 0.1% - Females at follow-up periods Y1 and Y3: <0.1% - Females at follow-up periods Y0 and Y2: 0%
Wadsworth et al. 2023	Examine cannabis use patterns amongst individuals who have purchased products legally.	Recent cannabis users (past 12 months) - Age range = 16–65 years old - 2020: n = 1830 males; n = 2822 females - 2021: n = 2485 males; n = 3317 females	- An online survey was administered between 2019–2021 to measure aspects of cannabis use, including: mode of consumption, use frequency, and legal product sourcing. - Only data from 2020–2021 will be reported as beverages were not yet legal in 2019.	- In 2020, 71.4% (of n = 1316) of participants who legally purchased all cannabis products in the past 12 months used beverages. - In 2021, 81.6% (of n = 1316 individuals) of participants who legally purchased all cannabis products in the past 12 months used beverages. - Consumers of beverages, dried flower, solid concentrates, vape oils, edibles, and hash/kief had higher odds of sourcing all products legally in 2021 vs. 2020. - Sex was associated with proportion of legal cannabis sourcing, where males had greater odds of sourcing "some" cannabis drinks legally. - Ethnicity/race was associated with amount of legal sourcing for all cannabis products except for beverages and vape oils. - Education was associated with legal sourcing for all cannabis products except beverages.

Note. Abbreviations: ABCD = Adolescent Brain Cognitive Development; BRFSS = Behavioural Risk Factor Surveillance System; CBD = Cannabidiol; CPCT = Cannabis Purchase and Consumption Tool; THC = Tetrahydrocannabinol. [a]Data reported within the table was received through correspondence with the first author.

Advertisement and Marketing

Marketing tactics and safety measures at Coloradoan dispensaries showed that 90% of stores followed appropriate security guidelines (e.g., signs indicating age requirements, customer identity verification, exterior security cameras), with similar beverage prices across dispensaries (~$6-8/serving) and cannabis beverages displayed on 16.3% of dispensary advertisements (Berg et al., 2017).

Acute Effects in Human Models

Studies exploring cannabis beverage effects in human participants are summarized in Table 4. Two of six studies were conducted in emergency care settings, whereas the remaining four studies directly acutely administered beverages and broadly examined subjective, neurocognitive, and physiological outcomes of cannabis ingestion.

Different reaction severities to accidental cannabis drink exposure were observed across n = 9 (2%) calls made to the emergency care room (Cao et al., 2016); one case described potentially toxic exposure causing vomiting, and two cases indicated adverse reactions inducing tachycardia, confusion, and mydriasis. In patients seeking emergency psychiatric care after consuming Bhang (a cannabis-infused beverage), patients were more likely to be chronic Bhang users and score significantly greater psychiatric ratings than controls, with greater "mania-like" symptoms (Chaudry et al., 1991).

Administration of a THC beverage increased pulse rate and anxiety in healthy subjects who were either occasional users or non-users (Karniol et al., 1974; Zuardi et al., 1982). THC ingestion altered time perception, but this effect was attenuated by combined THC+CBD doses (Karniol et al., 1974). THC+CBD at low, medium, and high-CBD dose combinations shifted subjective effects to be more pleasant, while medium and high-CBD dose combinations blunted the heart rate increase induced by low-CBD dose combinations and THC-alone. CBD-only lowered pulse rate and induced more pleasant subjective experiences than THC, whereas THC+CBD had no significant effect on subjective feelings (Zuardi et al., 1982).

Water-soluble CBD beverages increased plasma levels, bioavailability, half-life, and absorption rate of CBD compared to fat-soluble beverages (Hobbs et al., 2020). While the CBD elimination rate did not differ between beverages, CBD was more vastly distributed across tissue in participants consuming the fat-soluble drink.

Following hemp tea consumption, enzyme multiplied immunoassay technique did not detect any cannabis metabolites, whereas gas chromatography–mass spectrometry produced a positive THC screen in 7/20 participants' urine (Steinagle et al., 1999).

Table 4. *Summary of Findings on Acute Effects of Cannabis and Hemp Beverages in Human Models*

Author(s) Year	Purpose	Subjects	Protocol	Summary of Results
Cao[a] et al. 2016	Characterise edible marijuana exposures reported to poison centres within the US.	Individuals reporting toxic cannabis exposure. - Median age = 18 - *N* = 430 males and females	- Collected information from calls to the NPDS over two years which reported edible and drinkable cannabis exposure.	- 2% (*n* = 9) of calls were made regarding cannabis beverages, mostly in individuals ≥ 19 years old. Three toxic exposure reports following cannabis drink consumption were provided by the primary author: 1. 30 year old male: minor adverse reaction with tachycardia, confusion, mydriasis, and symptom coded "other". 2. 35 year old male: minor adverse reaction with symptom coded "other". 3. 27 year old male: potentially toxic exposure with vomiting
Chaudry et al. 1991	Systematically characterise symptoms of bhang-induced psychosis among individuals seeking psychiatric care in Pakistan.	Psychiatric patients in emergency care following consumption of Bhang. - Mean age(*SD*) = 25(6.71) - *n* = 15 males Control Bhang users presenting no psychiatric symptoms. - Mean age(*SD*) = 19(1.70) - *n* = 10 males	- Psychiatric symptoms were assessed using the BPRS in an emergency care setting.	Clinical estimation of bhang use frequency for patients and controls, respectively: - First time users: *n* = 1 (7%); *n* = 1 (10%) - Occasional users: *n* = 6 (40%); *n* = 9 (90%) - Chronic users: *n* = 8 (53%); *n* = 0 (0%) - Significantly more psychiatric patients were considered chronic bhang users compared to control participants. - Total BPRS scores for patients were significantly higher than ratings for the control group. Psychiatric symptoms were categorised into "factors" to describe symptom groupings that most significantly impacted differences in BPRS scores between patients and controls: - **Factor 1** ("mania-like behaviour": excitement, grandiosity, hostility, and uncooperativeness)

				accounted for 37.3% of total variance between groups. - **Factor 2** ("paranoid psychosis": suspiciousness, mannerisms & posturing, hallucinatory behaviour, and tension) accounted for 20.3% of variance between groups. - **Factor 3** ("cognitive dysfunction": unusual thought content, conceptual disorganisation, disorientation, blunted affect) accounted for 13.7% of variance between groups.
Hobbs et al. 2020	Compare the anti-inflammatory properties between a water-soluble and fat-soluble CBD beverage.	Healthy participants - Age range=22–51 years old - $n = 4$ males; $n = 6$ females	- 30mg fat-soluble or water-soluble CBD beverages were administered. - Blood samples measured CBD, PBMCs, and cytokines (i.e., IL-10, TNF) and were collected at baseline and 15, 30, 45, 60, 90, 120, 240, and 360 mins after beverage consumption. - Blood pressure was collected prior to each blood sample.	- More plasma CBD was detected in the water-soluble group between 45–120 min; peak CBD levels were significantly larger and were reached significantly faster than the lipid-soluble group. - Bioavailability of CBD was 4.5 times greater, the half-life of CBD was significantly longer, and the absorption rate was significantly greater in the water-soluble compared to the lipid-soluble group, though the elimination rate did not differ. - The volume of distribution of CBD throughout the body was significantly greater in the lipid-soluble compared to the water-soluble group. - Neither group displayed changes in SBP or DBP throughout the study. - Neither group displayed changes in levels of IL-10 or TNF between 0 and 90 minutes. - Across both groups, TNF levels were lower compared to baseline at 90 minutes in LPS-stimulated cells, but were not associated with CBD.
Karniol et al. 1974	Determine if high percentages of CBD induce less 'high' or psychotic-like	Healthy participants - Age range=21–34 years old - $N = 40$ males	- Participants either received a beverage containing 30 mg of THC, 15 mg, 30 mg or 60 mg of CBD, a combination of 30 mg of THC +	- Subjective effects onset between 30–50 min post-ingestion, peaked between 30–60 min following onset, and subsided 2 to 3 hours afterwards.

	effects than would be expected based on the concentration of THC.		either 15 mg, 30 mg or 60 mg of CBD, or a placebo beverage. - Pulse rate was measured before and after beverage consumption. - "Time Production Task": participants counted to a minute, either receiving no accuracy feedback (Estimation T1) or receiving feedback (Estimation T2). - This was repeated 45, 90, and 180 minutes following beverage ingestion, alternating without feedback (Estimation T3, T5, T7) and with feedback (Estimations T4, T6, T8). - At 55, 95, 155, and 185 min after beverage ingestion, participants were interviewed about subjective experiences which were graded by researchers from 0 to 4.	- Placebo and CBD-only beverages did not significantly alter psychological effects, time production accuracy, or pulse rate. - THC-only beverages produced significant psychological effects such as anxiety and near-panic occurring in waves, with 4 of 5 subjects scoring grade 4 effects. - THC-only significantly altered time perception at T3, T5, and T7 (without feedback) compared to the placebo beverage, with participants estimating time elapsing too quickly (averaging below 40 seconds), as well as at T4, T6, and T8 (with feedback), but with comparatively less significant underproduction. - THC-only increased pulse rate by 35% compared to baseline, peaking between 50–70 minutes following ingestion. - THC+CBD (15 mg, 30 mg, 60 mg) significantly reduced psychological effects compared to THC-only, and subjective feelings shifted from anxiety and panic to more pleasurable experiences. - THC+CBD (15 mg, 30 mg, 60 mg) significantly blunted time perception effects produced by THC, such that inaccuracies made on trials with feedback were not significantly different than the placebo group. - THC+CBD (15 mg) increased the average pulse rate by 53%; whereas THC+CBD (30 mg, 60 mg) significantly blunted this increase, reducing to an increase of 6.2% in the THC+CBD (60 mg) group.
Steinagle et al. 1999	Determine the presence of cannabis metabolites in urine following the consumption of a hemp beverage.	Healthy participants (no cannabis use in past 60 days) - Age range = 27–62 years old - $n = 7$ males; $n = 15$ females	Participants either received one 12-ounce cup of hemp tea, two 12-ounce cups of hemp tea, or one 12-ounce cup of placebo tea (orange pekoe tea).	Delta-9-THC was present in both hemp tea and hemp seed samples. - $n = 7$ (of 20) participants consuming hemp beverages had positive GC/MS results for 9,11 THC-COOH: four were initially positive after four hours (one of which tested positive again at

			- Hemp tea and hemp seed samples were analysed for the presence of THC using GC/MS. - Urine samples were collected at baseline and again 4, 8, and 24 hours following ingestion. - EMIT test was used to detect cannabis urinary metabolites, and GC-MS assays were used to identify presence of 9,11 carboxy-THC.	8 and 24 hours, and two of which tested positive again at 8 hours only), two were initially positive after eight hours, and one was initially positive after 24 hours. - Majority of positive tests ($n = 5$) came from the low hemp-dose group. - No metabolites were detected using the EMIT test.
Zuardi et al. 1982	Examine the impact of CBD on THC-induced anxiety in healthy individuals.	Healthy participants - Mean age = 27 years old - $n = 6$ males; $n = 2$ females	Five experimental sessions occurred (separated by at least 1 week) where participants were administered an oral mixture of: THC (0.5mg/kg), CBD (l mg/kg), a combination of THC+CBD (0.5 mg/kg+1 mg/kg), or placebo. - Pulse rate was collected before and 70 and 130 min following beverage ingestion. - At 30, 60, 120, and 180 min after drug ingestion, researchers interviewed participants about their subjective experiences, rated their anxiety on a scale of 0-3, and rated the predicted effects of C. sativa on a scale of 0-4. - Participants self-rated anxiety on the STAI, subjective symptoms using the ASRS-SF and the SBS, and drug-effects using the ARCI-Ma, before and 65 and 125 min after drug ingestion.	- Placebo and CBD drinks significantly decreased pulse rate after 1 and 2 hours, while THC and THC+CBD significantly increased pulse rate after 1 hour only. - Self-reported anxiety significantly increased in only the THC and THC+CBD groups. - Self-reported subjective effects were only measured in THC and THC+CBD groups, and significantly increased over time, with CBD altering feelings of being "quick witted" and "clear minded", and THC altering feelings of being "feeble", "incompetent", "muzzy", "discontented", "troubled" and "withdrawn". - THC-only and CBD-only produced opposite effects for subjective feelings of "alert-drowsy", "strong-feeble", "incompetent-proficient", "mentally-slow-quick-witted", and "muzzy-clear-minded". - CBD-only and THC-only produced significantly different feelings of "muzzy-clear minded" compared to placebo, but CBD+THC beverage did not produce significantly different effects compared to placebo.

Note. Abbreviations: ARCI-Ma = Addiction Research Center Inventory for Marihuana Effects; ASRS-SF = Analogue Self-Rating Scale for Subjective Feelings; BPRS = Brief Psychiatric Rating Scale; CBD = Cannabidiol; DBP = Diastolic Blood Pressure; EMIT = Enzyme Multiplied Immunoassay Technique; GC-MS = Gas Chromatography–Mass Spectrometry; IL-10 = Interleukin-10; LPS = Lipopolysaccharide; NPDS = National Poison Data System; PBMCs = Peripheral Blood Mononuclear Cells; SBP = Systolic Blood Pressure; SBS = Scale of Bodily Symptoms; STAI = Spielberger's State-Trait Anxiety Inventory; THC = Tetrahydrocannabinol; TNF = Tumour Necrosis Factor [a]Data reported within the table was received through correspondence with the first author.

Drink Composition

The compositional makeup of cannabis beverages was examined across 11 studies, which are summarized in Table 5. Three primary themes emerged across study aims: 1) examining the accuracy of beverage labeling; 2) examining cannabinoid makeup or potential beverage contamination; 3) examining how different preparation techniques impact cannabinoid levels.

Inaccurate and inconsistent cannabis beverage labeling was identified across three studies. THC was over-labeled in 61.5% of cannabis beverages, compared to 15.4% under- and 23.1% accurately labeled (Vandrey et al., 2015), while CBD was over-labeled in 78.57% of cannabis beverages, compared to 14.29% under- and 7.14% accurately labeled (Miller et al., 2022). Across 41 cannabis products, only six provided labels indicating the presence of cannabis and excluded other important requirements (e.g., ingredient lists, product name, expiration date; Lindsay et al., 2021); although it was not specified if this included beverage labels, beverage samples contained 0.01 mg of THC and 0.03 mg of CBD on average.

Several cannabinoids were quantified across cannabis and hemp drinks, including CBD, cannabinolic acid (CBDA), cannabinol (CBN), and THC (Christodoulou et al., 2023; Ciolino et al., 2018; Drager et al., 2022; Hazekamp et al., 2007; Lindsay et al., 2021; Miller et al., 2022; Pacifici et al., 2017; Song et al., 2023; Vandrey et al., 2015), and in some cases, trace levels of heavy metals and aflatoxins were also measured (Catenza et al., 2022; Greaves et al., 2021). An immunoaffinity column cleanup and enrichment step prior to liquid chromatography (LC), as required for determination of trace levels of aflatoxin and ochratoxin A in cannabis products, was validated and revealed no initial cannabis beverage contamination with toxins above method detection limits (Greaves et al., 2021). Moreover, CBD and THC drinks fell below maximum allowable consumable limits of 14 different heavy metals as observed through inductively coupled plasma (ICP)-MS, although tea samples still contained greater concentration ranges of heavy metals relative to other beverages (Catenza et al., 2022). Quantifiable THC content was observed in 31% of nonalcoholic hemp beverages (Drager et al., 2022). On the high end, THC content of 0.529 mg/L yielded a THC intake of 0.093 mg/day, resulting in an acute reference dose (ARfD; a measure of substance amount ingested with no appreciable health risk, expressed in milligrams per body weight in kilograms) exhaustion of 133%. In contrast, 88% of hemp teas had quantifiable THC, and its mean intake of 0.157 mg/day showed a much higher ARfD exhaustion of 224%. LC with diode array detection (LC-DAD) identified a respective average CBD content of 0.0058% (w/w), 0.0040% (w/w), and 0.033% (w/w) in hemp-based grapefruit sparkling coconut water, lemon sparkling black tea, and CBD coffee (Song et al., 2023). Other findings (Ciolino et al., 2018) yielded LC-DAD assay results of 0.042 mg/g of CBD in coffee beverage products ($n = 3$), 0.28 mg/g of CBD in flavoured liquid products ($n = 3$), and 0.30 mg/g of CBD and 0.012 mg/g of THC in aqueous supplement products ($n = 2$).

Two studies tested differences in cannabinoid content using LC in conjunction with tandem MS (MS/MS) based on altered tea preparations. Although changing water volume and increasing cannabis dosage did not significantly alter the THC or THCA concentration relative to a standard tea preparation, lowering the cannabis dose significantly reduced the concentration of both phytocannabinoids (Hazekamp et al., 2007). THC also significantly increased across boiling time length (10, 20, and 30 min), whereas THCA was minimally affected by boiling time. Conversely, a different study reported that increasing boiling times induced a trending decrease in the total cannabinoid concentration compared to a standard tea preparation (Pacifici et al., 2017); however, poor and inconsistent recovery rates of phytocannabinoids were observed, and THC:CBD ratios significantly decreased, due to lower extraction efficiencies of THC/THCA than CBD and CBDA.

Table 5. *Summary of Findings on Compositional Analyses of Cannabis Beverages*

Author(s) Year	Purpose	Composition Target & Analysis	Summary of Results	
Catenza et al. 2022	Determine the presence of metals in different cannabis products for safety analysis.	14 heavy metals were targeted for analysis: V, Cr, Co, Ni, Cu, Zn, As, Se, Mo, Cd, Hg, Tl, Pb, U. ICP-MS analysed various cannabinoid products, including beverages and teas. - This method was validated prior to sample analyses.	- $n = 12$ cannabis beverage samples were used for heavy metal analysis. - CBD content ranged from 2.5mg - 20mg, and THC content ranged from 0mg - 2.5mg. - $n = 4$ cannabis tea samples were used for heavy metal analysis, and all samples contained 10mg of CBD and 5mg of THC. Summary of the range of heavy metal concentrations (µg/Kg) in all beverage and tea products, respectively: V: 0.31 – 5.68; 75.51 – 106.30 Cr: 1.93 – 6.35; 143.52 – 326.76 Co: 0.05 – 1.45; 39.15 – 246.04 Ni: 0.63 – 4.96; 380.55 – 3,305.35 Cu: 2.80 – 61.20; 3,375.07 – 8,661.02 Zn: 28.19 – 261.62; 8,359.80 – 8,515.14 As: 0.79 – 2.41; 12.20 – 55.48 Se: 0.15 – 0.38; 25.65 – 122.83 Mo: 0.11 – 3.31; 16.23 – 200.20 Cd: 0.11; 6.91 – 40.65 Hg: 0.08; 1.73 – 5.47 Tl: <LOQ; 0.89 – 35.08 Pb: 0.17 – 1.76; 56.31 – 3189.23 U: 0.09; 2.58 – 7.03 - Tea and chocolate products had greater heavy metals concentrations compared to powders and beverages. - Heavy metal concentrations in all products were below the danger threshold for consumption.	
Christodoulou et al. 2023[a]	Determine a suitable technique for cannabinoid extraction in different liquid and solid forms of cannabis-based products.	- Cannabinoids of interest: CBC, CBD, CBG, CBN, OH-THC, THC, THC-COOH. - Cannabinoid concentration data was obtained via HPLC-MS analysis.	Soxhlet Extraction: **Hemp Tea (ug/g)** - CBD: 111 ± 4.40 - CBG: 44.5 ± 5.18 SPE Extraction: **Cannabis Energy drink (ng/g)** - CBD: 0.170 ± 0.020	UAE extraction: **Cannabis Tea (µg/g)** - CBC: 75.1 ± 9.02 - CBD: 4381 ± 76.5 - CBG: 750 ± 9.97 - CBN: 57.0 ± 2.00 - THC: 180 ± 4.56

		- Soxhlet and UAE extraction were used for the extraction of cannabinoids from solid cannabis edibles, including hemp tea. - SPE and UAE were used for the extraction of cannabinoids from cannabis beer and cannabis energy drinks. - Decoction and infusion processes were used for cannabis-based roasted coffee and hemp tea cannabinoid extraction, respectively.	- CBG: 0.312 ± 0.010 - OH-THC: 1.28 ± 0.030 **Cannabis Beer (ng/g)** - CBD: 0.380 ± 0.010 - CBG: 0.474 ± 0.030 Infusion: **Hemp Tea (µg/g)** - CBC: 0.100 ± 0.010 - CBD: 19.6 ± 0.410 - CBG: 2.43 ± 0.110 - CBN: 0.080 ± 0.010 - THC: 0.080 ± 0.001	**Cannabis Energy Drink (ng/g)** - CBD: 0.150 ± 0.013 - CBG: 0.240 ± 0.010 **Cannabis Beer (ng/g)** - CBD: 0.830 ± 0.014 - CBG: 0.271 ± 0.020 Decoction: **Roasted Coffee (µg/g)** - CBD: 0.042 ± 0.001 - CBG: Not quantified
Ciolino et al. 2018	Determine the presence of cannabinoids in commercial consumer products using HPLC-DAD.	- Cannabinoids of interest: CBC, CBD, CBDA, CBDV, CBG, CBGA, CBN, THC, THCA, and THCV. - Target compound retention, UV absorbance spectra/response was determined via HPLC-DAD analysis. - For aqueous substances such as coffee, 100% ethanol extractant was used.	- CBD and THC were the only cannabinoids present in drinkable cannabis products. **Coffee Beverage Products (n = 3)** - CBD assay (mg/g), spike (mg/g), and % spike recovery were: 0.042, 0.036, and 96, respectively. - No THC reported. **Flavoured Liquid Products (n = 3)** - CBD assay (mg/g), spike (mg/g), and % spike recovery were: 0.28, 0.29, and 94, respectively. - No THC reported. **Aqueous Supplement Products (n = 2)** - CBD assay (mg/g), spike (mg/g), and % spike recovery were: 0.30, 0.30, and 100, respectively. - THC assay (mg/g), spike (mg/g), and % spike recovery were: 0.012, 0.011 and 101, respectively.	
Dräger et al. 2022[b]	Identify THC content in a variety of hemp food products.	- THC content was determined using GC in combination with with methods of mass spectrometry and LC-MS. - THC intake, ARfD, and LOAEL was calculated using average daily consumption scenarios.	**Nonalcoholic Hemp-Containing Beverages (n = 61)** - THC content in 11% of the samples was below the LOQ, with 57% of samples falling below the LOD. - 31% of the samples showed a quantifiable THC content; mean THC intake (0.0002 mg/day) exhausted the ARfD with 0.3% to a low extent, while the exhaustion of the ARfD by the mean THC intake (0.005 mg/day) was 7%	

		- THC content (mg/kg product) was converted to daily THC intake (mg/day) using the mean daily consumption (g of product/day).	- THC intake for the sample with the highest THC content (0.529 mg/L) was 0.093 mg/day, which resulted in an ARfD exhaustion of 133%. **Hemp-Containing Teas ($n = 89$)** - 88% of samples demonstrated quantifiable THC content; mean THC intake (0.157 mg/day) demonstrated a high ARfD exhaustion of 224%, with a low LOAEL exhaustion of 6%. - The median THC intake (0.049 mg/day) was below the ARfD and demonstrated an ARfD exhaustion of 70%.
Greaves et al. 2021	To validate a method used to analyse the presence of aflatoxins and OTA in several cannabis products.	Three cannabis-infused beverages were used for analysis of both toxins. - An immunoaffinity column cleanup LC method was used to analyse the product. - Beverages were spiked with four different aflatoxins, and OTA, at low, medium, and high levels.	Initial analysis of all cannabis products showed no contamination of any aflatoxins or OTA. - The total within-day recovery rate (%) of aflatoxins was reported for cannabis beverages at each spiking level (low, medium, high) respectively: 93.2%, 92.6%, 95.7%. - The total within-day recovery rate (%) of OTA was reported for cannabis beverages at each spiking level respectively: 83.1%, 84.3%, 81.7%. - The within-day repeatability analysis yielded the following RSD (%) values for aflatoxins at each spiking level, respectively: 7.8%, 7.4%, 3.6%; and for OTA: 5.4%, 4.1%, 6.4%. - The total between-day recovery rate (%) of aflatoxins was reported for cannabis beverages at each spiking level (low, medium, high) respectively: 88.9%, 92.1%, 93.1% - The total between-day recovery rate (%) of OTA was reported for cannabis beverages at each spiking level respectively: 75.5%, 78.3%, 80.7% - The between-day repeatability analysis yielded the following RSD (%) values for aflatoxins at each spiking level, respectively: 8.5%, 11.3%, 12.8%; and for OTA: 9.4%, 14.5%, 11.6%
Hazekamp et al. 2007	Analyze how different methods of cannabis tea preparation impacts their cannabinoid composition.	Cannabinoids of interest: THC and THCA. LC was applied to quantitatively analyze the presence of both phytocannabinoids. - Cannabis residue on the sieve was analyzed using LC to determine the	There was no loss of total THC (THC+THCA) during tea preparation. Relative to the standard cannabis tea preparation: - Altering the water volume did not significantly change THC or THCA concentrations.

		concentration of cannabinoids before and after preparation. Tea preparation was altered in three ways: 1. Water volume: preparing 250 mg of cannabis in 250 ml of water, or 1 g of cannabis in 1 L of water. 2. Cannabis: preparing tea using either 0.5, 1, or 1.5 g of cannabis. 3. Boiling time: boiling tea for either 10, 20, or 30 min. All tea samples were compared to a standard preparation of cannabis tea, which was created by boiling 1.0 g of cannabis in 1.0 L of water for 15 minutes. - Tea samples were also stored for 1, 3, 5, or 12 days, then removed for a subsequent analysis to test possible reductions in cannabinoid concentrations.	- Lowering the dose of cannabis to 0.5g significantly decreased the presence of THC and THCA to approximately half. - Increasing the dose of cannabis to 1.5 g did not significantly alter the presence of THC or THCA. - Increasing the boiling time significantly increased the concentration of THC, but had no significant effect on THCA levels. However, THC concentration still remained lower than THCA concentration in every preparation. - After one day of storage, THC levels significantly decreased to 60% of its original concentration, and THCA levels significantly decreased to 71%. - After 12 days of storage, THC decreased to 6% of its original concentration and THCA decreased to 8%. - Recovery of precipitates were equal to the relative amount of cannabinoids lost from the solution – thus, the qualitative composition remained stable while overall potency declined. - Cyclodextrin and coffee creamer successfully stabilized teas during storage, such that the levels of THC and THCA were relatively unchanged after 5 days of storage.
Lindsay et al. 2021	To determine the presence of THC and CBD in different cannabis products.	Cannabinoids of interest: CBD, CBN, THC. - 45 cannabis samples were collected over four years, only two of which were cannabis beverages. - GC-MS was used to analyse cannabinoid concentrations in each sample. - Safety standards for packaging were also examined.	- The lowest levels of THC were detected in beverages compared to any other product, while baked goods had the highest concentration of THC. Amongst the two beverages samples analysed: - Mean and median levels of THC per beverage product were 0.01mg. - Mean and median levels of CBD per beverage product were 0.03mg. Most products ($n = 39$) did not adhere to packaging guidelines (i.e., excluded ingredients, name, storage condition, expiration date, etc.). - 85% of samples also did not indicate the amount of THC
Miller et al. 2022	Determine the purity and labelling accuracy of nonprescription commercial CBD	- Cannabinoids of interest: CBD, CBN, and THC. - Samples were analysed using LC to determine the concentration of CBD, CBN, and THC. Observed concentrations were	**Observed CBD Content** - Of the aqueous hemp products analysed (n = 21), only 14 provided specific CBD label claims, with a mean CBD concentration vs label claim of 59.93%. - Of the aqueous hemp products that provided a label claim, only one was labelled accurately.

	and hemp products.	then compared to product labels to assess for product labelling accuracy.	- Two of aqueous hemp products were found to be under-labelled, while 11 were identified as being over-labelled. **Observed CBN Content** - CBN was detected in two aqueous hemp products, both of which contain a CBN concentration of 0.0015% (w/v). **Observed THC Content** - THC was detected in five aqueous hemp products, with a maximum observed THC concentration of 0.0005% (w/v) and a minimum observed THC concentration of 0.0002% (w/v).
Pacifici et al. 2017	Analyzing cannabinoid composition of specific strains to examine their potential therapeutic effects.	Cannabinoids of interest: CBC, CBD, CBDA, CBG, CBN, THC, THCA. A standard cannabis tea was prepared by boiling 500 mg of medical cannabis in 500 ml of water for 15 min. - The effect of boiling time on the presence of cannabinoids was tested, altering its boiling by increments of 5 minutes, from 0 to 35 min total - Stability was tested of tea samples, storing either at room temperature or in the fridge for intervals of 1, 3, 7, and 14 days. - LC-MS/MS analysed tea samples	The respective extraction efficiencies (mean recovery) for THC, THCA, CBD, CBDA, CBN, CBG, CBC cannabinoids were 18.5%, 13.8%, 28.1%, 58.2%, 19.6%, 16.6%, 11.5%. - Respective extraction efficiencies of THC and THC-AA, and CBD and CBDA, significantly reduced the total THC:CBD ratio from 0.71 to 0.25. Altering boiling time significantly altered the cannabinoid concentration, and the standard preparation yielded the greatest concentration. - There was a trending decrease in cannabinoid concentration from 20–35 minutes boiling time. - CBDA was the only cannabinoid to maintain a stable concentration across 14 days of refrigeration. - THC, CBN, CBG, and CBC reduced to less than 65% of their original concentrations by day 3 of refrigeration. - THCA reduced to less than 70% its original concentration by day 7 of refrigeration. - CBD reduced to less than 40% its original concentration by day 7 of refrigeration. - In non-refrigerated samples, mold began growing by day 5 of storage. - Mold began growing in samples after 5 days of non-refrigerated storage.
Song et al. 2023	Analysing the presence of 16 different cannabinoids across several	Cannabinoids of interest: CBLA CBCA CBC THCA, d8-THC, THC, CBN, THCVA, CBD, THCV, CBD, CBG, CBGA, CBDA, CBDV, CBDVA.	Only CBD was present in hemp-infused beverages, and was present in the following concentration levels (%, w/w): - Sparkling coconut water = 0.0058 - Lemon sparkling black tea = 0.0040 - CBD coffee = 0.033

	hemp-infused products.	- Solutions were prepared for LC-DAD analysis to examine the concentration of different cannabinoids.	
Vandrey et al. 2015	To determine label accuracy of different cannabis products throughout dispensaries in the US.	- Dispensaries which sold a minimum of one edible product were randomly chosen across three US cities (San Francisco, Los Angeles, Seattle). - Purchasers bought a variety of products that were analysed using HPLC. - Label accuracy of THC and CBD was determined within a 10% range: anything >10% than labelled was determined to be "under labeled", anything <10% less than labelled was determined to be "over labelled". - A total of 75 products (from 47 different brands) were included in the analysis.	13 of the 75 products analysed were cannabis beverages. - Only 3 (23.1%) cannabis beverages had accurately labelled amounts of THC in the product (the product's true amount was within 10% of its label). - 2 (15.4%) beverages were under labelled (>10% more THC than indicated on the label), and 8 (61.5%) were over labelled (<10% THC than indicated on the label). - Comparatively, 9.1% of baked goods were accurately labelled, and 20% of candy/chocolate products were accurately labelled.

Note. Abbreviations*:* ARfD = Acute Reference Dose; CBC = Cannabichromene; CBCA = Cannabichromenic Acid; CBD = Cannabidiol; CBDA = Cannabidiolic Acid; CBDV = Cannabidivarin; CBDVA = Cannabidivarinic Acid; CBG = Cannabigerol; CBGA = Cannabigerolic Acid; CBLA = Cannabicyclolic Acid; CBN = Cannabinol; D8-THC = Δ8-Tetrahydrocannabinol; GC = Gas Chromatography; GC-MS = Gas Chromatography–Mass Spectrometry; HPLC = High Performance Liquid Chromatography; HPLC-DAD = High Performance Liquid Chromatography–Diode-Array Detection; HPLC-MS = High Performance Liquid Chromatography–Mass Spectrometry; ICP-MS = Inductively Coupled Plasma–Mass Spectrometry; LC = Liquid Chromatography; LC-DAD = Liquid Chromatography–Diode Array Detection; LC-MS = Liquid Chromatography–Mass Spectrometry; LC-MS/MS = Liquid Chromatography–Tandem Mass Spectrometry; LOAEL = Lowest Observed Adverse Effect Level; LOD = Limit of Detection; LOQ = Limit of Quantification; OH-THC = 11-Hydroxy-Δ9-Tetrahydrocannabinol; OTA = Ochratoxin A; RSD = Relative Standard Deviation; SPE = Solid-Phase Extraction; THC = Tetrahydrocannabinol; THCA = Tetrahydrocannabinolic Acid; THC-COOH = 11-Nor-9-Carboxy-Tetrahydrocannabinol; THCV = Tetrahydrocannabivarin; THCVA = Tetrahydrocannabivarinic Acid; UAE = Ultrasound-Assisted Extraction [a]In the interest of brevity, cannabinoids of interest that were not detected through extraction processes are not reported in the table. [b]The LOAEL dosage corresponds to 36 μg/kg of body weight in a 70 kg person.

DISCUSSION

Consumption Patterns and Beliefs

Consumption rates and attitudes across studies provide limited insight into beverage intake prevalence and perceptions. All but one of these studies (Sikorski et al., 2020) were conducted in the US; however, numbers are relatively consistent with the 2022 Canadian Cannabis Survey, where 19% of past-year cannabis users consumed beverages and 8% of past-month users drank cannabis (Health Canada, 2022b). Clinical populations residing in the US also mirror low Canadian consumption rates; 1.1% of cancer patients and 7.7% of epilepsy patients consumed cannabis beverages (Donovan et al., 2022; Kerr et al., 2019), while 8% of Canadians reported using cannabis beverages for medical purposes in the past year (Health Canada, 2022b). Legalizing beverages showed a trend toward increasing consumption, with legal purchasing growing 10.2% between 2020–2021 (Wadsworth et al., 2023), and consumers being 1.5-2.5X more likely to purchase drinks in legal than illegal markets (Goodman et al., 2020). Although cannabis beverages before legalization could have been made by consumers at home, availability in stores likely increased their accessibility and thus the ease of consumption. Differences in the legal status of cannabis beverages may partially explain varied reports of cannabis beverage prevalence identified in this review, considering some studies were conducted where cannabis was illegal (Dowd et al., 2023; Goodman et al., 2020; Schuaer et al., 2020; Sikorski et al., 2021). Heterogeneity could also be influenced by mean age; many studies were conducted in young adults (Dunbar et al., 2022; Fedorova et al., 2021; Sikorski et al., 2021; Sullivan et al., 2022) consistent with the mean age of cannabis use initiation (Health Canada, 2022b). These cohort effects make it difficult to draw clear consumption patterns across studies, and more research is necessary across wider population demographics to obtain more potential cohort effects. Studies on beverage preferences and attitudes suggest low reports of alcohol replacement, since 15.8% reported desire to replace alcohol with a cannabis drink (Charlebois et al., 2020). Both medical and recreational motives for cannabis beverage consumption are reported (Dowd et al., 2023; Fedorova et al., 2021); while some consumers may be CBD-only users and others prefer THC-dominant products, it is possible that the appeal of these beverages may be in unique cannabinoid effects, which cannot be substituted with alcohol.

Advertisement and Marketing

The Marijuana Retail Surveillance Tool (MRST) in Colorado dispensaries suggest that most dispensaries investigated follow appropriate security guidelines (Berg et al., 2017), including cannabis beverages offered across all dispensaries, with relatively consistent prices. Comprehensive marketing and promotion regulations should be widely applied across markets as novel products continue to emerge, including standardised cannabis surveillance tools, such as the MRST, to identify public health risks and monitor responsible marketing practices.

Acute Effects in Human Models

Human studies elucidated aversive cannabis beverage effects in emergency care settings and following acute administration, including increased pulse rate, anxiety, symptoms of mania, and inaccurate time perception (Cao et al., 2016; Chaudry et al., 1991; Karniol et al., 1974; Zuardi et al., 1982). However, these effects were often mitigated when THC was combined with CBD doses or when participants were administered CBD alone. Only one of these four studies reported including chronic or frequent cannabis users. Notably, infrequent cannabis users are more susceptible to psychoactive and physiological effects induced by THC and the blunting effects of cannabinoid interactions (Colizzi et al., 2018; Solowij et al., 2019). Thus, the frequency of cannabis use should be considered an important variable when understanding reported acute effects in these studies. Aversive outcomes of consumption and THC+CBD interactions may be heightened due to participants' infrequent consumption rates, and may therefore not be generalizable to all consumers' experiences with cannabis beverages. Furthermore, new cannabis users should take caution with the cannabinoid dosage and makeup when consuming to limit any potential health-related and psychological harm.

One study reported greater bioavailability of water-soluble CBD beverages relative to fat-soluble drinks (Hobbs et al., 2020). This may have occurred due to the prior fasting of participants, which alters phytocannabinoid bioavailability and pharmacokinetics enhanced by the fat content of meals (Birnbaum et al., 2019). Future investigations should therefore require control of participants' fed status – ideally following a standardised meal. Potential adverse drug interactions when consuming cannabis-infused beverages with variable THC and CBD content also require greater attention given CBD inhibition of CYP2C9-mediated oral THC clearance (Bansal et al., 2023). Hobbs and colleagues (2020) also reported no changes in interleukin-10 or tumour necrosis factor levels following the consumption of water- and fat-soluble CBD drinks, contrasting previous findings indicating suppressive effects of CBD administration on inflammation in human and rat models (El-Remessy et al., 2006; Han et al., 2009). Thus, broader investigations are required to determine whether CBD beverages can reduce inflammation and be used as a viable medical treatment.

Administration of hemp beverages produced a positive THC screen in some participants (Steinagle et al., 1999). In this case, cannabis plants with low residual THC content < 0.3% on a dry weight basis are classified as hemp from a regulatory framework in North America and Europe. Although this could only be detected using a precise analytic method, these findings highlight trace cannabinoid amounts still present in hemp products, which is important to highlight to consumers who may not be knowledgeable of their presence.

Drink Composition

Two studies observed that changes to tea preparation techniques altered cannabinoid composition (Hazekamp et al., 2007; Pacifici et al., 2017), albeit with conflicting results. Despite both studies using the same cannabis:water ratios in their standard preparations, trending decreases and significant increases in cannabinoid levels at increasing boiling times were observed. Regardless of these inconsistencies, potential differences in phytocannabinoid concentrations can vary depending on preparation techniques; thus, it is essential for consumers to be knowledgeable of these effects to minimize risks for overconsumption.

Inconsistent labeling accuracy observed across current research (Lindsay et al., 2021; Miller et al., 2022; Vandrey et al., 2015) may partially occur due to the illicit or criminalized nature of cannabis in certain regions. Specifically, these studies were conducted in the US and Jamaica, where cannabis has not yet been nationally legalized, and thus, packaging and label requirements either vary between states or are nonexistent (Kruger et al., 2022; Lindsay et al., 2021). Labeling inaccuracy still occurs for other cannabis products within regulatory frameworks, and another systematic review has identified five studies reporting between 17 and 86% packaging accuracy. Thus, while the Canadian government has implemented strict packaging requirements (Health Canada, 2022c), consumers should still take caution when consuming cannabis products. Inaccurate reports of cannabis content can pose serious risks for overconsumption, and it is therefore essential to inform consumers of these risks. Considering cannabis has been legalized in Canada since 2018, more research should examine label and packaging accuracy, including minor cannabinoids, terpenes, caffeine, and other psychoactive constituents, to directly observe the influence of cannabis legalization and regulations.

Regulated cannabis products require validated analytical methods to determine cannabinoid potency and ensure product efficacy, safety, and consistency. Surveillance testing for adulterated cannabis products is warranted, as accidental exposure can lead to injury or death, such as emerging synthetic cannabinoid receptor agonists (Krotulski et al., 2021). Minor cannabinoids, such as CBN, cannabichromene (CBC) and cannabigerol (CBG; Walsh et al., 2021), were not consistently reported in most studies involving drinkable cannabis products. Importantly, two acidic variants of THC and CBD, THCA and CBDA, are widely overlooked constituents of cannabis that have unique physiological properties and therapeutic applications (Kim et al., 2023), but these were only targeted in four of 11 studies (Ciolino et al., 2018; Hazekamp et al., 2007; Pacifici et al., 2017; Song et al., 2023). Thus, the inclusion of THCA and CBDA information (rather than total THC

and CBD) in cannabis beverages is important to accurately assess product formulation.

Terpene profiles are widely used to classify cannabis strains, as they impact aroma attributes and generate synergistic effects with phytocannabinoids (Kaur et al., 2023); however, their analysis in cannabis-infused beverages is sparse. Reversed-phase LC with UV absorbance or DAD detection is frequently used for phytocannabinoid potency testing with improved selectivity and lower detection limits achieved by LC-MS/MS; however, different extraction and/or sample cleanup methods may be applied to various cannabis products, which might yield variable recovery rates. For instance, Christodoulou et al. (2023) demonstrated that solid-phase extraction increased recovery for accurate determination of cannabis-infused beverages (e.g., cannabis coffee, beer, energy drinks, and hemp tea) prior to LC-MS analysis compared to ultrasound-assisted extraction. Therefore, optimising pre-analytical protocols to process distinct cannabis products is critical for reliable determination of phytocannabinoid content without bias.

Limitations and Future Directions

This review highlights a dearth of available research on cannabis beverages, particularly acute intoxication. A lack of standard dosing produces limitations across studies. From a policy perspective, maximum legal dosages are vague; although the Canadian government enforces a legal limit of 10 mg/THC per beverage and a possession limit of 17.1 L of cannabis beverages (Health Canada, 2022a), it is not stated how much liquid must be present per 10 mg of THC. Thus, there is no government-determined standard size for cannabis beverages, which range from 30 mL 'shots' to over 500 mL. Considering the amount of liquid may affect the speed at which someone consumes their beverage, this may affect the onset and duration of intoxication. This issue is not specific to cannabis drinks, as standard cannabis doses across modes do not yet exist (Volkow & Weiss, 2020). Although a standard of 5 mg per product has been proposed (Freeman & Lorenzetti, 2020), this may not produce consistent intoxication effects (Cloutier et al., 2022; Hughes et al., 2014; Russel et al., 2018; Thayer et al., 2019). Therefore, effects observed in human and animal models may not be indicative of real-world effects. Importantly, THC bioavailability and pharmacokinetics are highly dependent on the specific formulation of the cannabis beverage and whether it is consumed with meals and/or use of other drugs co-metabolized by cytochrome P450 enzymes. Future work should seek to replicate findings using consistent dosages, including considerations of phytocannabinoid profiles, mode of consumption, and individual consumer characteristics. Most methods to date have been developed for the analysis of cannabis dried flowers and concentrates/resins rather than edibles or beverages that have different matrix interferences. Recently, the Association of Official Agricultural Chemists have issued Standard Method Performance Requirements in 2022 for the quantification of five phytocannabinoids in beverages within a recommended analytical range (0.002-10% w/w), recovery (< 70-130%) and reproducibility (CV < 12%), namely CBD, CBDA, THC, THCA and CBN (Audino et al., 2017); moreover, nine additional minor phytocannabinoids were named in a desirable list for quantification, including CBG, cannabigerolic acid (CBGA), CBC, cannabichromenic acid (CBCA), cannabidivarin (CBDV), cannabidivarinic acid (CBDVA), Δ8-THC, tetrahydrocannabivarin (THCV), and tetrahydrocannabivarinic acid (THCVA). With the exception of Song et al. (2023), few studies have performed comprehensive potency testing of up to sixteen phytocannabinoids in cannabis beverages using LC-MS/MS that also allows for chromatographic resolution of isomeric phytocannabinoids, such as Δ8-/Δ9-THC.

While the global cannabis beverage market is expanding to include drugs, such as caffeine, herbal extracts, taurine, and alcohol, few systematic studies exist for these blends. The US National Alcohol Survey reports that most cannabis users simultaneously consume alcohol (Subbaraman & Kerr, 2015), increasing the likelihood of consuming greater quantities of alcohol, drinking more frequently, reporting more alcohol-related consequences than alcohol-only users, and increasing odds of drunk driving, social consequences, and personal harms. A systematic review (Gunn et al., 2022) reported heightened behavioural and cognitive effects and increased plasma THC following low dose alcohol consumption among individuals concurrently

consuming alcohol and cannabis. Higher alcohol doses can also blunt subjective THC effects, which may encourage overconsumption, thereby highlighting the need for explorations of blended drinks.

Given the historical and cultural significance that the cannabis beverage Bhang holds, particularly in eastern countries such as India (Karki & Rangaswamy, 2023), our review conducted a secondary search to uncover more on this drink. However, despite its widespread use, no additional studies assessing acute Bhang effects were revealed. While one study highlighted the potential psychotic effects of Bhang (Chaudry et al., 1991), more research should apply similar systematic and controlled explorations of Bhang consumption.

Conclusion

While the Canadian government made amendments to the *Cannabis Act* in December 2022 to facilitate better access to cannabis beverages for research (Health Canada, 2022c), there are minimal investigations of acute intoxication effects. Current evidence also makes it difficult to draw conclusive statements, due to limited systematic comparisons of subjective, physiological, and cognitive effects across cannabis products. Conducting more comprehensive research using cannabis drinks, implementing different cultural applications, and targeting broader subject groups can help fill these gaps. Although cannabis beverages may offer a less harmful mode of delivery than smoking/vaping, it is also more convenient and socially acceptable. Thus, strategies are needed to mitigate the potential harms from misuse or overconsumption of novel cannabis-infused beverages.

REFERENCES

Arkell, T. R., Vinckenbosch, F., Kevin, R. C., Theunissen, E. L., McGregor, I. S., & Ramaekers, J. G. (2020). Effect of cannabidiol and Δ9-tetrahydrocannabinol on driving performance: A randomized clinical trial. *JAMA: The Journal of the American Medical Association, 324*(21), 2177. https://doi.org/10.1001/jama.2020.21218

Audino, S., Angerhofer, M., Atkins, P., Brauninger, R. M., Brown, P. N., Burdette, C. Q., Clifford, R., Cook, J. M., Donelson, J., George, K., Gibson, P., Harris, H. L., Hartlein, T., Hodgin, G., Inerowicz, D., Johnson, H. E., Joseph, G., Konings, E. J. M., Kowalski, J. A., … Coates, S. G. (2017). AOAC SMPR® 2017.001. Standard method performance requirements (SMPRs) for quantitation of cannabinoids in cannabis concentrates. *Journal of AOAC International, 100*(4), 1200–1203. https://doi.org/10.5740/jaoacint.SMPR2017_001

Bansal, S., Zamarripa, C. A., Spindle, T. R., Weerts, E. M., Thummel, K. E., Vandrey, R., Paine, M. F., & Unadkat, J. D. (2023). Evaluation of cytochrome P450-mediated cannabinoid-drug interactions in healthy adult participants. *Clinical Pharmacology and Therapeutics, 114*(3), 693–703. https://doi.org/10.1002/cpt.2973

Berg, C. J., Henriksen, L., Cavazos-Rehg, P., Schauer, G. L., & Freisthler, B. (2017). The development and pilot testing of the marijuana retail surveillance tool (MRST): Assessing marketing and point-of-sale practices among recreational marijuana retailers. *Health Education Research, 32*(6), 465–472. https://doi.org/10.1093/her/cyx071

Birnbaum, A. K., Karanam, A., Marino, S. E., Barkley, C. M., Remmel, R. P., Roslawski, M., Gramling-Aden, M., & Leppik, I. E. (2019). Food effect on pharmacokinetics of cannabidiol oral capsules in adult patients with refractory epilepsy. *Epilepsia, 60*(8), 1586–1592. https://doi.org/10.1111/epi.16093

Cao, D., Srisuma, S., Bronstein, A. C., & Hoyte, C. O. (2016). Characterization of edible marijuana product exposures reported to United States poison centers. *Clinical Toxicology (Philadelphia, Pa.), 54*(9), 840–846. https://doi.org/10.1080/15563650.2016.1209761

Catenza, K.F., & Donkor, K.K. (2022). Determination of heavy metals in cannabinoid-based food products using microwave-assisted digestion and ICP-MS. *Food Analytical Methods, 15*, 2537–2546. https://doi.org/10.1007/s12161-022-02315-1

Charlebois, S., Music, J., Sterling, B., & Somogyi, S. (2020). Edibles and Canadian consumers'

willingness to consider recreational cannabis in food or beverage products: A second assessment. *Trends in Food Science & Technology, 98*, 25–29. https://doi.org/10.1016/j.tifs.2019.12.025

Chaudry, H.R., Moss, H.B., Bashir, A., & Suliman, T. (1991). Cannabis psychosis following bhang ingestion. *British Journal of Addiction, 86*, 1075–1081. https://doi.org/10.1111/j.1360-0443.1991.tb01874.x

Christodoulou, M. C., Christou, A., Stavrou, I. J., & Kapnissi-Christodoulou, C. P. (2023). Evaluation of different extraction procedures for the quantification of seven cannabinoids in cannabis-based edibles by the use of LC-MS. *Journal of Food Composition and Analysis, 115*, 104915. https://doi.org/10.1016/j.jfca.2022.104915

Ciolino, L. A., Ranieri, T. L., & Taylor, A. M. (2018). Commercial cannabis consumer products part 2: HPLC-DAD quantitative analysis of cannabis cannabinoids. *Forensic Science International, 289*, 438–447. https://doi.org/10.1016/j.forsciint.2018.05.033

Cloutier, R. M., Calhoun, B. H., & Linden-Carmichael, A. N. (2022). Associations of mode of administration on cannabis consumption and subjective intoxication in daily life. *Psychology of Addictive Behaviors: Journal of the Society of Psychologists in Addictive Behaviors, 36*(1), 67–77. https://doi.org/10.1037/adb0000726

Colizzi, M., McGuire, P., Giampietro, V., Williams, S., Brammer, M., & Bhattacharyya, S. (2018). Previous cannabis exposure modulates the acute effects of delta-9-tetrahydrocannabinol on attentional salience and fear processing. *Experimental and Clinical Psychopharmacology, 26*(6), 582-598. https://doi.org/10.1037/pha0000221

Department of Justice. (2021). Cannabis legalization and regulation. https://www.justice.gc.ca/eng/cj-jp/cannabis/

Donovan, K. A., Dolan, A., Lubrano di Ciccone, B. B., Babilonia, M. B., Skinner, A., Reed, D. R., & Portman, D. G. (2022). Cannabis consumption in young adults with cancer: Descriptive study. *BMJ Supportive & Palliative Care, 13*. https://doi.org/10.1136/bmjspcare-2021-003353

Dowd, A. N., Zamarripa, C. A., Sholler, D. J., Strickland, J. C., Goffi, E., Borodovsky, J. T., Weerts, E. M., Vandrey, R., & Spindle, T. R. (2023). A cross-sectional survey on cannabis: Characterizing motives, opinions, and subjective experiences associated with the use of various oral cannabis products. *Drug and Alcohol Dependence, 245*, 109826. https://doi.org/10.1016/j.drugalcdep.2023.109826

Dräger, H., Barthlott, I., Golombek, P., Walch, S. G., & Lachenmeier, D. W. (2022). Time trends of Tetrahydrocannabinol (THC) in a 2008-2021 German national survey of hemp food products. *Foods (Basel, Switzerland), 11*(3), 486. https://doi.org/10.3390/foods11030486

Drennan, M. L., Karoly, H. C., Bryan, A. D., Hutchison, K. E., & Bidwell, L. C. (2021). Acute objective and subjective intoxication effects of legal-market high potency THC-dominant versus CBD-dominant cannabis concentrates. *Scientific Reports (Nature Publisher Group), 11*(1). https://doi.org/10.1038/s41598-021-01128-2

Dunbar, M. S., Seelam, R., Tucker, J. S., Firth, C. L., Pedersen, E. R., Klein, D. J., Rodriguez, A., & D'Amico, E. J. (2022). Patterns and correlates of cannabidiol product and marijuana co-use in a sample of U.S. young adults. *Addictive Behaviors, 126*, 107185. https://doi.org/10.1016/j.addbeh.2021.107185

El-Remessy, A. B., Al-Shabrawey, M., Khalifa, Y., Tsai, N.-T., Caldwell, R. B., & Liou, G. I. (2006). Neuroprotective and blood-retinal barrier-preserving effects of cannabidiol in experimental diabetes. *The American Journal of Pathology, 168*(1), 235–244. https://doi.org/10.2353/ajpath.2006.050500

Fedorova, E. V., Wong, C. F., Ataiants, J., Iverson, E., Conn, B. M., & Lankenau, S. E. (2021). Cannabidiol (CBD) and other drug use among young adults who use cannabis in Los Angeles. *Drug and Alcohol Dependence, 221*, 108648. https://doi.org/10.1016/j.drugalcdep.2021.108648

Freeman T.P., & Lorenzetti V. (2020). 'Standard THC units': A proposal to standardize dose across all cannabis products and methods of administration. *Addiction, 115*(7), 1207-1216. https://doi.org/10.1111/add.14842

Goodman, S., Wadsworth, E., Leos-Toro, C., Hammond, D., & International Cannabis

Policy Study team (2020). Prevalence and forms of cannabis use in legal vs. illegal recreational cannabis markets. *The International Journal on Drug Policy, 76*, 102658. https://doi.org/10.1016/j.drugpo.2019.102658

Greaves, A., Maddison, K., Doran, M., Lin, S., & Geiling, B. (2021). Single-laboratory validation of an immunoaffinity column cleanup LC method for the analysis of aflatoxins and ochratoxin A in cannabis plant material, resins, vapes, isolates, and edible products. *Journal of AOAC International, 104*(5), 1264–1271. https://doi.org/10.1093/jaoacint/qsab057

Gunn, R. L., Aston, E. R., & Metrik, J. (2022). Patterns of cannabis and alcohol co-use: Substitution versus complementary effects. *Alcohol Research: Current Reviews, 42*(1), 4. https://doi.org/10.35946/arcr.v42.1.04

Han, K. H., Lim, S., Ryu, J., Lee, C.-W., Kim, Y., Kang, J.-H., Kang, S.-S., Ahn, Y. K., Park, C.-S., & Kim, J. J. (2009). CB1 and CB2 cannabinoid receptors differentially regulate the production of reactive oxygen species by macrophages. *Cardiovascular Research, 84*(3), 378–386. https://doi.org/10.1093/cvr/cvp240

Hazekamp, A., Bastola, K., Rashidi, H., Bender, J., & Verpoorte, R. (2007). Cannabis tea revisited: A systematic evaluation of the cannabinoid composition of cannabis tea. *Journal of Ethnopharmacology, 113*(1), 85–90. https://doi.org/10.1016/j.jep.2007.05.019

Health Canada. (2022a). *Taking stock of progress: Cannabis legalization and regulation in Canada*. https://www.canada.ca/en/health-canada/programs/engaging-cannabis-legalization-regulation-canada-taking-stock-progress/document.html

Health Canada. (2022b). *Canadian cannabis survey 2022: Summary*. https://www.canada.ca/en/health-canada/services/drugs-medication/cannabis/research-data/canadian-cannabis-survey-2022-summary.html

Health Canada. (2022c). *Health Canada finalizes amendments on cannabis research and testing, and cannabis beverages*. https://www.canada.ca/en/health-canada/news/2022/12/health-canada-finalizes-amendments-on-cannabis-research-and-testing-and-cannabis-beverages.html

Hobbs, J. M., Vazquez, A. R., Remijan, N. D., Trotter, R. E., McMillan, T. V., Freedman, K. E., Wei, Y., Woelfel, K. A., Arnold, O. R., Wolfe, L. M., Johnson, S. A., & Weir, T. L. (2020). Evaluation of pharmacokinetics and acute anti-inflammatory potential of two oral cannabidiol preparations in healthy adults. *Phytotherapy Research, 34*(7), 1696–1703. https://doi.org/10.1002/ptr.6651

Hughes, J. R., Fingar, J. R., Budney, A. J., Naud, S., Helzer, J. E., & Callas, P. W. (2014). Marijuana use and intoxication among daily users: An intensive longitudinal study. *Addictive Behaviors, 39*(10), 1464–1470. https://doi.org/10.1016/j.addbeh.2014.05.024

Karki, P., & Rangaswamy, M. (2023). A review of historical context and current research on cannabis use in India. *Indian Journal of Psychological Medicine, 45*(2), 105–116. https://doi.org/10.1177/02537176221109272

Karniol, I. G., Shirakawa, I., Kasinski, N., Pfeferman, A., & Carlini, E. A. (1974). Cannabidiol interferes with the effects of delta 9 - tetrahydrocannabinol in man. *European Journal of Pharmacology, 28*(1), 172–177. https://doi.org/10.1016/0014-2999(74)90129-0

Kaur, J., Sun, N., & Hill, J. E. (2023). Comprehensive profiling of terpenes and terpenoids in different cannabis strains using GC × GC-TOFMS. *Separations, 10*(9), 500. https://doi.org/10.3390/separations10090500

Kendall, D. A., & Yudowski, G. A. (2017). Cannabinoid receptors in the central nervous system: Their signaling and roles in disease. *Frontiers in Cellular Neuroscience, 10*, 294–294. https://doi.org/10.3389/fncel.2016.00294

Kerr, A., Walston, V., Wong, V. S. S., Kellogg, M., & Ernst, L. (2019). Marijuana use among patients with epilepsy at a tertiary care center. *Epilepsy & Behavior: E&B, 97*, 144–148. https://doi.org/10.1016/j.yebeh.2019.05.037

Krotulski, A. J., Cannaert, A., Stove, C., & Logan, B. K. (2021). The next generation of synthetic cannabinoids: Detection, activity, and potential toxicity of pent-4en and but-3en analogues including MDMB-4en-PINACA. *Drug Testing and Analysis, 13*(2), 427–438. https://doi.org/10.1002/dta.2935

Lee, C. M., Neighbors, C., Hendershot, C. S., & Grossbard, J. R. (2009). Development and preliminary validation of a comprehensive

marijuana motives questionnaire. *Journal of Studies on Alcohol and Drugs*, *70*(2), 279–287. https://doi.org/10.15288/jsad.2009.70.279

Lindsay, C. M., Abel, W. D., Jones-Edwards, E. E., Brown, P. D., Bernard, K. K., & Taylor, T. T. (2021). Form and content of Jamaican cannabis edibles. *Journal of Cannabis Research, 3*(1), 29. https://doi.org/10.1186/s42238-021-00079-9

Martín-Moreno, A. M., Brera, B., Spuch, C., Carro, E., García-García, L., Delgado, M., Pozo, M. A., Innamorato, N. G., Cuadrado, A., & de Ceballos, M. L. (2012). Prolonged oral cannabinoid administration prevents neuroinflammation, lowers β-amyloid levels and improves cognitive performance in Tg APP 2576 mice. *Journal of Neuroinflammation, 9*, 8. https://doi.org/10.1186/1742-2094-9-8

Miller, O. S., Elder, E. J., Jones, K. J., & Gidal, B. E. (2022). Analysis of cannabidiol (CBD) and THC in nonprescription consumer products: Implications for patients and practitioners. *Epilepsy & Behavior, 127*, 108514–108514. https://doi.org/10.1016/j.yebeh.2021.108514

Oldfield K., Ryan J., Doppen M., Kung S., Braithwaite I., & Newton-Howes G. (2021). A systematic review of the label accuracy of cannabinoid-based products in regulated markets: Is what's on the label what's in the product? *Australasian Psychiatry, 29*(1), 88-96. https://doi.org/10.1177/1039856220965334

Pacifici, R., Marchei, E., Salvatore, F., Guandalini, L., Busardò, F. P., & Pichini, S. (2017). Evaluation of cannabinoids concentration and stability in standardized preparations of cannabis tea and cannabis oil by ultra-high performance liquid chromatography tandem mass spectrometry. *Clinical Chemistry and Laboratory Medicine, 55*(10), 1555–1563. https://doi.org/10.1515/cclm-2016-1060

Panlilio, L. V., Ferré, S., Yasar, S., Thorndike, E. B., Schindler, C. W., & Goldberg, S. R. (2012). Combined effects of THC and caffeine on working memory in rats. *British Journal of Pharmacology, 165*(8), 2529–2538. https://doi.org/10.1111/j.1476-5381.2011.01554.x

Rubin-Kahana, D. S., Crépault, J. F., Matheson, J., & Le Foll, B. (2022). The impact of cannabis legalization for recreational purposes on youth: A narrative review of the Canadian experience. *Frontiers in Psychiatry, 13*, 984485. https://doi.org/10.3389/fpsyt.2022.984485

Russell, C., Rueda, S., Room, R., Tyndall, M., & Fischer, B. (2018). Routes of administration for cannabis use – basic prevalence and related health outcomes: A scoping review and synthesis. *International Journal of Drug Policy, 52*, 87–96. https://doi.org/10.1016/j.drugpo.2017.11.008

Schauer, G. L., Njai, R., & Grant-Lenzy, A. M. (2020). Modes of marijuana use - smoking, vaping, eating, and dabbing: Results from the 2016 BRFSS in 12 States. *Drug and Alcohol Dependence, 209*, 107900. https://doi.org/10.1016/j.drugalcdep.2020.107900

Sikorski, C., Leos-Toro, C., & Hammond, D. (2021). Cannabis consumption, purchasing and sources among young Canadians: The Cannabis Purchase and Consumption Tool (CPCT). *Substance Use & Misuse, 56*(4), 449–457. https://doi.org/10.1080/10826084.2021.1879142

Solowij, N., Broyd, S., Greenwood, L., van Hell, H., Martelozzo, D., Rueb, K., Todd, J., Liu, Z., Galettis, P., Martin, J., Murray, R., Jones, A., Michie, P. T. & Croft, R. (2019). A randomised controlled trial of vaporised Δ9-tetrahydrocannabinol and cannabidiol alone and in combination in frequent and infrequent cannabis users: Acute intoxication effects. *European Archives of Psychiatry and Clinical Neuroscience, 269*(1), 17-35. https://doi.org/10.1007/s00406-019-00978-2

Song, L., Meyer, G., Adejumo, E., Jovanovich, E., LeBlanc, L., & Provis, J. (2023). Potency testing of up to sixteen cannabinoids in hemp-infused edibles using liquid chromatography diode array detector with optional confirmation of identity by electrospray ionization time-of-flight mass spectrometry. *Food Chemistry, 417*, 135819. https://doi.org/10.1016/j.foodchem.2023.135819

Steinagle, G. C., & Upfal, M. (1999). Concentration of marijuana metabolites in the urine after ingestion of hemp seed tea. *Journal of Occupational and Environmental Medicine, 41*(6), 510–513.

https://doi.org/10.1097/00043764-199906000-00018

Subbaraman, M. S., & Kerr, W. C. (2015). Simultaneous versus concurrent use of alcohol and cannabis in the National Alcohol Survey. *Alcoholism, Clinical and Experimental Research, 39*(5), 872–879. https://doi.org/10.1111/acer.12698

Sullivan, R. M., Wade, N. E., Wallace, A. L., Tapert, S. F., Pelham, W. E., 3rd, Brown, S. A., Cloak, C. C., Feldstein Ewing, S. W., Madden, P. A. F., Martz, M. E., Ross, J. M., Kaiver, C. M., Wirtz, H. G., Heitzeg, M. M., & Lisdahl, K. M. (2022). Substance use patterns in 9 to 13-year-olds: Longitudinal findings from the Adolescent Brain Cognitive Development (ABCD) study. *Drug and Alcohol Dependence Reports, 5*, 100120. https://doi.org/10.1016/j.dadr.2022.100120

Thayer, R. E., YorkWilliams, S. L., Hutchison, K. E., & Bryan, A. D. (2019). Preliminary results from a pilot study examining brain structure in older adult cannabis users and nonusers. *Psychiatry Research: Neuroimaging, 285*, 58–63. https://doi.org/10.1016/j.pscychresns.2019.02.001

Vandrey, R., Raber, J. C., Raber, M. E., Douglass, B., Miller, C., & Bonn-Miller, M. O. (2015). Cannabinoid dose and label accuracy in edible medical cannabis products. JAMA, 313(24), 2491–2493. https://doi.org/10.1001/jama.2015.6613

Ventresca, M., & Elliott, C. (2022). Cannabis edibles packaging: Communicative objects in a growing market. *The International Journal of Drug Policy, 103*, 103645–103645. https://doi.org/10.1016/j.drugpo.2022.103645

Volkow, N. D., & Weiss, S. R. B. (2020). Importance of a standard unit dose for cannabis research. *Addiction (Abingdon, England), 115*(7), 1219–1221. https://doi.org/10.1111/add.14984

Wadsworth, E., Rynard, V., Driezen, P., Freeman, T. P., Rychert, M., Wilkins, C., Hall, W., Gabrys, R., & Hammond, D. (2023). Legal sourcing of ten cannabis products in the Canadian cannabis market, 2019-2021: A repeat cross-sectional study. *Harm Reduction Journal, 20*(1), 19. https://doi.org/10.1186/s12954-023-00753-6

Walsh, K. B., McKinney, A. E., & Holmes, A. E. (2021). Minor cannabinoids: Biosynthesis, molecular pharmacology and potential therapeutic uses. *Frontiers in Pharmacology, 12*, 777804. https://doi.org/10.3389/fphar.2021.777804

Zuardi, A. W., Shirakawa, I., Finkelfarb, E., & Karniol, I. G. (1982). Action of cannabidiol on the anxiety and other effects produced by delta 9-THC in normal subjects. *Psychopharmacology, 76*(3), 245–250. https://doi.org/10.1007/BF00432554

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