

Commentary

Communicating THC levels and ‘dose’ to consumers: Implications for product labelling and packaging of cannabis products in regulated markets



David Hammond

University of Waterloo, School of Public Health and Health Systems, 200 University Ave W., Waterloo, ON, N2L 3G1, Canada

ARTICLE INFO

Keywords:

Cannabis
Policy
Substance use

ABSTRACT

In a well-regulated drug market, consumers should be able to understand and titrate their dose with little difficulty. In the cannabis market, despite substantial increases in THC levels over time, users have had limited information on the strength of their products. In principle, cannabis legalization provides greater opportunity to communicate clear, accurate information to consumers through packaging and labelling standards. However, jurisdictions that have legalized cannabis have experienced an increase in adverse events from higher strength products, particularly from edibles and other concentrates. What little research exists suggests that current regulatory practices of labelling THC levels on packages may be ineffective due to consumer difficulties understanding numbers (e.g., mg vs. percentage), and the different ways THC levels are communicated across product categories. In particular, current labelling practices provide little guidance in terms of ‘dose expression’—how THC ‘dose’ translates into consumption amounts for specific products. The current paper identifies five principles to guide cannabis labelling and packaging regulations, including considerations for numeric THC labelling, the use of standard servings or dose across different product forms, strategies to communicate ‘dose expression’, and ‘dose-unit packaging’. Overall, there is a need for regulated cannabis markets to develop more effective packaging and labelling standards to allow consumers to effectively titrate their THC intake, with the goal of promoting lower-risk cannabis use.

Background

In October 2018, Canada became only the second country after Uruguay to legalize non-medical cannabis (Government of Canada, 2019b). One advantage of a regulated drug market is the ability to implement product standards to promote lower-risk use (Kilmer, 2014). In the area of pharmaceutical drugs, packaging and labelling standards serve the basic function of providing guidance on the strength or ‘dose’ of drugs (Health Canada, 2016a; The Institute for Safe Medication Practices Canada, 2018). Guidelines for effective drug labelling require that labels meet consumers’ needs within of the context of their use to ensure appropriate selection and usage of products; in other words, effective labelling goes beyond disclosing the contents of a product to provide consumers with practical guidance on usage amounts (U.S. Department of Health & Human Services, 2013). Therefore, in a regulated cannabis market, consumers should be easily able to identify the strength of products and determine how much of the product to consume based on their desired dose or outcome.

The diversification of the cannabis market over the past decade has increased the complexity of consumer decision making. Growth in the legal cannabis industry has led to more highly processed products us-

ing cannabis extracts,¹ and an increasing variety of cannabis formulations and modes of administration (Borodovsky et al., 2017; Russell, Rueda, Room, Tyndall, & Fischer, 2018). Although smoking dried herb remains the most common mode of use, cannabis extracts have become more popular in both illicit and legal non-medical cannabis markets (Health Canada, 2018). In Canada, prior to the legalization of non-medical cannabis, approximately one third of cannabis users reported consuming edibles, one third reported vaping cannabis, and approximately one tenth reported using high strength concentrates in the past year (Health Canada, 2018). Consumption of edibles and other cannabis extracts is even higher in established legal markets (Borodovsky & Budney, 2017; Borodovsky et al., 2017; Oregon Liquor Control Commission, 2019). In Colorado, forms other than dried herb have increased after legalization to account for approximately one third of the market in 2017 (Brohl, Kammerzell, & Koski, 2015; Orens, Light, Lewandowski, Rowberry, & Saloga, 2017), while extracts—including oils, vape cartridges, hash and concentrates such as wax and shatter—accounted for one fifth of the market in Washington State following legalization

¹ In the current paper, we use the term ‘extracts’ to refer to products other than dried herb, which includes edibles (products that are ingested from eating or drinking), oils, and solid concentrates. ‘Solid concentrates’ refers to products such as wax, shatter, and butter, which are typically higher strength products.

E-mail address: dhammond@uwaterloo.ca

<https://doi.org/10.1016/j.drugpo.2019.07.004>

(Caulkins et al., 2018). The use of cannabis extracts are particularly common among youth and young adults (Knapp et al., 2018).

The potency of cannabis products has increased in parallel with the diversification of products. THC is the primary component responsible for the psychoactive effects of cannabis and a common indicator of a product's strength (Room, Fischer, Hall, Lenton, & Reuter, 2010). The THC concentration of dried herb has been increasing for several decades, especially within the past 5 years, along with greater commercial availability in regulated markets (Chandra et al., 2019; ElSohly et al., 2016). Currently, the average THC levels of commercially available dried herb is between 15% and 20% in both licit and illicit markets (Caulkins et al., 2018; Chandra et al., 2019; Jikomes & Zoorob, 2018). The typical THC concentration of cannabis extracts is around 60%, while solid extracts, such as wax or shatter, can exceed 90% (Caulkins et al., 2018; Cavazos-Rehg et al., 2018; Jikomes & Zoorob, 2018; Raber, Elzinga, & Kaplan, 2015; Stogner & Miller, 2015). At the same, cannabidiol (CBD), a non-psychoactive cannabinoid rich products have emerged, many of which have very low levels of THC. The result is a product market with a diversity of THC levels, both within and across leading product categories.

The strength of a cannabis product often has few, if any, visual cues. Titrating THC is somewhat more straightforward for inhaled products, given that users can roughly gauge their intake based on the amount of smoke inhaled. However, cannabis extracts offer few immediate sensory cues with respect to the strength of a product, which can be problematic given that very small differences in consumption can translate into substantial differences in dose. In the case of edibles, a single product can include as many as 10 or 20 'servings' of THC, whereas oils are often measured in fractions of a millilitre. Thus, the margin of error for dose titration is very narrow, particular if consumers are uncertain of a product's THC content.

Problems with cannabis dosing are common. While 'overdoses' of cannabis products are not fatal, they can be highly unpleasant, with negative impacts on consumers and the industry. Some studies suggest more than half of medical cannabis users have experienced episodes of severe cannabis-induced behavioural impairment due to excess consumption (Barrus et al., 2016). Indeed, US jurisdictions that have legalized cannabis have experienced an increase in adverse events and health care visits due to accidental overconsumption (Reed, 2019b; Vigil et al., 2018). Edible products are responsible for the majority of health care visits due to cannabis intoxication, in part due to the longer latency period from oral ingestion, during which some users consume additional quantities (Hudak, Severn, & Nordstrom, 2015; Monte, Zane, & Heard, 2015). The challenges of dose titration from edibles and other concentrates have been compounded by inaccurate labelling and inconsistent manufacturing standards (Barrus et al., 2016; Jikomes & Zoorob, 2018; Vandrey et al., 2015).

Overall, providing accurate dosing information is among the primary challenges confronting regulated cannabis markets (Ritter, 2010). Similar challenges have been observed in the pharmaceutical market, in which consumer confusion related to dose expression is a common factor in medication incidents (Institute for Safe Medication Practices Canada, 2013). The increasing shift towards higher THC products in legal cannabis markets has highlighted a need for more effective regulatory approaches, particularly with respect to product labelling and packaging. The following sections discuss five core principles to guide regulatory practice in this area.

THC content should be clearly labelled and should require minimal numeracy to understand

In most legal markets, the dose of cannabis products is communicated in the form THC numbers printed on packages. In Canada, cannabis products must display the milligrams (mg) of "THC per unit" and the total quantity of THC that each unit could yield, as well as the corresponding values for CBD (see Fig. 1) (Government of Canada,

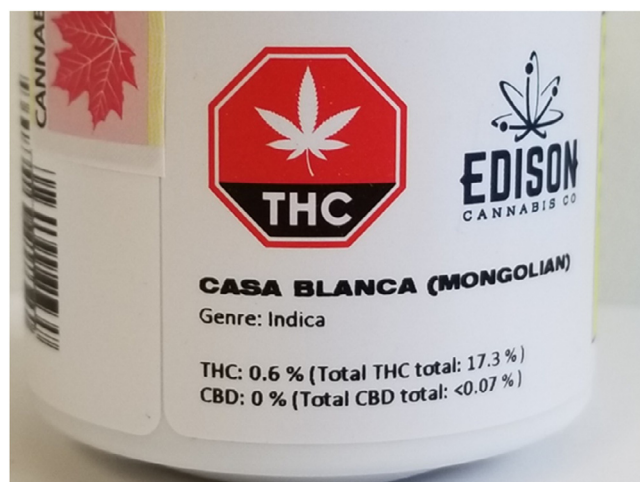


Fig. 1. THC and CBD labelling on Canadian dried herb products.

2019a). US states that have legalized cannabis also require THC numbers—along with 'universal THC symbols' and other labelling information—to be displayed on products (Barrus et al., 2016).

To date, there is very little research on consumer understanding of THC numbers. What little research exists suggests that very few consumers know the THC levels of their cannabis products. An experimental study conducted in Canada prior to recreational cannabis legalization found that consumers had little or no context for interpreting THC numbers (Leos Toro, Fong, Meyer, & Hammond, 2019). When shown a container of dried herb indicating 25% THC—close to the upper limit of THC content available in most markets—less than one third of respondents identified the product as 'high' in THC. Similarly, when viewing labels for edibles, most consumers assume that one dose or serving is equivalent to an entire edible, despite the presence of a label indicating 40 mg of THC, which represents a very high dose for most users.

Presumably, consumer understanding of THC amounts would increase following legalization, due to greater exposure to standardized THC labelling. However, focus groups conducted with consumers in Washington and Colorado revealed that confusion over dosing persists. Both users and non-users do not understand the meaning of '10 mg of THC' (Kosa, Giombi, Rains, & Cates, 2017). Problems were particularly evident among non-users, who had little idea of the typical amount that should be consumed or how 10 mg of THC would affect them. Even regular edible users reported widespread concerns about the unpredictable strength of edibles, trouble with dose control, and challenges understanding packaging/serving sizes (Giombi, Kosa, Rains, & Cates, 2018), consistent with previous research (O'Connell & Bou-Matar, 2007; Swift, Gates, & Dillon, 2005).

Consumer difficulties in understanding THC levels can be exacerbated by the ways in which these numbers have been presented to consumers, and the amount of information displayed on labels. For example, Canadian regulations require products to display a "Total THC amount"—which includes both THCA and THC—as well as a "THC amount", which only includes the amount of THC that has been converted at the time of packaging (Government of Canada, 2019a; State of Colorado, 2019). THCA is the cannabinoid found in the plant that is converted to THC during the curing phase and in response to heat. The distinction between THC and THCA for dried herb is practically meaningless to consumers: reporting a single THC number that takes into account the standard conversion factor represents a much more straightforward and intuitive labelling approach. Other jurisdictions require additional information on potency, such as the requirement in Colorado to display a range of THC numbers to express possible ranges in potency due to variability in product testing (Barrus et al., 2016; State of Colorado, 2019). These practices provide little or no guidance for con-

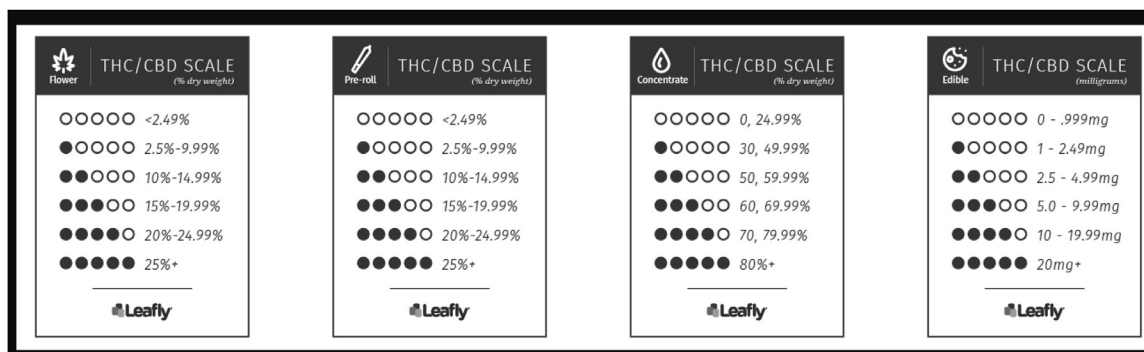


Fig. 2. Source: <https://www.leafly.com/news/cannabis-101/understanding-marijuana-thc-cbd-levels>.

sumers with respect to dose titration, and contribute more confusion than clarity (Kosa et al., 2017).

Cannabis retailers often provide additional non-numeric indicators of product potency. In Canada, where retail distribution is under provincial control, the province of Quebec uses a system based on three descriptors—‘moderate’, ‘medium’, and ‘high’—for labelling THC levels in dried herb, oils and capsules (Société québécoise du cannabis, 2019). Popular sources of online cannabis information, such as Leafly, have promoted more intuitive THC dose systems that use symbols to provide context for THC amounts (see Fig. 2). While the validity of these systems would benefit from additional data exploring dose effects in clinical trials, these approaches have the advantage of providing consumers with basic context for THC numbers, as well as some guidance regarding the relative strength across product categories.

The standard dose or serving of THC labelled on products should not exceed the typical level required to induce intoxication among most consumers

Consumers have expressed a desire for information on a standard serving or dose to guide consumption amounts (Kosa et al., 2017; Leos Toro et al., 2019). The concept of a standard drug dose is well established for pharmaceutical products, which are required to display a recommended single and daily dose as part of “adequate directions for use of the drug product” (Health Canada, 2015).

To date, no jurisdiction has explicitly identified a standard dose for THC. However, both 5 mg and 10 mg of THC are widely used as standard serving sizes for edibles in US states, based on the maximum allowable serving size (Government of Canada, 2019a; Kosa et al., 2017; State of Colorado, 2019). Interestingly, the concept of a standard THC serving has not been widely applied to other cannabis product categories. For example, in Colorado, whereas the potency statement for edibles requires products to label the number of servings in each product and the amount of THC in each serving, labels for vapourizers, ingested oils, and solid concentrates only require the amount of THC expressed in either a percentage or mgs, with no information on the number of servings in the product (State of Colorado, 2019).

The decision to use 10 mg as a serving size appears to have been somewhat arbitrary. Indeed, a 10 mg THC serving is notably higher than typical recommendations provided to medical cannabis users. For example, in Canada, Licensed producers of medical cannabis typically recommended a starting dose of ≤ 5 mg THC for ingested oils (Green Relief, 2019; Medreleaf, 2019; Tweed/Harvest Medicine, 2019), while Health Canada recommends that new medical cannabis users begin “at a very low dose (e.g. 1 mg THC)” (Health Canada, 2016b).

The desired dose of THC among recreational users is highly subjective and depends upon a range of factors, including individual tolerance levels. While some medical cannabis users seek CBD-rich products with little to no THC, other users report consuming very high THC levels (Grotenhermen, 2001; Prince, Conner, & Pearson, 2018). However, as a general principle, a standard dose should be set sufficiently low

to allow consumers to effectively titrate to minimize adverse effects, while attaining the desired therapeutic or psychoactive effect. The alcohol market illustrates this concept. As is the case for cannabis, alcohol is consumed in a wide range of quantities by different consumers, depending upon the occasion and individual preference and tolerance. Nevertheless, the percentage of alcohol in a ‘standard drink’—which roughly corresponds to typical serving sizes for beer, wine, and spirits—is lower than the level that would induce intoxication or impairment for most consumers (Centre for Substance Abuse and Addiction (CCSA), (2012)). Even many heavy drinkers monitor the ‘number of drinks’ to gauge their consumption levels (Osioy et al., 2015). As a general rule, it is easier for consumers to add standard units or servings than it is to divide products into smaller units. Thus, in regards to cannabis products, it is far easier to titrate THC by consuming two 5-mg edibles than to divide a single 10-mg chocolate in half, particularly given that THC may not be equally distributed within the product (Giombi et al., 2018). Overall, given that ‘recreational’ guides to cannabis use and guidelines for medical cannabis users both recommend lower doses, a standard dose of no more than 5 mg THC for edibles and oils would provide consumers with greater ability to titrate their dose (Green Relief, 2019; Medreleaf, 2019; Tweed/Harvest Medicine, 2019).

Labelling should provide guidance on THC amounts or ‘dose expression’

A critical component of labelling is to express the drug dose in the volume or amount of the product. For example, Health Canada’s guidance for non-prescription drug products states, “The dosage on consumer-available non-prescription drug product labels should state the number of tablets or capsules per dose, or the volume of product to be delivered (e.g., ml, teaspoon, tablespoon or where a calibrated dosing device should be used” (Health Canada, 2015). This is consistent with dosing recommendations for orally ingested oils provided by medical cannabis providers. For example, licensed producers provide information on THC and CBD concentrations, as well as recommendations to ingest 0.2 mL of a particular cannabis oil to consume 5 mg of THC (Green Relief, 2019; Medreleaf, 2019; Tweed/Harvest Medicine, 2019). Currently, there is no such guidance as part of cannabis labelling requirements in Canada or other jurisdictions. Thus, even if consumers know approximately how much THC they wish to ingest, they need to calculate the corresponding consumption amount from the THC concentration displayed on the label. For example, THC oils containing 25 mg of THC per mL are common in the Canadian market. Therefore, if a consumer wishes to ingest 5 mg of THC, they will need to divide 25 by 5, and then divide 1 mL by 5 to determine they should ingest 0.2 mL of oil. It is well established that most consumers lack the requisite numeracy skills to perform these calculations (Lipkus, Samsa, & Rimer, 2002), as has been repeatedly demonstrated in nutrition labelling research, in which most consumers are unable to calculate amounts of nutrients in different serving sizes (Vanderlee, Goodman, Sae Yang, & Hammond, 2012).

Labelling regulations that are based on the principle of dose expression would indicate the amount of product corresponding to a standard THC serving, rather than relying on consumers to calculate this information. Dose expression is particularly relevant for cannabis products that contain multiple doses or servings, including oils and potentially dried herb and solid concentrates. This approach provides consumers with practical guidance on how to achieve their desired dose and provides a common basis for comparing products.

THC labelling should be reinforced by other packaging regulations, such as unit-dose packaging

The principle of dose-expression can also be applied to packaging standards. Currently, many edibles are packaged such that one product has multiple servings of THC. States such as Colorado and Washington have established limits of 100 mg of THC, or 10 servings, per product (State of Colorado, 2019; Washington State Legislature, 2019). In addition, each serving must be “physically demarked in a way that enables a reasonable person to intuitively determine how much of the product constitutes a single serving of active THC”, such as separate squares of chocolate in a bar. Nevertheless, many consumers believe that the entire product—such as a cookie or chocolate bar—represent one serving, even when the number of doses are clearly labelled (Hudak et al., 2015; Leos Toro et al., 2019). To date, official statistics from the Government of Colorado do not indicate any reduction or decline in the rate of hospitalizations, emergency department visits or poison control centre calls associated with cannabis (Reed, 2019a). These data would suggest that the revised labelling standards implemented in Colorado have had no measurable effect.

‘Unit-dose packaging’ represents a more direct approach to reflecting serving size or drug dose on packaging. Unit-dose packaging refers to the practice of packaging each dose separately, so that each pill or unit contains one standard dose. So-called ‘blister’ packages are widely used both for convenience and safety of pharmaceutical products. Similar practices are used for non-pharmaceutical products, such as chewing gum, in which each individual pieces are wrapped or packaged separately and contained within a larger package. Implementing unit-dose packaging would also address cases in which the THC content of an edible is not evenly distributed within a multi-serving product, for which efforts to dose-control by dividing the product into smaller portions would be unpredictable and ineffective (Giombi et al., 2018).

Canada has recently proposed a form of ‘unit-dose packaging’ for cannabis edibles, in which each 10-mg serving would require separate packaging (Government of Canada, 2018). The proposed regulations extend the same concept to cannabis extracts, by requiring that a maximum of 10 mg THC could be dispensed in a single ‘activation’, such as a spray.

Overall, unit-dose packaging for cannabis products would provide consumers with clear, unequivocal information on THC content and a superior ability to titrate THC dose. Although edibles represent the best candidate for unit-dose packaging, the same approach could be applied to ingested oils through the use of metered pumps which express a fixed amount of solution, and through vapourizers that can control the dosing in each puff. Unit-dose packaging could also be applied to solid concentrates, such as wax or shatter; based on current THC concentrations, the unit of each product would be very small, such that unit-dose packaging based on standard servings may incentivize the production of more dilute solid extracts.

Labelling should provide a common basis for comparisons between products, to the extent possible

Ideally, a standard THC dose or serving would be applied across the full range of cannabis products, including dried herb and solid concentrates intended for inhalation. Indeed, consumers have expressed a desire for ‘dose expression’ labelling and information about the potency

of products across product categories, such as how 10 mg of THC in an edible is equivalent to the number of hits or tokes from smoking dried herb (Kosa et al., 2017).

Physical equivalency can be expressed in several ways, such as the total THC content of a product. In some cases, physical equivalency has also been expressed as the amount of flower or dried herb required to produce extracts, such as edibles or solid concentrates (Caulkins et al., 2018; Orens, Light, Rowberry, Matsen, & Lewandowski, 2015). For example, Health Canada required medical cannabis licensed producers to indicate the product’s equivalency to one gram of dried cannabis, which was communicated to consumers in different ways (Government of Canada, 2016). Physical equivalencies are also used in possession limits for different types of cannabis products, such as oils and solid concentrates (Government of Canada, 2019a). In Colorado, one ounce of cannabis flower is equivalent to 80 ten-milligram servings of THC (State of Colorado, 2019).

However, comparing products based on physical equivalencies or THC ‘content’ has limitations, in part because physical equivalency depends on the production method, form of supply, and the THC/CBD yield. More importantly, the mode of administration changes a drug’s pharmacokinetics (Grotenhermen, 2003; MA, 2007). For example, not all the THC in dried herb products is actively inhaled—much of it is released in the smoke between puffs—and not all the THC that is inhaled is absorbed. Recent research suggests potentially greater bioavailability of THC from dried herb that is vapourized versus smoked (Spindle et al., 2018). Studies estimate that approximately 20% of THC content in dried herb is metabolised and absorbed into the blood stream, compared to approximately 10% of that in edibles. The latter depends on a number of other factors, such as the presence of other foods in the stomach. The time to onset and duration of effect also differs: smoke inhalation and THC absorption into the bloodstream via the lungs produces faster, higher-peak effects; however, THC levels also abate more quickly. In contrast, oral ingestion leads to slower onset and longer duration, as well as higher concentrations of 11-OH-THC, a THC metabolite that crosses the blood-brain barrier more easily, producing greater psychoactive effects (Huestis, Henningfield, & Cone, 1992; Law, Mason, Moffat, Gleadle, & King, 1984; Nahas, 1975; Nadulski et al., 2005).

One non-peer reviewed report examined the differences in THC metabolism between inhalation and oral ingestion and estimated that 1 mg of THC in edibles is equivalent to 5.7 mg of THC in smoked cannabis (Orens et al., 2015). However, additional research is required to establish pharmacokinetic equivalency across consumption modes, and it remains to be determined whether the qualitative differences between THC consumed via inhalation versus oral ingestion can be adequately represented in quantitative equivalencies (O’Connell & Bou-Matar, 2007). In the absence of established pharmacokinetic equivalencies, the ability to apply dose-expression labelling for inhaled products remains uncertain, particularly for larger quantities of dried herb, or for solid concentrates that are packaged in a wide variety of quantities. For dried herb, although THC servings could potentially be labelled on a ‘per gram’ basis, many users have difficulty estimating grams (Goodman, Leos-Toro, & Hammond, 2019). It remains unclear whether labelling the number of THC servings or doses in a pre-rolled joint or solid concentrate would provide effective guidance to consumers.

Conclusions

One of the basic components of a well-regulated drug market is the ability of consumers to identify and safely consume their desired dose. To date, the regulatory practice of labelling THC levels of cannabis products using milligrams and percentages has had limited effectiveness. As a greater number of jurisdictions legalize non-medical cannabis—and consumers transition to more potent products—there is a need to develop clear, easy-to-understand THC content labels to minimize the risks of ‘overconsumption’. Ideally, THC labelling for cannabis products should address five basic principles: 1) THC content should be clearly labelled

and should require minimal numeracy to understand; 2) the standard dose or serving of THC labelled on products should be lower than the typical level required to induce intoxication for most consumers; 3) labelling should provide guidance on THC amounts or 'dose expression'; 4) to the extent possible, labelling should provide a common basis for comparisons between products; and 5) THC labelling should be reinforced by other packaging regulations, such as unit-dose packaging

Enhancements to THC labels may also support efforts to promote 'lower-risk' cannabis use. Lower-risk guidelines typically recommend avoiding high THC products and consumers are often advised to 'start slow and go slow' (Fischer et al., 2017; Health Canada, 2016b). However, this qualitative guidance will have little impact if consumers do not know what constitutes a 'low' dose or have difficulty selecting low doses, particularly for cannabis extracts. Setting the standard serving at 5 mg or lower is consistent with principles of harm reduction and promoting lower-THC products, particularly when combined with unit-dose packaging. Enhanced labelling may also support the recommendation to avoid combustible modes by reducing uncertainty surrounding the potency of edibles and other orally ingested products (Moir et al., 2008; National Academies of Sciences, Engineering, & Medicine, 2017).

More effective labelling would be particularly beneficial for novel and very occasional users, who often lack basic context for product strength. The cannabis industry may also benefit to the extent that enhanced product labelling may reduce the likelihood of overconsumption. Some industry stakeholders have suggested that a 5 mg serving is too low on the basis that many consumers seek to ingest far higher THC quantities (Doherty, 2019). However, smaller serving sizes do not limit the ability of consumers to ingest larger quantities any more than standards servings of food limit how much is eaten or standard alcohol servings limit alcohol consumption. Standard serving sizes simply provide a metric for quantifying THC doses for users across the consumption spectrum.

Cannabis labelling will likely evolve over time in response to new research and increasing regulatory experience, as has been the case for tobacco labelling (Hammond, 2011). In particular, the use of THC numbers as an overall indicator for potency is simplistic and disregards the importance of other cannabinoids, such as CBD. CBD is widely recognized as an important moderator of the psychoactive effects of THC, but is poorly understood and requires further research (Russo, 2011). CBD levels should continue to be labelled alongside THC, as is currently the case in legalized markets. Enforcement to ensure accurate testing and compliance with labelling standards will be important under any regulatory framework, as noted in recent reviews of US state systems (Secretary of State, Oregon Audits Divisions, 2019). Finally, THC labelling should not take the place of public education on cannabis potency and differences across modes of administration. For example, Canada and several US states require statements on edibles informing consumers about latent onset and duration. Collectively, these labelling regulations have the potential to minimize adverse outcomes among consumers and promote lower risk cannabis use.

Funding acknowledgment

This study was supported by a Canadian Institutes of Health Research (CIHR) Project Bridge Grant (PJT-153342). Additional support was provided by a CIHR Research Chair in Applied Public Health (DH).

Declarations of Interest

None to declare.

References

Barrus, D. G., Capogrossi, K. L., Cates, S. C., Gourdet, C. K., Peiper, N. C., Novak, S. P., et al. (2016). *Tasty THC: Promises and challenges of Cannabis edibles*. Methods Rep RTI Press. Nov 2016

- Borodovsky, J. T., & Budney, A. J. (2017). Legal cannabis laws, home cultivation, and use of edible cannabis products: A growing relationship? *International Journal of Drug Policy*, 50, 102–110.
- Borodovsky, J. T., Lee, D. C., Crosier, B. S., Gabrielli, J. L., Sargent, J. D., & Budney, A. J. (2017). U.S. Cannabis legalization and use of vaping and edible products among youth. *Drug and Alcohol Dependence*, 177, 299–306.
- Brohl, B., Kammerzell, R., & Koski, W. L. (2015). *Colorado Marijuana enforcement division: Annual update*. Denver, CO: Colorado Department of Revenue.
- Caulkins, J. P., Bao, Y., Davenport, S., Fahli, I., Guo, Y., Kinnard, K., et al. (2018). Big data on a big new market: Insights from Washington State's legal cannabis market. *International Journal of Drug Policy*, 57, 86–94.
- Cavazos-Rehg, P. A., Krauss, M. J., Sowles, S. J., Floyd, G. M., Cahn, E. S., Chaitan, V. L., et al. (2018). Leveraging user perspectives for insight into cannabis concentrates. *American Journal of Drug and Alcohol Abuse*, 44(6), 628–641.
- Centre for Substance Abuse and Addiction (CCSA) (2012). *Canada low-risk alcohol drinking guidelines*. Available at: <http://www.ccdus.ca/Resource%20Library/2012-Canada-Low-Risk-Alcohol-Drinking-Guidelines-Brochure-en.pdf>.
- Chandra, S., Radwan, M. M., Majumdar, C. G., Church, J. C., Freeman, T. P., & El-Sohly, M. A. (2019). New trends in cannabis potency in USA and Europe during the last decade (2008–2017). *European Archives of Psychiatry and Clinical Neuroscience* [Epub ahead of print]. 10.1007/s00406-019-00983-5.
- Doherty, B. (2019). *Brownies in Canada could be 10 times weaker than in several U.S. States. Here's why some people think that could be a big problem*. Hamilton Spectator 2019 Feb 8.
- ElSohly, M. A., et al. (2016). Changes in cannabis potency over the last 2 decades (1995–2014): Analysis of current data in the United States. *Biological Psychiatry*, 79(7), 613–619.
- Fischer, B., Russell, C., Sabioni, P., van den Brink, W., Le Foll, B., Hall, W., et al. (2017). Lower-risk Cannabis use guidelines: A comprehensive update of evidence and recommendations. *American Journal of Public Health*, 107(8), e1–e12.
- Giombi, K. C., Kosa, K. M., Rains, C., & Cates, S. C. (2018). Consumers' perceptions of edible marijuana products for recreational use: Likes, dislikes, and reasons for use. *Substance Use & Misuse*, 53(4), 541–547.
- Goodman, S., Leos-Toro, C., & Hammond, D. (2019). Methods to assess Cannabis consumption in population surveys: Results of cognitive interviewing. *Qualitative Health Research* [Epub ahead of print]. 10.1177/1049732318820523.
- Government of Canada (2016). *Access to Cannabis for medical purposes regulations. Controlled drugs & substance act. P.C. 2016-743 August 5, 2016*. Available at: <http://gazette.gc.ca/rp-pr/p2/2016/2016-08-24/html/sor-dors230-eng.html>.
- Government of Canada (2018). *Canada gazette, part I, volume 152, number 51: Regulations amending the Cannabis regulations (New classes of Cannabis)* 22 Dec 2018. Available at: <http://www.gazette.gc.ca/rp-pr/p1/2018/2018-12-22/html/reg4-eng.html>.
- Government of Canada (2019). *Cannabis act*. Available at: <https://laws-lois.justice.gc.ca/PDF/C-24.5.pdf>.
- Government of Canada (2019). *Cannabis regulations (SOR/2018-144)* Available at: <https://laws-lois.justice.gc.ca/eng/regulations/SOR-2018-144/>.
- Green Relief (2019). *Cannabis oil dosage: A how-to guide*. Available at: <https://www.greenrelief.ca/blog/cannabis-oil-dosage/>.
- Grotenhermen, F. (2001). Harm reduction associated with inhalation and oral administration of cannabis and THC. *Journal of Cannabis Therapeutics*, 1(3–4), 133–152.
- Grotenhermen, F. (2003). Pharmacokinetics and pharmacodynamics of cannabinoids. *Clinical Pharmacokinetics*, 42(4), 327–360.
- Hammond, D. (2011). Health warning messages on tobacco products: A review. *Tobacco Control*, 20, 327–337.
- Health Canada (2015). *Guidance document: Labelling of pharmaceutical drugs for human use 2015/06/13*. Available at: <https://www.canada.ca/en/health-canada/services/drugs-health-products/drug-products/applications-submissions/guidance-documents/labelling-pharmaceutical-drugs-human-use-2014-guidance-document.html>.
- Health Canada (2016). *Good label and package practices guide for prescription drugs* June 30, 2016 Available from: <https://www.canada.ca/en/health-canada/services/drugs-health-products/reports-publications/medeffect-canada/good-label-package-practices-guide-prescription-drugs.html>.
- Health Canada (2016). *Access to Cannabis for medical purposes regulations – daily amount fact sheet (Dosage)* July 2016. Available at: <https://www.canada.ca/en/health-canada/services/drugs-medication/cannabis/information-medical-practitioners/cannabis-medical-purposes-regulations-daily-amount-fact-sheet-dosage.html>.
- Health Canada (2018). *Canadian Cannabis survey: 2018 summary*. Available at: <https://www.canada.ca/en/services/health/publications/drugs-health-products/canadian-cannabis-survey-2018-summary.html>.
- Hudak, M., Severn, D., & Nordstrom, K. (2015). Edible cannabis-induced psychosis: Intoxication and beyond. *American Journal of Psychiatry*, 172(9), 911–912.
- Huestis, Henningfield, J. E., & Cone, E. J. (1992). Blood cannabinoids. I. Absorption of THC and formation of 11-OH-THC and THCCOOH during and after smoking marijuana. *Journal of Analytic Toxicology*, 16, 276–282.
- Institute for Safe Medication Practices Canada (2013). *Labelling and packaging: An aggregate analysis of medication incident reports. Project report [Internet]* 2013 Sep 14. Available at: Toronto (ON): The Institute. http://www.ismp-canada.org/download/LabellingPackaging/ISMPC2013_LabellingPackaging_FullReport.pdf
- Jikomes, N., & Zoorob, M. (2018). The cannabinoid content of legal Cannabis in Washington state varies systematically across testing facilities and popular consumer products. *Scientific Reports*, 8, 4519.
- Kilmer, B. (2014). Policy designs for cannabis legalization: Starting with the eight Ps. *American Journal of Drug and Alcohol Abuse*, 40(4), 259–261.

- Knapp, A. A., Lee, D. C., Borodovsky, J. T., Auty, S. G., Gabrielli, J., & Budney, A. J. (2018). Emerging trends in Cannabis administration among adolescent Cannabis users. *Journal of Adolescent Health* pii: S1054-139X(18)30301-X.
- Kosa, K. M., Giombi, K. C., Rains, C. B., & Cates, S. C. (2017). Consumer use and understanding of labelling information on edible marijuana products sold for recreational use in the states of Colorado and Washington. *International Journal of Drug Policy*, 43, 57–66.
- Law, B., Mason, P. A., Moffat, A. C., Gleadle, R. I., & King, L. J. (1984). Forensic aspects of the metabolism and excretion of cannabinoids following oral ingestion of cannabis resin. *Journal of Pharmacy and Pharmacology*, 36, 289–294.
- Leos Toro, C., Fong, G. T., Meyer, S., & Hammond, D. (2019). *Cannabis labelling and consumer understanding of THC levels and serving sizes*. Under Review.
- Lipkus, I. M., Samsa, G., & Rimer, B. K. (2002). General performance on a Numeracy Scale among highly educated samples. *Medical Decision Making*, 21, 37–44.
- MA (2007). Human cannabinoid pharmacokinetics. *Chemistry & Biodiversity*, 4(8), 1770–1804.
- Medreleaf (2019). *Prescribing and dosing*. Available at: https://medreleaf.com/app/uploads/2017/08/MedReleaf_oil_E_digital.pdf.
- Moir, D., Rickert, W. S., Levasseur, G., Larose, Y., Maertens, R., White, P., et al. (2008). A comparison of mainstream and sidestream marijuana and tobacco cigarette smoke produced under two machine smoking conditions. *Chemical Research in Toxicology*, 21(2), 494–502.
- Monte, A. A., Zane, R. D., & Heard, K. J. (2015). The implications of marijuana legalization in Colorado. *JAMA*, 313(3), 241–244.
- Nadulski, T., et al. (2005). Simultaneous and sensitive analysis of THC, 11-OH-THC, THC-COOH, CBD, and CBN by GC-MS in plasma after oral application of small doses of THC and cannabis extract. *Journal of Analytical Toxicology*, 29(8), 782–789.
- Nahas, G. G. (1975). Marijuana: Toxicity and tolerance. In R. W. Richter (Ed.), *Medical aspects of drug abuse* (pp. 16–36). Baltimore, MD: Harper & Row.
- National Academies of Sciences, Engineering, and Medicine (2017). *The health effects of Cannabis and cannabinoids: The current state of evidence and recommendations for research*. Washington, DC: The National Academies Press. Available from 10.17226/24625.
- O'Connell, T. J., & Bou-Matar, C. B. (2007). Long term marijuana users seeking medical cannabis in California (2001–2007): Demographics, social characteristics, patterns of cannabis and other drug use of 4117 applicants. *Harm Reduction Journal*, 4, 16.
- Oregon Liquor Control Commission (2019). *Recreational Marijuana supply and demand legislative report* January 31, 2019. Available at: [https://www.oregon.gov/olcc/marijuana/Documents/Bulletins/2019%20Supply%20and%20Demand%20Legislative%20Report%20FINAL%20for%20Publication\(PDFA\).pdf](https://www.oregon.gov/olcc/marijuana/Documents/Bulletins/2019%20Supply%20and%20Demand%20Legislative%20Report%20FINAL%20for%20Publication(PDFA).pdf).
- Orens, A., Light, M., Rowberry, J., Matsen, J., & Lewandowski, B. (2015). *Marijuana Equivalency in Portion and Dosage: An assessment of physical and pharmacokinetic relationships in marijuana production and consumption in Colorado. Prepared for the Colorado Department of Revenue*. 2015 Aug. Available at: https://www.colorado.gov/pacific/sites/default/files/MED%20Equivalency_Final%2008102015.pdf.
- Orens, A., Light, M., Lewandowski, B., Rowberry, J., & Saloga, C. (2017). *Market size and demand for marijuana in Colorado 2017 market update. Prepared for the Colorado Department of Revenue*. Available from <https://www.colorado.gov/pacific/sites/default/files/MED%20Demand%20and%20Market%20%20Study%20%20082018.pdf>.
- Osiowy, M., Stockwell, T., Zhao, J., et al. (2015). How much did you actually drink last night? An evaluation of standard drink labels as an aid to monitoring personal consumption. *Addiction Research & Theory*, 23, 163–169.
- Prince, M. A., Conner, B. T., & Pearson, M. R. (2018). Quantifying cannabis: A field study of marijuana quantity estimation. *Psychology of Addictive Behaviors*, 32(4), 426–433.
- Raber, J. C., Elzinga, S., & Kaplan, C. (2015). Understanding dabs: Contamination concerns of cannabis concentrates and cannabinoid transfer during the act of dabbing. *Journal of Toxicological Sciences*, 40(6), 797–803.
- Reed, J. K. (2019). *Impacts of marijuana legalization in Colorado: A report pursuant to senate bill 13-283* Available at: Colorado Division of Criminal Justice, Department of Public Health. https://cdpsdocs.state.co.us/ors/docs/reports/2018-SB13-283_Rpt.pdf
- Reed, J. K. (2019). *Impacts of Marijuana legalization in Colorado: A report pursuant to senate Bill 13–283*. Available at: Colorado Division of Criminal Justice, Department of Public Health. http://cdpsdocs.state.co.us/ors/docs/reports/2018-SB-13-283_report.pdf
- Ritter, A. (2010). Illicit drugs policy through the lens of regulation. *International Journal of Drug Policy*, 21(4), 265–270.
- Room, R., Fischer, B., Hall, W., Lenton, S., & Reuter, P. (2010). *Cannabis policy: Moving beyond stalemate*. Oxford, UK: Oxford University Press.
- 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.
- Russo, E. B. (2011). Taming THC: Potential cannabis synergy and phytocannabinoid-terpenoid entourage effects. *British Journal of Pharmacology*, 163(7), 1344–1364.
- Secretary of State, Oregon Audits Divisions (2019). *Oregon liquor control commission Oregon health authority Oregon's framework for regulating marijuana should be strengthened to better mitigate diversion risk and improve laboratory testing*. January 2019 2019-04. Available from: <https://sos.oregon.gov/audits/Documents/2019-04.pdf>.
- Société québécoise du cannabis (2019). *Cannabis products*. Available at: <https://www.sqdc.ca/en-CA/>.
- Spindle, T. R., Cone, E., Schlien, N. J., Mitchell, J. M., Bigelow, G. E., Flegel, R., et al. (2018). *Acute effects of smoked and vaporized cannabis in healthy adults who infrequently use Cannabis: A crossover trial*.
- State of Colorado (2019). *Retail marijuana rules: 1 CCR 212-2*. Available at: <https://www.colorado.gov/pacific/sites/default/files/ColoradoRegister.pdf%20CCR%20212%20-%20Retail%20Effective%20022018.pdf>.
- Stogner, J. M., & Miller, B. L. (2015). *Assessing the dangers of "Dabbing": Mere Marijuana or harmful new trend? Pediatrics*, 136, 1–3.
- Swift, W., Gates, P., & Dillon, P. (2005). *Survey of Australians using cannabis for medical purposes. Harm Reduction Journal*, 2, 18.
- The Institute for Safe Medication Practices Canada (2018). *Good label and package practices guide for non-prescription drugs and natural health products* September 28, 2018. Available at: Health Canada <https://www.canada.ca/en/health-canada/services/drugs-health-products/reports-publications/medeffect-canada/good-label-package-practices-guide-non-prescription-drugs-natural-health-products.html>.
- Tweed/Harvest Medicine (2019). *Tweed oil titration guide*. Available at: <https://hmed.ca/wp-content/uploads/2018/07/Tweed-Titration-Guide-July-2018.pdf>.
- U.S. Department of Health and Human Services (2013). *Food and Drug Administration. Center for Drug Evaluation and Research (CDER). Guidance for industry: Safety considerations for container labels and carton labeling design to minimize medication errors (draft guidance) [Internet]* 2013 Apr [cited 2014 Jan 20]. Available from: Rockville (MD): The Administration. <http://www.fda.gov/downloads/Drugs/GuidanceComplianceRegulatoryInformation/Guidances/UCM349009.pdf>.
- Vanderlee, L., Goodman, S., Sae Yang, W., & Hammond, D. (2012). Consumer understanding of calorie amounts and serving size: Implications for nutritional labelling. *Canadian Journal of Public Health*, 103(5), 327–331.
- 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, 2491–2493.
- Vigil, D. I., Van Dyke, M., Hall, K. E., Contreras, A. E., Ghosh, T. S., & Wolk, L. (2018). Marijuana use and related health care encounters in Colorado before and after retail legalization. *International Journal of Mental Health and Addiction*, 16, 806–812.
- Washington State Legislature (2019). *Packaging and labeling requirements (WAC 314-55-105)*. Available at: <http://apps.leg.wa.gov/wac/default.aspx?cite=314-55-105>.