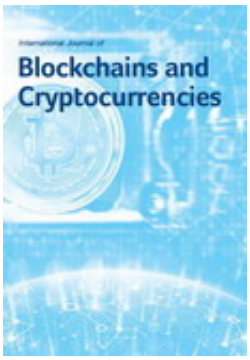

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Exploring the potential impact of blockchain technologies in Health Canada's cannabis supply chain

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Exploring the potential impact of blockchain technologies in Health Canada's cannabis supply chain

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Abstract: This case study explores Health Canada's ability to detect and prevent illegal cannabis infiltration into its supply chain and investigates how blockchain might help address identified weaknesses. The Canadian government's regulatory framework reveals a need for stricter oversight of the cannabis supply chain to enhance security. Current monitoring has a critical weakness, making it susceptible to black market infiltration. This deficiency has led to negative customer perceptions of cannabis production and distribution. Maintaining the status quo risks customers switching to cheaper, higher-quality black-market cannabis. Introducing blockchain technology could shift Health Canada's regulatory approach from human-dependent to a shared responsibility model involving all cannabis ecosystem stakeholders. Blockchain could effectively track cannabis production and distribution, enhance state monitoring of quality standards, detect contaminants, and reduce consumer risks. The study highlights blockchain's potential benefits but also acknowledges its potential high costs.

Keywords: blockchain; cannabis; government regulations; supply chains; cyber security; cannabis reform; digital transformation.

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1 Introduction

Over the last five years, policymakers at the macro and multilateral levels adopted a softer stance on marijuana as a psychoactive substance. In December 2020, the United Nations reclassified marijuana as a non-prohibitive drug, acknowledging its therapeutic use through Schedule IV of the 1961 Single Convention on Narcotic Drugs with some

states attempting to enact domestic laws that reflected this multilateral stance (United Nations News, 2020; World Health Organization, 2020). However, before this reclassification, multiple states attempted to optimise or scale up their emergent cannabis supply chain (Laqueur et al., 2020; von Hoffmann, 2020; Government of Canada, 2016; Government of Canada, 2018a). Extant states that sought access to the global cannabis supply chain were challenged to allay the concerns of stakeholders who were sceptical about their capacity to build and safeguard the industry against infiltration from the black market. This was a valid concern given developments with companies such as CannTrust Canada (CBC, 2019). CannTrust Holdings had its licence reinstated by Health Canada in May 2020, after a one-year suspension for cultivating marijuana in unlicensed rooms. The detection and suspension were a testament that regulation worked, and the system was functioning to design. However, the grounds on which CannTrust Holdings' licence was suspended created an 'I-told-you-so' moment for critics of an industry, which is built on trust, notwithstanding its history of organised crime, narco-trafficking, and money laundering. The situation raised a fundamental question in building a sustainable legal cannabis industry; namely, was it possible to build a regulated marijuana industry that was impenetrable by illegally cultivated marijuana?

For years, advocates argued for a regulated cannabis industry as an alternative strategy to the failed war on drugs (Adinoff and Cooper, 2019; Grund and Breeksema, 2013). The creation of a legal cannabis industry could reduce the demand for black-market produced cannabis and perhaps, organised crime (Hajizadeh, 2016). A compliant licensee who introduces illegal cannabis in a purportedly sterile environment does irreparable harm to an industry trying to distance itself from past adversities. Although the Canadian government demonstrated its monitoring and detection capabilities, there is still an acute need to build an impenetrable regulatory environment. This is necessary to gain the confidence of critical stakeholders such as investors, shareholders, financial institutions, law enforcement medical professionals and concerned parents. The question that now arises is – What is an appropriate strategy to build a regulated industry that minimises the risk of the introduction of illegal cannabis?

Recent researches suggest Blockchain could be used to build and supervise a cannabis value chain (Holste and Schoeber, 2019; Schaupp, 2019). Blockchain technology is renowned for its security and immutability and is currently used in the meat and pharmaceutical industry to enhance traceability across supply chains (Bakarich and Castonguay, 2021; Kassahun et al., 2014). Accordingly, in this analysis, I argue that the introduction of blockchain technology to the Canadian Cannabis supply chain could enhance the state's capacity for regulation.

In this paper, the argument is developed in four distinct sections: Section 1 outlines Health Canada's Cannabis regulatory framework; Section 2 delves into the fundamentals of blockchain technology; Section 3 explores how the adoption of block chain technology could reinforce Health Canada's regulatory framework for cannabis and discussing the potential challenges of its implementation; Section 4 provides the concluding remarks.

2 An overview of Health Canada's cannabis regulatory framework

Before 2018, there was widespread skepticism among stakeholders about the legalisation of cannabis. They doubted the government's ability to effectively set up and regulate a

legal market for cannabis (Fischer, 2017; Haines-Saah and Fischer, 2021; Hall et al., 2019; Hopfer, 2014; Kelsall, 2017; Matheson and Le Foll, 2020; Melchior et al., 2019).

In 2018, Canada passed the Federal Government bill C-45 legalising marijuana in Canada. Post 2018, Cannabis legalisation was supplemented by a regulatory framework which prescribes requirements for production model and safety, packaging, labelling and distribution networks (Power, 2020). The regulatory framework was designed to increase the state's capacity to oversee the domestic cannabis supply chain cultivation, production and distribution, and consumption as the state had the power to grant licences (Government of Canada, 2018b). Cannabis licensee are required to provide a safe and secure production of legal marijuana operation in a sterile environment, and retain greater control over the cannabis supply chain from seed to supplier (Government of Canada, 2016). Based on the provision of the Federal Government bill C-45, the production of cannabis would shift from government and household production to the private sector which would ensure product control, as cannabis would adhere to the Canadian Health and Safety standards. The centralised location would have to meet security requirements to prevent the infiltration of illegal marijuana or stop the diversion of legal cannabis away from the legal supply chain. Moreover, the regulatory framework could facilitate the government's spot checks and testing of licences for the introduction of pesticides and other contaminants (Government of Canada, 2016).

Currently, Health Canada has regulatory oversight for enforcement of the cannabis supply chain using a three-pronged approach: compliance promotion to increase awareness of risk and risk mitigation strategies among stakeholders, compliance monitoring, and enforcement. Of the three regulatory dimensions, compliance monitoring warrants the most examination. The existing strategy is human-dependent. Surveillance is dependent on health inspectors physically visiting warehouses/facilities, inventories, documentation and sample collation for examination. Health Canada depends on its health inspectors and its internal and external sources for intelligence to identify and report health risks. Internal sources may confidentially report illegal practices while external sources such as medical practitioners have a duty of care to report health complications from cannabis consumption (Government of Canada, 2018b).

While there is evidence that the state surveillance effective in tracing the movement of cannabis across its supply chain, there is room for improvement. For example, the 2022 Cannabis Survey revealed influential factors driving cannabis sales were price (30%), safe supply (23%) and quality (12%). Reports have indicated legally grown cannabis was of poorer quality, as growers sometimes omitted several key steps in their rush to market their products (Government of Canada, 2019, 2020; Power, 2020, Turvill, 2020; Wadsworth et al., 2022). Unless the state's regulatory system includes a mechanism to monitor quality, it is unlikely that consumers will choose poor quality legal weed at a higher price over better-quality weed at a lower price on the black market (Government of Canada, 2019, 2020; Levinson-King, 2019; Wadsworth et al., 2022). Consequently, the security gains of Canadian government legal cannabis framework could be easily eroded. To prevent this, it is worth exploring how block chain could help the state increase surveillance, inspire trust and confidence among its stakeholders.

3 Potential impact of blockchain on Health Canada's cannabis regulatory framework

Blockchain technology has evolved significantly since its emergence. Blockchain is "an open, immutable distributed public ledger that allows transactions to take place in a decentralised manner, without a need for a trusted third party" (Jaganathan and Veeramani, 2019). Immutability makes it almost impossible to alter blockchain records stored in the distributed ledger, as the chain-linked blocks expand over time. Blockchain starts with a single node or block that depends on cryptography to store encrypted records. All additional blocks are linked to previous blocks using a cryptographic hash for which a critical feature is its one-way function, as it is almost impossible to reverse the computation of the record (Valeri and Baggio, 2021; Wang et al., 2019). The chain is managed by a peer-to-peer network, where parties are required to follow protocols to verify and permit the addition of blocks to the existing chain (Raj, 2021; Valeri and Baggio, 2021; Gururaj et al., 2020a).

In its early stages, blockchain was acclaimed for its openness. Any peer could join a network and add a block subject to peer consensus, which is the process by which other parties verify and accept the block, albeit the more recent literature has expanded beyond permissionless (public) blockchains to include permissioned (private) blockchains (Polge et al., 2021). The fundamental difference between permissionless and permissioned blockchains is that access to the peer-to-peer network must be granted for the type of node and peer that can access and join. Like public permissionless networks, private permissioned networks also facilitate a decentralised architecture. Accordingly, participants in the permissioned network rely on consensus among the consortium of decision-making members.

One example of a decentralised permissioned blockchain that facilitates a network of nodes is Hyperledger Fabric. These nodes can take several forms such as client nodes, which establish and broadcast transactions to be ordered and executed; peer nodes, which maintain the network interconnection among peers within the network; and, ordering-service-nodes, which establish the order of all transactions. Smart contracts or 'chain codes' are used to validate the transactions within the permissioned network, once all conditions of the contract have been met. Similarly, another permissioned blockchain, known as Quorum, relies on smart contracts such as Ethereum. The Quorum branch of Ethereum differs from the Public Ethereum Network, although Quorum allows network members to establish smart contracts with the public. The privacy of network members is guaranteed as transaction information is only visible to members within these parameters (Polge et al., 2021; Gururaj et al., 2020a, 2022; Shekar et al., 2022).

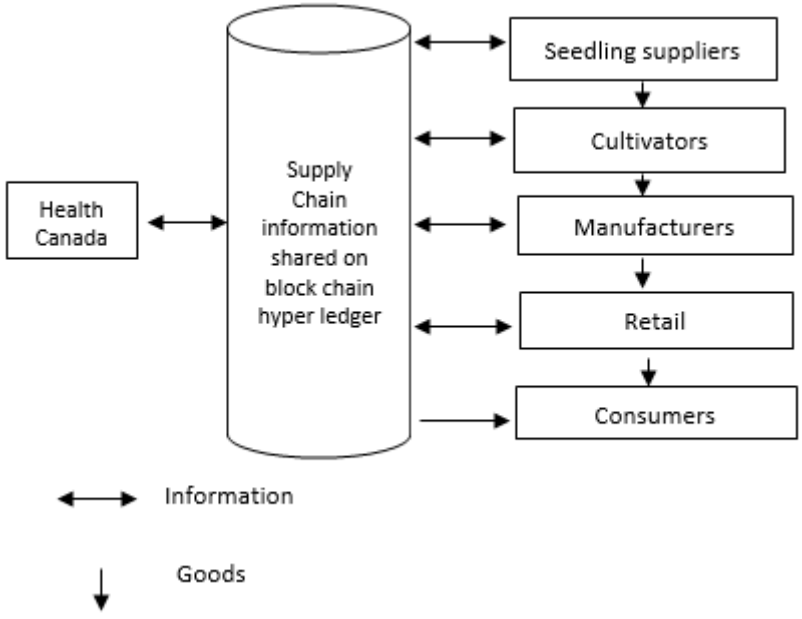
Smart contracts are validated through the use of consensus algorithms or a voting-based system. Each transaction represents a new block in a blockchain network. However, before a new block can be added to the chain, existing members must agree that the transaction was executed and verify the information to be stored in the new block (Raj, 2021). Therefore, consensus algorithms serve as a protocol that allows each blockchain member to democratically participate in validating the information. For example, in a Hyperledger Fabric permissioned blockchain, peers use -Solo- to vote for consensus on a particular transaction. After a transaction is initiated, and before it is accepted as a new block and added to the network chain, Solo relies on an endorsement policy that specifies which sets of peers within the network should vote to endorse a transaction. Similarly, in the Quorum blockchain, the smart contract Ethereum relies on

proof of work (POW) to validate a transaction. A node must provide POW as consensus allows members of the network to validate the information and once achieved, the new block is added to the network (Raj, 2021, Romashkova, 2021; Gururaj et al., 2020a).

4 Exploring blockchain's potential application to the Canadian cannabis supply chain

An overview of involved stakeholders is necessary to apply blockchain technology to the cannabis supply chain. Currently, the Canadian government has regulatory oversight over the entire process. However, the challenge with this top-down bureaucracy is its human dependency which limits the state's capacity to continuously monitor the entire supply chain. As highlighted in Figure 1, blockchain technology would shift the regulatory burden from the state and share the responsibility among all stakeholders in the cannabis supply chain.

Figure 1 Overview of blockchain's application to Canada's cannabis supply chain



The Canadian supply chain is divided into three stages: cultivators, producers, suppliers of raw materials, seeds, seedlings, cannabis for research, plants and plant materials; stakeholders who focus primarily on processing, large scale production by-products, packaging; and labelling of cannabis products for distribution to retailers for sale to the public. Other stakeholders include Health Canada and the federal government which maintain regulatory oversight and local scientists who test the product for quality and contaminants (Health Canada, 2016). Given the current structure of the Canadian cannabis supply chain and the interaction among stakeholders, the fundamental question remains: How can blockchain strengthen the existing regulatory framework?

One response to this question is to first determine the appropriate type of blockchain for use in the case of Health Canada, whether Hyperledger Fabric or Quorum blockchain. Decentralisation is one of the potential benefits of applying blockchain to the Canadian cannabis supply chain (see the Hyperledger Fabric argument outlined earlier). Each stakeholder could be treated as a node in the permissioned network. Through the solo consensus algorithm, the requisite stakeholder would be empowered to collectively validate the transaction. Stakeholders can validate a transaction within the blockchain in a significantly shorter period than it would take Health Canada's inspectors to physically visit a plant or peruse paperwork submitted by cannabis licensees (Gururaj et al., 2020b).

Increased capacity to conduct surveillance is a second potential benefit of blockchain technology applications. Surveillance increases the chance of stakeholder accountability (Chattu et al., 2019; de Chilla et al., 2021; Fitriawijaya et al., 2019; Hihi et al., 2021; Holste and Schoeber, 2019), and enables Health Canada to track the movement of seeds in the supply chain. For instance, each stakeholder is a peer within the supply chain network at different stages and is represented by a node. At stage one, all seeds and seedlings (purchased from the government) can be assigned a batch code that would mandate stakeholders to register the sale of each seed and seedling. Sale-quantity and transaction could be registered on a smart contract, an unencumbered record of the sale and transfer to another node in the network. At stage two would be the purchaser at the other node in the network who would be required to register whatever value was added to the raw materials; the state or another peer would be privy to this record and agree to its accuracy by consensus protocol (Bocek et al., 2017; Health Canada, 2016). Within this network, the state could trace the movement of records across the network, since both the state and company will be able to track the movement of cannabis across the supply chain. If at any stage a company sells more cannabis than is registered in the blockchain, the licensee would be required to give an account for the deficit or surplus quantity. This measure would compel licensees to stay within the confines of their licence.

As mentioned earlier, the key drivers of legal cannabis are price and quality. Information exchanged between consumers and suppliers is indirectly linked to existing supply chains. Since information flows one step backwards between suppliers and one step forward between suppliers and customers, it is proposed that blockchain technology could improve this flow and hold stakeholders accountable within a decentralised permissioned network. Suppliers within the permissioned network should be required to share information with its members. Information could be streamed across stakeholders in the supply chain to increase the level of transparency and trust (Bakarich and Castonguay, 2001; Kassahun et al., 2014). Greater transparency with product information means producers in the cannabis supply chain would be more inclined and incentivised to produce more quality products (Gururaj et al., 2020b). Blockchain could improve the flow of information across all stakeholders in the supply chain through labelling and scanning to improve authenticity and reduce counterfeiting (Kassahun et al., 2014; Kamath, 2018).

Reports of poor quality of legal cannabis in the industry such as inadequate drying time can be improved through blockchain technology, supplemented by artificial intelligence (AI) (Salah et al., 2019; Woods, 2018; Holste and Schoeber, 2019). Health Canada could mandate that all drying rooms be equipped with temperature controlling monitors. Guided by the principle of device to device (D2D) and device to cloud (D2C), the data captured could be fed into the blockchain network or used to increase the accuracy of the information supplemented to the blockchain (Raj, 2021). Once the

temperature falls below a certain degree, all the respective stakeholders would be alerted. If the cannabis is subjected to the required drying standard, the AI could automatically issue a quality seal of approval (Wang et al., 2020).

Through the integration of blockchain, the customer would be able to scan a barcode on a package, which would provide a trail of the cannabis movement across the supply chain. The customer will also gain information on the drying time, chemicals used and source producer. With the introduction of blockchain, health and safety inspectors such as chemists, lab technicians, cannabis board, producers, sellers and quality control officers, would be able to monitor, verify and share results within the cannabis supply chain. Early detection, prevention, testing and recording of the results at each stage could allow state inspectors to detect contamination before the product reaches the consumer. Early detection and increased information exchange across the cannabis supply chain could also increase confidence in the supply chain among producers, retailers and consumers consequently reducing the need to purchase cannabis from the black market (Kassahun et al., 2014).

An added incentive for blockchain technology is the ability to monitor the cannabis supply chain to engender higher levels of trust (Gururaj et al., 2020a, 2020b). Trust helps to build integrity in the cannabis industry. Even though cannabis was declassified as a psycho narcotic substance by the UN Commission on Psychotic Substances, cannabis companies are unable to transact with most financial institutions. Under the know-thy-customer principle, banks cannot vouch for cannabis companies; they cannot ascertain that these companies are not involved in money laundering, or their supply chains are not being infiltrated by the black market (Ballard, 2021). This concern is not unfounded as cases like CannTrust highlight the vulnerability of current black market cannabis supply chains. With greater surveillance and increased transparency of blockchain implementation in the cannabis supply chain, the industry gains greater legitimacy, consequently lessening the chances of illegal infiltration and money laundering. The possible paradigm shift from the introduction of blockchain could strengthen the case for banks to handle financial transactions with the confidence that they know their customer (the cannabis company). Overall, banks and cannabis stakeholders could move closer to having negotiations based on Health Canada's improved capacity to regulate the cannabis supply chain.

4.1 Exploring the possible challenges of applying blockchain technology to Health Canada's supply chain

The untapped potential of blockchain technology in Health Canada's supply chain has the ability to revolutionise the cannabis industry. Although not without challenges, this integration of blockchain technology could enhance stakeholder buy-in through the implicit shift towards enhanced trust and quality assurance. One such challenge to be overcome, has to do with the antiquated technology often employed by the cannabis industry (Wang et al., 2016, 2020). As interoperability is a requirement for the blockchain technology to function, Saberi et al. (2018) highlights the importance of implementing a robust framework aimed at facilitating a smooth transition to a compatible system while minimising disruptions in the supply chain during integration.

Walmart undertook a case study in collaboration with IBM Food Trust after being unable to efficiently track the origins of a bag of sliced mangos. They utilised a traditional method of tracking the origins by calling and emailing distributors and using

the results to establish a benchmark for the proof of concept. After the blockchain integration, the time it took to trace the origins of the sliced mangos went from 6.5 days using the traditional methods to seconds. This successful blockchain integration into its supply chain relied on a phased, cautious framework. Initially, the company focused on less critical, peripheral systems before advancing to core operations. The staff also underwent extensive training to be able to use and understand the new technology. This gradual and intentional approach allowed for adjustments without compromising core business functions. The successful blockchain integration led Walmart to expand the system to additional items (Sharma and Kumar, 2021; Kamath, 2018).

The benefits granted by the immutability and record-keeping mechanism inherent to blockchain technology are often accompanied by challenges around scalability. Increased transaction volume leads to an increase in required resources which can lead to inefficacies and congestion in the supply chain (Zheng et al., 2018). Consensus mechanisms needed for maintaining ledger integrity in decentralised blockchain networks emphasise these challenges through the potential to obstruct performance and scalability (Croman et al., 2016).

According to Roeck et al. (2020), an increase in volume does not have to be accompanied by scalability issues. Roeck et al. (2020) points to De Beers' 'Tracr' initiative as an example of a blockchain platform that manages large data volumes and complex processes smoothly while also ensuring speed and scalability. Born out of a desire to foster trust for stakeholders throughout the diamond value chain, the platform meticulously records each diamond's attributes and journey. The collaborative and strategically planned framework employed provides a transparent and tamper-proof system, illustrating the vast potential of thoughtful blockchain design.

The immutability of records on a blockchain, while preventing post-entry alteration, does not automatically ensure the accuracy of the data upon entry.

Valeri and Baggio (2021) have highlighted concerns about the potential for stakeholders to input falsified data, such as incorrect drying times and temperatures. To mitigate this risk, a verification mechanism is necessary. Artificial intelligence (AI) has been used to monitor critical metrics in the supply chains of the German meat industry and Indian agriculture industry. It automatically generates secure hashes that are recorded on the blockchain (Hihi et al., 2021; Jaganathan and Veeramani, 2019; Kassahun et al., 2014). The system quickly detects any attempt at post-entry tampering, and alerts are triggered facilitating a prompt response to maintain system integrity. This collaboration between AI and blockchain could set the standard for the cannabis industry, ensuring data integrity from the very beginning.

While utilising supplementary technologies like AI in blockchain technology it is important to ensure that the full spectrum of impact is considered. The introduction of AI for data verification in blockchain systems incurs additional costs, a point noted by Yeşem Kurt et al. (2020) and Zhao et al. (2019). There are substantial expenses associated with configuring a blockchain system related to software development, hardware procurement, and staff training (Rejeb et al., 2020). Additional expenses in the already price sensitive cannabis industry could lead to increased product prices and the potential for consumers to seek unregulated markets. Although, when compared with traditional systems like enterprise resource planning (ERP) platforms, which are described by Li et al. (2023) as particularly costly for small to medium enterprises, blockchain presents a compelling alternative.

The IBM Food Trust initiative illustrates the major investment required to build a scalable system that is compatible with existing infrastructure (Galvez et al., 2018). Walmart's blockchain implementation for food traceability illustrates that notwithstanding ongoing operational costs such as system maintenance and updates, and data storage, the benefit brought on by efficiency improvements in inventory and quality control can counteract these expenses over time (Kamilaris et al., 2018; Petter Olsen et al., 2019).

De Beers' blockchain application for diamond verification has led to both cost savings and an improved user experience. This suggests operational costs can be counterbalanced by long-term system efficiency and fraud reduction (Soko, 2020). The surge of proof-of-work blockchain networks has brought about concerns around energy consumption; at the same time, these concerns have moved the industry towards more sustainable consensus mechanisms, such as proof-of-stake which offer promising methods to eventually mitigate these issues (Kamilaris et al., 2018; Bentov et al., 2016).

5 Conclusion

The legalisation of cannabis by the Canadian government has introduced surveillance challenges to the state's cannabis supply chain. Although the state has had some success in tracking the movement of cannabis across its supply chain, more can be done. The critical feature in the analysis of Health Canada's regulatory framework is its human dependency. In the case of CannTrust, Health Canada showed the state's ability to detect the infiltration of illegal cannabis. However, since a transparent and accountable centralised structure relies on paper trails, random inspections and whistleblowing, the regulatory system would require more work to be functional and trusted.

Blockchain is not foolproof and the full potential and possible drawbacks have not been explored comprehensively. Nonetheless, based on its application in food, agriculture and diamond supply chain management, the adoption of blockchain in Health Canada's cannabis supply chain could supplement human regulatory oversight. Health Canada's surveillance capacity could be increased through decentralisation to improve accountability, as each stakeholder would be responsible for providing and validating information within a permissioned blockchain. The increased stringency could engender greater transparency as stakeholders would be compelled to provide accurate information within the blockchain or risk suspension and reputational damage. With increased accountability and transparency, suppliers would more likely provide greater quality products across the Canadian cannabis supply chain. The production of better-quality products could inspire trust, confidence and by extension greater levels of satisfaction among customers, which would increase the demand for legal cannabis and reduce the dependence on the black market.

The potential benefits of Health Canada's blockchain network serve as an incentive for cannabis supply chain members. Therefore, it is in the interest of all affected stakeholders to participate. Notwithstanding further research is required to explore the actual cost of implementing blockchain technology in Health Canada's Cannabis supply chain.

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