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Meeting Changing Customer Requirements in Food and Agriculture Through the Application of Blockchain Technology

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This research summarizes the implementation of blockchain technology in the food and agriculture industry in Canada. Our research indicates that blockchain solutions are an existing and proven set of technologies. We also describe how blockchain based supply chain traceability information has many more benefits than its current use for food safety and product recalls. We recommend that costs for development of blockchain based solutions should also be distributed across stakeholders, and apportioned by the relevant industry associations. Our research indicates that adoption of blockchain technology in agriculture will achieve critical mass earlier when the industry applies a consortium approach, in a regulatory environment that is supported by government. This report also makes recommendations relevant to the integration of blockchain for end consumers of food.

Keywords: agriculture, food, supply chains, blockchain, distributed database systems, canada, traceability, consumer

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1 INTRODUCTION

The global food and agriculture industry is in a state of flux, in the short-term due to the Covid-19 pandemic, and due to longer term social, environmental, and cultural trends. Like many other industries, the food and agriculture industry is continuously increasing its use of information technology and data to improve efficiency and manage production and delivery of products. One area of current development, blockchain technology, is currently being piloted in different parts of the food and agriculture industry (Kim, H. and Laskowski, 2018) across the world (Sylvester, 2019). This document describes the potential for blockchain technology in the context of the food and agriculture industry in Canada, and many of the findings are applicable to other similar countries.

What Is Blockchain?

Blockchain is a Distributed Leger Technology (DLT). A DLT is a technology that maintains a record, or a ledger of transactions in a distributed format across separate nodes. With its roots and primary use being the foundational technology for cryptocurrency, blockchain was developed as a technology intended to disintermediate existing processes and incumbent business models. Blockchain technology has evolved beyond its initial applications for cryptocurrency to a generic technology that can be used for specific purposes in different industries.

The food and agriculture industry sector has different stakeholders, common and overlapping interests, and a lack of complete transparency. The following features of blockchain provide a foundational technology for solution development in the food and agriculture industry sector:

(1) Permanent record of transactions (Casey and Vigna, 2018).
(2) Transparency and visibility of each transaction (Tapscott and Tapscott, 2016).
(3) Distributed ledger technology without centralized authority (Antonucci et al., 2019).
(4) Smart Contracts/Programmatically Executable Transactions (Salah et al., 2019).
(5) Private permissioned blockchains enable control of what content is visible to each stakeholder (Franke et al., 2020; Yuan et al., 2019; Ding et al., 2020).

First, permanent record of transactions provides different stakeholders connected through a supply chain with confidence that information associated with a product is reliable and it has not been altered. The food industry is susceptible to fraud through opportunism and falsification of information records, due to the price premiums paid for brand name products and product characteristics such as organic growing methods. Information fraud in the food industry includes falsifying records and labels that enable low quality products to be sold as higher priced brand name products (Manning and Monaghan, 2019). Blockchain technology is not a panacea for known ethical issues across all supply chains (Simangunsong et al., 2016). Rather blockchain technology provides additional deterrents and disincentives for unethical behaviour such as collusion, and makes such unethical behaviours more discoverable and more expensive to implement. Both consumer interest in food brand values (Günday et al., 2020), and institutional investor interest in Corporate Social Responsibility issues such as Environmental, Social and Governance (ESG) have been increasing over time (Sambo, 2020). In the context of this paper, the increasing interest in ESG issues is accompanied by increasing requirements in reporting of ESG information in Canada (Cho et al., 2020), and in the food industry (Bellantuono et al., 2018). Solutions have been developed in the blockchain context for the possibility of changing records, such as Byzantine Fault Tolerance (Wang et al., 2019) and prototypes have been built for these solutions (Sheikh et al., 2020). In other words, blockchain does not provide a solution that prevents people from attempting to change transaction records, therefore it's not purely "immutable", but any malicious changes are more clearly detectable and replaceable with the consensus version of transaction records. Therefore a blockchain enabled record of transactions associated with each food product enhances traceability, making falsification of information more discoverable and therefore more expensive in terms of the costs to the brand and consequences to potential bad actors in the process.

Second, blockchain technology enables transparency and visibility of each transaction, which provides both consumers and intermediate stakeholders deep visibility into the food supply chain, enabling the ability for any stakeholder provided with permission to verify claims of origin, quality, and any change of ownership or custody of the product in the supply chain. For increased transparency of food supply chain information to have increased economic value, it is important not only to have a greater quantity of information available, but the quality of the information needs to have a high level of trust by different stakeholders including the end customer. The level of trust in food supply chain information is higher when the certification organizations are independent from the food producers (Wu et al., 2014), and involve government approvals (Wu et al., 2016). In the food and agriculture industry, where the deep transparency described by Tapscott and Tapscott (2016) has not necessarily been a primary practice for many stakeholders, there is a significant level of economic value to be realized from additional transparency of transactions.

Third, another advantage of blockchain is a distributed database or distributed ledger system (Antonucci et al., 2019). In the food and agriculture industry, stakeholder size and market power dynamics create an environment where information is more often centralized than decentralized, and sub-sectors and products in the industry are susceptible to monopolies and oligopolies where information asymmetries can be used to maintain market share. A distributed database that is accessible to permissioned stakeholders will provide an additional layer of assurance that information provided is verifiable and trustworthy for all stakeholders regardless of their size or market position. The technical benefits of blockchain can only be realized when they are coupled with appropriate organizational governance mechanisms. To be specific, a consortium approach is proposed in this paper which provides the appropriate governance mechanisms for realizing the benefits of distributed ledger systems (Mao et al., 2019; Tao et al., 2019; Ding et al., 2020).

Fourth, the greatest long-term potential for applying blockchain technology in the food and agriculture industry comes from the application of Smart Contracts/ Programmatically Executable Transactions (Salah et al., 2019). In agreement with Halaburda (2018), this paper argues that Smart Contracts are one of the high value added features of a distributed ledger solution for the food supply chain. Smart Contracts were originally proposed and described by Szabo (1996). At the most elemental level, Smart Contracts are simply modules of software program code. Blockchain technology enables not only the recording of transactions but the execution of transactions that can be coded as software programs. In the food and agriculture industry in Ontario, contracts are the prevalent form of business to business agreements, and are the basis for the majority of transactions. At the same time, different contracts are mediated through separate markets. For example, commodity contracts, weather futures, and insurance policies are bought, sold or otherwise traded in separate markets. Blockchain technology based Smart Contracts provide the capability of building in any programmable condition into the same contract, therefore allowing a set of different possibilities to be built into contracts. In the food and agriculture industry, premium products demanded by consumers, such as brand name, local and organic produce, require increased long-term investment by producers to attain the characteristics demanded by consumers. Producers would be more willing to make the necessary long-term investments if the risk of obtaining premium prices were reduced through Smart Contracts, which would guarantee payment if clearly pre-specified terms and conditions are met for each product. Therefore over the long-term, blockchain based Smart Contracts enable additional growth in the market for premium products and enable greater capture of economic value per product.

Fifth, private permissioned blockchains enable control of what content is visible to which stakeholder. As opposed to public and open blockchain implementations such as the Bitcoin blockchain, private permissioned blockchains are first private, and only organizations with explicit permission can view or post transactions on the blockchain. Additionally, private permissioned blockchains are permissioned, therefore only stakeholders with specific permissions can view and post specific fields of data. Therefore an organization that is part of the private group of organizations that has access to a private permissioned blockchain can post transactions with a number of different fields, and can set the permissions for which other organizations can view each field. Our rationale for initial implementation in a private permissioned format is that trust and confidence has to be built among the internal stakeholders first, before all information is eventually opened up to end customers. Over the long term, we see increasing openness being an important feature of food supply chain traceability, and a private permissioned blockchain is a building block to creating the initial trust required toward more long-term transparency and openness. In advocating for an initial private, permissioned blockchain solution, we are not advocating for a particular vendor solution, instead we advocate for common standards based solutions in agreement with Flood and McCullagh (2020) to enable the interoperable chain and Smart Contact benefits (Halaburda, 2018) that are essential to create sufficient economic value to cover costs.

In spite of these benefits of blockchain technology in food and agriculture, the industry is a slow adopter of blockchain technology compared to other industry sectors. Deloitte (2018) surveyed international stakeholders on the perceived disruption of blockchain technology by industry, and found that the Food industry had the second lowest perception of disruption, only above the Public Sector. Our research indicates blockchain technology can be as disruptive to the food and agriculture industry as any other industry. Gartner the specialized technology research firm, predicts that "20% of Top Global Grocers Will Use Blockchain for Food Safety and Traceability by 2025" (Omale, 2019, pp1). In agreement with Stevens et al. (2018) in another Gartner report, we accept that the probability of success will increase for blockchain technology projects when Governance, Process, and Culture steps are implemented before the technology implementation step.

Definition of Traceability

Food supply chain traceability is a key concept in this paper, and specifically we utilize the GS1 definition of traceability, which in turn is based on ISO 9001:

> "Traceability is the ability to trace the history, application or location of an object [ISO 9001:2015]. When considering a product or a service, traceability can relate to:
>
> (1) origin of materials and parts;
> (2) processing history;
> (3) distribution and location of the product or service after delivery." (GS1, 2017, p. 1)

2 WHY IS BLOCKCHAIN BENEFICIAL TO AGRICULTURE?

Within the global food and agriculture industry, blockchain has been used for farmer land registries, ensuring humanitarian aid is delivered to the rightful recipients, recording traceability in global supply chains, and reducing waste for small cooperative farmers (Sylvester, 2019). In the context of the food and agriculture industry in Ontario, our research indicates application of blockchain to supply chain traceability has the largest potential benefit (Kim, H. and Laskowski, 2018). Our research indicates application of blockchain to supply chain traceability provides the following potential categories of benefits:

(1) Reduction of time, scope, and costs for food product recalls
(2) Reduction of disputes in quality assurance in the food supply chain
(3) Increase in the size of the market based on assurance of quality
(4) Increase in pricing and value capture based on value for customers
(5) Distribution of value to stakeholders in the supply chain through Smart Contracts
(6) Ability to connect to additional blockchain solutions such as insurance products and services
(7) Ability to meet increasing consumer demands for information on food origins and processes.

Reduction of Time, Scope, and Costs for Food Product Recalls

Blockchain technology is particularly suited to addressing issues of supply chain traceability (Kim, H. and Laskowski, 2018). In the context of the food industry which involves physical product, it is useful to re-emphasize that blockchain provides a chain of information, where linking an information chain accurately to the physical food product requires additional technologies such as per item labeling solutions, and verification methods such as chemical or DNA testing. The food industry often involves a long and complex supply chain of stakeholders that are involved in growing, storing, processing, manufacturing, distributing, retailing and consuming food. Due to the complexity of this supply chain, the traceability of food, including the ability to pinpoint the origin of a particular item, is limited. On occasion there is a health-related contamination of food discovered through consumption, resulting in health issues through restaurants or retail grocery stores. The food safety issue results in removal of the specific product from retailers, restaurants, and distributors traced as far as possible to the point of origin. The point of origin of food products, or food provenance, is often not quickly or easily identifiable, and therefore all related products are often discarded at a significant cost since it is not known which particular product is problematic and which is not. Determining true food provenance requires physical testing such as DNA testing of meat origins (Sander et al., 2018), or mass spectrometry for wine origins (Violino et al., 2020). Blockchain technology provides an information system based solution that does not prevent physical contamination of products, but provides information that enables greater accuracy in pinpointing the origin of problematic product. Therefore blockchain technology reduces the time required for identification, and consequently reduces volume of product removed from sale. Ultimately this results in lower financial costs for retailers as well as lower health risks for consumers.

The *permanent record of transactions* feature of blockchain technology enables tracing supply chain information available on problematic food products. True determination of food provenance in contamination related risks, for example, require a number of steps including pathogen provenance, scientific provenance followed by technology based supply chain records. In an ideal solution, every organization that interacts with a food product item can and should ensure their information is recorded in a database that is accessible by other stakeholders, in both emergency and non-emergency scenarios. Blockchain technology provides the DLT that enables maintenance of records in an immutable state, where changes can easily be detected and corrected. Each handover of a food item within organizations and between organizations in the food supply chain is recorded as a transaction, and each transaction can be recorded in an accounting like ledger of transactions, where each transaction and organization is uniquely identifiable. The GS1 Global Traceability Standard (GTS) provides an international standard for information required for each handover event in a food supply chain (GS1, 2017). Tracing the information available on a supply chain through a blockchain solution, then becomes an exercise of traceability of a food item through the record of transactions. Blockchain essentially provides a database that enables tracking of the chain of information available for each food item.

Reduction of Disputes in Quality Assurance in the Food Supply Chain

The next issue that blockchain technology can mitigate is the frequent disputes on food quality that happen between different stakeholders in the food supply chain. The food industry like many other industries, includes products that vary on different parameters of quality. Uniquely, the food industry primarily includes products that are perishable, and therefore the perceived quality of each item can change over time and during transitions in the food supply chain. One of the parameters of quality is freshness, related to time since harvest from origin. The freshness of food is maintained by techniques including refrigeration, humidity control, gassing, spraying of products to maintain their freshness and other qualities desired by consumers. Revenues are generally highest per item when the product is perceived to be the most fresh by customers (He et al., 2020; Günday et al., 2020), and revenue per product declines over time, and inventory costs increase over time.

Blockchain technology enables not only recording of transactions between stakeholders, but recording of inspections, conditions of transport and transition of product between stakeholders. For example, parameters related to the maintenance of freshness could be temperature and humidity at a certain level throughout transportation in the supply chain using Internet Of Things (IOT) technology (Rejeb et al., 2019; Markovic et al., 2020). Data collected and maintained through a blockchain enabled application is not only limited to alphanumeric data, but can include image data, such as images of product that is collected at each transition point in the food supply chain. Moreover, the actual data recorded on a blockchain based system does not need to be raw data in the form of continuous temperature monitoring, image or video files. A "hash" or in other words a unique representation of the data file can be stored on a blockchain, which enables simple detection of any change in the file, or an attempt to change a record. The detailed data need only be retrieved and viewed in the case of a dispute between stakeholders. In the majority of food industry transactions, where there is no dispute, simply verifying that a record exists and that it has not been altered provides a sufficient level of assurance of quality.

Increase in the Size of the Market Based on Assurance of Quality

The third possibility blockchain technology provides is potential growth in the size of the market for Canadian products. Food products from Canada are considered to be high quality items across the global marketplace. From specialized products like award winning wines, to more commodity level products, Canada exports high quality food products across the world. Canada exports "…half of our beef/cattle, 70% of our soybeans, 70% of our pork, 75% of our wheat, 90% of our canola and 95% of our pulses. Over 90 percent of Canada's farmers are dependent on exports … " (Canadian Agri-Food Trade Alliance, 2018). The high quality of Canadian products as perceived by the customers and retailers is evidenced by the premium price paid for Canadian products over local alternatives, for example in China (Smith, 2017). Blockchain enables international purchasers to have a high level of assurance on the traceability of Canadian food products. Canadian food organizations interacting with a food product item can ensure their information is recorded in a blockchain enabled distributed database that is accessible by international purchasers. A record of transactions of food products with Canadian organizations includes not only the producers but government agencies, including inspections. An inclusion of government agency food inspections will provide an additional layer of assurance for international buyers of Canadian food products.

Increase in Pricing and Value Capture Based on Value for Customers

Different organizations that interact with the food supply chain can record data on a blockchain solution. The information captured as transactions in a ledger can not only include traceability data for transfer within an organization, and transfer of product from one organization to another, but can also include government inspections and independent organization certifications. Therefore, a blockchain solution can include a broader range of information on each food item, that is valuable to consumers (Lassoued and Hobbs, 2015). Some consumers value organic food items and are willing to pay premium prices for these products when they have some level of confidence in the organic nature of the product (Akaichi et al., 2020), such as a certification by an independent body (Hou et al., 2019), while others may pay premium prices for humane treatment of animals (Dickinson and Bailey, 2005). Other consumers may value the type of ownership of a farm (Mellizo, 2018), such as a family owned farm or a worker owned cooperative farm. The type of organization involved in the food supply chain, such as organic, family owned, or cooperative farm can be recorded as part of a transaction in a blockchain technology enabled solution. A deep level of information on any organization interacting with a food product can be accessed by permissioned stakeholders in the food supply chain, including end consumers of food. In a private permissioned blockchain solution, each information providing organization can decide which other organizations or stakeholders, including consumers, have permissions to view each field of information.

Distribution of Value to Stakeholders in the Supply Chain Through Smart Contracts

Another benefit of a blockchain solution, is the distribution of value, specifically payments to different stakeholders in an efficient and timely manner. Smart Contracts as part of a blockchain solution enable an efficient and reliable method of distribution of payments as conditions of each contract are met. Smart Contracts should not be thought of as replacements to legal contracts in the food industry, but as enhancements to an existing legal contract. Smart Contracts enable efficient distribution of payments by automatically initiating payments from funds which have been authorized by payees when stipulated conditions have been met. Smart Contracts also enable a reliable system of recording exact conditions that have been met, and payments subsequently made as transactions on a blockchain solution.

Ability to Connect to Additional Blockchain Solutions Such as Insurance Products and Services

The benefits of blockchain in food and agriculture extend beyond the use of single purpose solutions. The solutions described in this document can be conceivably captured on a single chain, but more usefully, blockchain solutions can connect independent but interoperable chains (Yang et al., 2018). For example, a food data provenance chain could be implemented independently from an insurance chain, but they can intersect where required. A food producer may be required to provide similar information to the next entity in the supply chain such as a wholesaler or a customer, and similar information to an insurance provider. The information required may be connected to different blockchains from different technology and service providers.

Ability to Meet Increasing Consumer Demands for Information on Food Origins and Processes

The Covid-19 pandemic in 2020 has made end consumers more active and informed consumers of food (Günday et al., 2020). Specifically in Canada, consumers have been purchasing more food directly from local grocery stores (Government of Canada S. C, 2020) and buying less prepared food from restaurants (Restaurants Canada, 2020). In the process of purchasing and preparing food, consumers have become more demanding about information on food origins and processes, and this trend is recognized by both industry (Whelan, 2020) and government policy (Government of Canada Canadian Food Inspection Agency, 2019). Consumers want information about whether the food is local or grown in another jurisdiction. Canadian consumers are interested in determining if food is processed at a plant (The Canadian Press, 2020), or grown on a farm (Edmiston, 2020), where workers have tested positive for Covid-19 (Kelley et al., 2020). All these elements of information can be easily collected and reported through blockchain solutions, with user friendly mechanisms for providing the information to the consumer on demand, such as scanning a QR code on a food product with a smart phone camera. The key point is that consumers can make more informed decisions on food purchases, in conjunction with information available, and the value of the information increases when it is generated from different and independent sources.

3 WHAT IS THE CURRENT STATE OF ADOPTION IN AGRICULTURE?

One of the earliest large-scale adoptions of Blockchain in the food and agriculture industry has been by Walmart, starting with pilots of mango and pork products (Kamath, 2018). Walmart requires use of IBM's Food Trust blockchain service by Walmart's leafy green suppliers, following a widespread food safety event (Redman, 2019). Walmart is a large buyer of food products on a global scale and can therefore influence its suppliers to comply with requirements for providing information that is recorded on a blockchain based solution (Bloom and Hinrichs, 2017). The reported benefits of adoption of blockchain by Walmart for its food supply chain include: reducing food safety risks, enhancing efficiency in the supply chain, and accelerating collaboration (Tan et al., 2018). It is expected that Walmart will expand its use of blockchain based solutions to a broader variety of products with supply chain safety issues, such as drugs (Redman, 2019).

Walmart's primary technology partner in implementing a blockchain based solution is IBM. IBM has developed its own food industry specific blockchain based service, IBM Food Trust. IBM Food Trust enables organizations of different sizes who may not have the capacity to develop and maintain their own

Blockchain solutions to utilize IBM's solution in the form of a Software as a Service (SaaS) (Redman, 2018). The main objective of blockchain technology adoption by food retailers such as Walmart has been the traceability of food required for adverse food safety events (Nelson, 2018). In our view, although there are benefits to this approach, it is a limited and reactive use of blockchain that will not necessarily obtain the full potential benefits of blockchain technology. Without the full benefits of blockchain technology accruing to a broad range of stakeholders the adoption of blockchain technology will be slower than expected.

A more proactive example of blockchain technology adoption in the food and agriculture sector is demonstrated by the Grassroots Farmers Cooperative (2019), which is a much smaller organization than Walmart. As a food producer, the Grassroots Farmers Collective is utilizing blockchain to provide reliable information on the cooperative type of farm, and organic food production processes to end consumers. The use of blockchain by the Grassroots Farmers Collective is less about being able to react quickly to food safety events and more about enabling consumers to trust its brand and select food products based on verified information. Blockchain based food industry solutions are therefore available to both large and small organizations that do not necessarily need to have an internal technology capacity to develop and maintain a blockchain based solution. It is our position that blockchain technology will be adopted more widely in the food and agriculture sector, when the benefits are maximized for the broadest range of stakeholders, which requires a more proactive rather than a reactive adoption strategy for the technology by the food and agriculture sector.

4 WHAT ARE THE BARRIERS TO ADOPTION?

Although the individual components of blockchain technology have been applied in the food industry, there are a number of significant issues for broader adoption of blockchain across supply chains. Significant issues include vertical adoption of blockchain technology across a supply chain to maintain an unbroken chain of data provenance, and horizontal adoption of blockchain technology across a critical mass of suppliers (Sternberg et al., 2020). Therefore, blockchain will not be adopted simultaneously across a global and diverse food industry, but will be adopted at different rates by different subsectors of the food industry, for example, in eggs (Bumblauskas et al., 2020), meat (Sander et al., 2018), grain (Zhang et al., 2020), and olive oil (Violino et al., 2020).

Additionally, blockchain adoption rates will differ across countries as the issues around food supply chains are not the same across Asia and Europe (Qian et al., 2020). In Canada, the initial broad scale adoption of blockchain technology is being driven by food safety issues. In the environment of food supply chains that ultimately deliver food to end consumers in Canada, the issue of food contamination is the primary safety issue, where other issues may be more prominent in other countries. "1 in 8 people (4 million Canadians) get sick each year from contaminated food" (Public Health Agency of Canada, 2016). There is a basic expectation by the Canadian end consumer that food consumed through a grocery retailer or a restaurant is safe to eat and will not cause illness (Legislative Services Branch, 2019). The assurance of food safety is a multi-party and multi-sector issue. Most Canadian produce comes from the United States, especially in the fall, winter and spring. The cross jurisdictional and cross border issues of food traceability are addressed by initiative such as the Produce Traceability Initiative (Produce Marketing Association, 2020). The primary responsibility for food safety is placed on the producers and suppliers of food, since their reputation and brand is highly dependent on maintaining food safety and quality. A secondary role is played by governments and government agencies, such as the Canadian Food Inspection Agency (CFIA) in Canada and the Food and Drug Administration (FDA) in the United States, which provide licenses, and perform inspections to ensure specific standards are met. The third type of organization performs audits of food systems, and to maintain independence, these are typically nonprofit or non-governmental organizations that are distinct from both private sector food companies and government agencies. As an ecosystem, these different types of organizations have an important role in adopting and maintaining the use of blockchain technology in the food and agriculture industry.

The barriers to adoption of blockchain technology need to be understood in the context of information politics in the food and agriculture industry. The food industry has traditionally been a closed industry in terms of information, with each player "holding their cards close to the chest", whereas blockchain is an open technology that enables transparency. The food industry typically deploys technology as Black Box systems, where few people understand how the processes work. Blockchain technology is typically deployed as a White Box system where the ledger of transactions is visible and transparently understandable by all permissioned stakeholders. The information needs and interests of the retailers are more closely aligned with those of the end consumer. A study by Label Insight Inc (2016) indicates that:

(1) "75 percent of respondents say they do not trust the accuracy of food labels.
(2) Nearly all respondents (94%) say it is important to them that the brands and manufacturers they buy from are transparent about what is in their food and how it is made.
(3) 67% of consumers believe it is the brand or manufacturer's responsibility to provide them with complete product information."

The same report study by Label Insight Inc (2016) provides support for the type of blockchain solution described in this report:

(1) "Brands have an opportunity to gain market share by providing increased transparency:

More than a third of those surveyed (37%) said they would be willing to switch brands if another brand shared more detailed product information that they could understand.

(1) Consumers are open to using digital channels to find the information they need:

The 37% of consumers who say they would switch brands in favor of ones providing more detailed product information are nearly twice as likely to value access to this information through digital labels."

Therefore food producers can provide more detailed information on their products to consumers and other stakeholders in the food supply chain. Producers that utilize a blockchain solution to provide additional information to consumers can increase market share, therefore recovering any additional costs required for implementation and maintenance of a blockchain solution. In summary, the barriers to increased adoption of blockchain in the food and agriculture industry are not technological or economic; the barriers to increased adoption of blockchain in the food and agriculture industry are political and cultural in applying an open technology designed for trust, blockchain to a traditionally closed food industry.

5 ADDITIONAL REQUIREMENTS

Research completed by Macready et al. (2020) indicates that openness or transparency of food manufacturers is one of the most important factors for increasing trust by consumers. Sayogo et al. (2014) find that information that increases trust such as certification of products, is most useful to consumers when it is aggregated and provided in an easy to access format to the consumer e.g., on a mobile phone app. Cao et al. (2021) demonstrate a prototype of blockchain based beef supply chain information available to consumers on mobile phones, and how it can increase trust. Galvez et al. (2018) make the case that blockchain is the technology with the greatest potential for addressing trust issues in food supply chains.

A blockchain based solution should not be envisioned simply as a "plug and play" single chain solution. Pilot projects on food supply chain traceability supported by the United States FDA have demonstrated the value of sharing information, and the speed of tracing information. Simultaneously the pilots indicated necessary information and training required for traceability that is required to enhance current processes (IFT, 2020). More broadly, Keogh et al. (2020) have described additional data collection issues required to enable effective blockchain solutions in current food supply chain traceability systems. Therefore, blockchain based traceability systems should not be envisioned as a layer of technology on top of existing data collection processes, but these systems necessarily require substantial change in the data collection processes themselves, and must be accompanied by appropriate training. Moreover, blockchain based traceability solutions should not be envisioned as a single chain collection of all required information, but as interoperable chains interacting with each other with respective information requirements, where interoperability has its own challenges (Flood and McCullagh, 2020) and solutions (Sai and Tipper, 2019).

Information on the food item supply chain as a whole and information on the social and environmental responsibility of each food producer are important components of consumer trust. Blockchain technology provides the opportunity to address trust in the supply chain as a whole and simultaneously on the social and environmental responsibility of each food producer. Given that branding and marketing by itself is not sufficient for engendering trust by the end consumer, we suggest that individuals brands build blockchain technology enabled trust through a consortium approach rather than each firm attempting to build its own solution.

Role of the Government

The different levels of government play an important role in overcoming the barriers to blockchain adoption. Under current regulations, the government already promotes Canadian brands through trade in food and agriculture. The government also regulates food and agricultural production to ensure safety for consumers. The government plays an essential role in ensuring that information provided on food is accurately labeled and understood by consumers. The Federal Government of Canada has come to the realization that advances in technology-based information flows that accompany physical food products require updating of regulations and policies (Government of Canada Canadian Food Inspection Agency, 2019). To its credit, the Federal Government of Canada, and more specifically the Canadian Food Inspection Agency (CFIA), has recognized distributed ledger technology, and in particular blockchain technology applications requires examination for regulatory impact, and regulatory direction (Government of Canada Canadian Food Inspection Agency, 2019). The federal government can demonstrate leadership in food information technology related regulation and policies not only to provinces in Canada, but to other countries in the world. We do not believe government should forcefully mandate the use of a specific blockchain technology in the food and agriculture industry. Rather, governments should ensure that changes in regulation allow different implementations of blockchain technology within the food and agriculture industry. We also believe the government is an important stakeholder in enhancing the information provision role it already plays through information technology. The partnership role the US FDA has played in participating in industry food supply chain traceability pilots provides an encouraging model for Canadian regulators (IFT, 2020). Specifically we would encourage the government to consider how the licensing, approval, and inspection and other information produced by government can be integrated into the blockchain based solutions as they are developed for the food and agriculture industry in Canada.

Role of Industry Associations

Canadian food industry associations promote food products produced by Canadian food producers to local and international consumers, where the collective brand is "made in Canada". Our research indicates that greater adoption of blockchain technology will be enabled through consortium approaches, ideally led by existing marketing associations. A consortium approach to implementing blockchain technology solutions will enable fair and accepted distribution of costs, as well as strengthening of current efforts by existing industry associations to increase market share and revenues. Industry associations already promote practices of verifiability of information and truth in advertising within their own members in order to protect the interests of the industry as a whole, compared to an individual firm.

Industry associations are also ideal vehicles for information and education activities required to engage stakeholders on blockchain technology. Food industry associations are often involved in change management both in changing behavior of end consumers, but also in changing behavior by food producers to improve collective processes and quality standards. The United States based Produce Marketing Association (PMA) already has a blockchain task force, which demonstrates the interest and ability of industry associations to design solutions appropriate for members. A change management process that does not completely disrupt, but builds on existing networks that already work for member's interests will be more readily acceptable to food producers.

6 PER ITEM LABELING SOLUTIONS

One of the essential requirements for successful long-term implementation of blockchain technology is the ability to have traceability of the supply chain per discrete item of product. Food items typically get sorted into differing quality products at source, but along the supply chain they often get mixed with products of similar quality from different sources. The mixing of food products can occur at an item level, where the end consumer buying a single fruit item may find another with a somewhat separate supply chain in the same retail store and in the same product location. Proven technology and solutions exist for per item labeling enabling identification of supply chain traceability at the individual item level, instead of a batch, pallet or carton level. A per item labeling solution has a strong ability for managing food supply chain traceability, and therefore is an ideal fit for blockchain technology based supply chain traceability solutions. Per item labeling solutions are compatible with GS1standards that have been previously mentioned. GS1 Digital Link includes provisions for a single bar code that enables per item labeling (GS1, 2018, p. 1).

The benefits of per item labeling also accrue to the end consumer who typically purchases single items or small quantities of food. An end consumer can simply read a bar code on a food item label using their own mobile device, and can receive a deep level of information about the food item. A blockchain solution in combination with a per item labeling solution provides a reliable database of information, with an additional layer of trustworthiness. Therefore, the end consumer, and other stakeholders in the food supply chain, do not need to put in a high level of effort to verify the information provided. When the consumer can trust the information provided per food item, without having the need to put in a large amount effort to verify the information provided, the food consumer can make efficient and effectively informed choices about food items.

7 SUMMARY OF RECOMMENDATIONS

(1) Pilot different blockchain technologies to determine the best fit for the industry and organization. Blockchain is not a monolithic or single vendor technology. Different vendors utilize different blockchains and they should be piloted to determine the most appropriate technology for given requirements. Consider the role of interoperable blockchain solutions and standardization of information requirements in proposed traceability systems and pilot projects.
(2) Determine information that is of value to stakeholders in the supply chain, such as end consumers, and what they are willing to pay for. Research indicates that consumers are willing to pay premium prices for products such as organic food, when the information provided is reliable. Blockchain technology adoption in the food and agriculture industry will be accelerated when it is implemented not simply as a cost to mitigate food safety issues, but additionally a means for generating additional revenues and market share.
(3) Distribute the costs of blockchain technology development across different stakeholders in a consortium approach through industry associations. The costs of blockchain solution development, and more importantly, the buy in required from stakeholders across a supply chain requires a fair distribution of costs and revenues. Industry associations can pre-determine a fair and appropriate distribution of costs and revenues since they already have a high level of trust and credibility with their members. Already existing capabilities of blockchain technology, Smart Contracts can enhance the level of transparency and assurance that both costs and revenues are distributed according to pre-determined rules, and that the process is automated.
(4) Ensure that a robust mechanism exists to bridge information flows with physical food product flows. The per item labeling solution available from existing technology suppliers achieves this purpose by enabling variable information per individual food product in a reliable format. Labeling solutions which include bar codes that follow GS1 standards utilize unique identifiers that can be connected to any information on a distributed database. Food supply chain traceability is not only about traceability of information, but also traceability of physical product, often at the per item level of detail.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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