CA Gov Ops Blockchain Working Group

Blockchain Applications in Food and Agriculture

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California is the agricultural powerhouse of the United States. About 73% of the state's agricultural revenues are derived from crops while the other 27% of revenues are generated by livestock commodities.[1] California is known for its agricultural abundance and diversity, including over 400 commodities. Over a third of the country's vegetables and two-thirds of the country's fruits and nuts are grown in California. California is the leading US state for cash farm receipts[2], accounting for over 13% of US total agricultural value.[2] California also supplies 19% of dairy for the US.
There are several important applications of blockchain technology for the food and agriculture industry. They include:

- Supply chain traceability (specifically provenance tracking, logistics, and safety)
- Supporting small farms and the circular supply chain
- Supporting the emerging cannabis industry, particularly with regulatory conformance
- Protecting the rights of farm workers and providing them social services

There are many others, but we chose to focus on these domains and hint at a few more in this chapter.

Blockchain for Supply Chains[3]

Adapted from Enterprise Blockchain Has Arrived, by Jorden Woods and Radhika Iyengar, Chapter 11

Blockchain-based systems can provide visibility and better data across supply chains. Common applications relating to Food and Ag include:

• Product traceability
• Authenticity and product provenance
• Process transparency

Product Traceability

The ability to quickly find the origin of a product, i.e. food traceability, is important in different contexts. Food contamination from *Salmonella*, *E. coli*, *Listeria*, or parasites can create food scares. These incidents usually lead to significant losses for food producers and distributors when specific products (i.e. spinach, lettuce, beef, etc.) are pulled from shelves en masse and destroyed both in store and at the farm. Severe events have an average cost of over $100 million. As many food-borne illnesses are eventually traced back to a single farm or even a single batch of product, finding the source of contamination quickly can save tens of millions of dollars.

With current supply chain systems, food traceability often takes a week or more since data is fragmented and siloed across the actors in the chain. Most members of a supply chain are only familiar with activities one step forward and one step back, those directly connected to their organization. As there is no over-arching system that captures all transactions across the chain, each part of the supply chain needs to be contacted directly to understand the full path that a product took to reach a retailer.

As the media reports on illnesses and deaths mount, retailers and farmers are forced to destroy products quickly to regain consumer confidence. In the US every year, foodborne illnesses affect one in six Americans, lead to hundreds of thousands of hospitalizations, and cause more than 3000 deaths. They also cost the US economy more than $93 billion annually. Globally the numbers are much larger, according to the World Health Organization (WHO) there are 600 million illnesses and over 400,000 deaths annually from food contamination. Smaller retailers and farmers are especially hard hit since they have to absorb the losses, and some may be forced into bankruptcy.

Blockchain-based supply chain systems can provide an accurate and immutable record of all transactions across the chain. These systems assign a unique ID and secure decentralized tagging system that tracks food at the batch or lot number. Often the unique ID is based on a global standard to ensure that all stakeholders are using the same approach for identifying their products. Since all nodes have access to this record, traceability becomes routine.

Pilots with Walmart and other large food retailers have already demonstrated that blockchain-based systems can determine the origin of a package of food in seconds (IBM Food Trust), as opposed to 6–7 days under current systems. Since these blockchain-based systems can rapidly find the source of food safety outbreaks they provide the opportunity to greatly reduce the scale of food borne illnesses and related supply chain economic losses.

Food security is one specific use case that has gained significant traction, but the same approach can be applied to any product within a supply chain. Traceability is an important step in determining product authenticity, which is discussed in more detail below.

Key Deployments

The largest deployed enterprise consortium focused on food safety and traceability is IBM Food Trust:

- **IBM Food Trust** is focused on food safety and provides track and trace plus point of origin for food products in supply chains. The platform's primary use case is the elimination of costly and damaging 'food scares' by rapidly identifying the source of tainted products. Food Trust was developed by IBM on Hyperledger Fabric and launched in late 2018. Members of the consortium can trace food back to its origin in seconds, versus 6-7 days with standard processes. Key members include Walmart, The Kroger Co., Carrefour, Albertsons, Nestlé, Tyson Foods, Unilever, Dole, Driscoll's, Topco Associates, Wakefern Food Corp. (ShopRite), Golden State Foods, McCormick and Co., and McLane Co. Both Walmart and Carrefour, a large European supermarket, are requiring all vendors for particular food products to use the platform in 2019.

Another significant consortium in development is with Walmart China:

- **Walmart China Blockchain Traceability Platform (WCBTP)** is focused on food safety, like IBM Food Trust above. The consortium will provide track and trace plus point of origin for food products in Walmart China's supply chains. It is being developed with VeChain, PwC, Mongolia Kerchin, and the China Chain-Store & Franchise Association. By the end of 2019 over 120 food product lines will be fully tested across 10 product categories. The service will launch during 2020 and by the end of the year will cover 50% of meat product sales, 40% of vegetable product sales, and 12.5% of seafood product sales. Consumers will be able to access product traceability

information and food inspection reports by scanning a QR code with their smartphones. The platform is being developed with VeChainThor.

Authenticity and Product Provenance

In today's supply chain systems, there is no simple way to track the provenance and authenticity of a product. More sophisticated centralized systems, such as EPCglobal, have used barcodes, unique electronic product codes (EPC), and RFID technology to track items through the supply chain. These systems rely on centralized certificate authorities and centralized databases. They are fundamentally insecure since they have single points of failure that make them susceptible to cyberattacks and insider fraud.

Decentralized and immutable blockchain systems allow product tracking to its origin (traceability) and through every step of the supply chain (authenticity). Building on this foundation, a number of blockchain projects have already deployed decentralized apps (dApps) that use information in the supply chain to authenticate that a product, such as a luxury good or a food product, is in fact authentic. The dApp enables a user to scan a QR code on the product which provides a full trace and validation of the product's authenticity.

Such an approach tracks the product or a product's components through every step in the chain, for example via an embedded RFID or NFC chip. At each step in the chain, the RFID chip is scanned, a smart contract is executed, and then multiple trusted nodes verify the information is correct before it is written to the blockchain ledger. Each entry in the blockchain ledger is cryptographically signed and encrypted which deters fraud and reduces the chance of hacking. Since the entire supply chain process becomes transparent, it becomes possible to quickly and inexpensively validate product authenticity. Any product that doesn't enable dApp-based authenticity then becomes suspect which disincentivizes fraud.

Provenance takes authenticity one step further by also providing information about the entire history of a product through the supply chain. So, for example, the location history, the custody history, and the environmental conditions during the journey can be tracked and stored immutably on the blockchain. This type of information — GPS coordinates, custody IDs, temperature data, accelerometer information (for damage assessment) — is typically provided by Internet of things (IoT) devices. These devices send out data streams that in combination with decentralized consensus are then written to the blockchain. Since blockchain technology reduces verification costs it will likely gain widespread adoption and so make checking product authenticity and provenance commonplace.

Examples of this capability include Walmart China's WCBTP (above), and an offering from Carrefour for over 20 different products including milk, meat, eggs, and fruit sold in their stores. Consumers can use a smartphone to scan a QR-code on the product which provides information such as harvest date, freshness, certifications, and sustainability. Carrefour has indicated these initial blockchain pilots have boosted trust and increased sales markedly. As a result, they are now rolling out the same capability to 100 more products. The feature has been most popular in China and in Europe.

Process Transparency

Another important aspect of supply chain is process transparency, or exactly what happens at each point in the chain. So, for example, if a retailer or distributor receives damaged goods it may often not be possible to know where in the chain the damage took place. As a result, the supplier of the damaged goods or a member of the chain that damaged the goods, will have no incentive to change their practices. Also, costs increase for all members of the chain since insurance premiums will increase if claims become common.

Since blockchain technology can be used to quickly track information through every step in the process, it is also possible to combine tracking information with environmental or product integrity data. Many blockchain projects have proposed including IoT sensor data in smart contracts to make additional important information part of the immutable ledger.

With IoT sensor data, one of the growing trends is temperature tracking for products in a temperature-controlled supply chain or 'cold chain'. Perishable products like food or medicine often need to be refrigerated and freshness or viability can be impacted by temperature swings. A significant fraction of food and medicine is spoiled during shipment due to intentional or accidental conditions that warm the product above recommended or agreed 'cold chain' temperatures. IoT devices can continuously measure temperature and store the log, via a hash on the blockchain. This log then provides an immutable and independent temperature record that can be used for enforcing accountability and understanding conditions that led to spoilage or damage.

Using IoT and other sensors, food supply chain and logistics have greater visibility and realtime data capture to optimize transportation of produce. Growers are able to determine if the product will be able to arrive at destination with enough shelf life remaining. Growers can then optimize routes and destinations so that consumers can find the freshest produce at the markets.

For example, Intel's blockchain was utilized in a successful pilot with blueberries from Oregon[4]. Intel used remote sensors in crates of blueberries to track various data realtime including temperature, location and other environmental data. "Food safety regulators in Oregon are confident that will lessen the time it takes to trace back the source of a food-borne disease outbreak from days or weeks to minutes or even seconds, helping to decrease illnesses while issuing more precise recalls. Growers benefit by ensuring their fruits, vegetables, meat and seafood are as fresh as possible by the time it reaches customers."

Traceable supply chains

The FAO[5] has indicated that sustainability and responsible consumption as well as bringing greater efficiencies to agricultural and food supply chains and fighting counterfeit products are all driving the interest in blockchain-based systems.

Food safety

Danone[6] has announced its Track & Connect service, a blockchain food traceability solution to provide greater transparency for its baby formula brands, including Aptamil. It has already launched in China and will be rolled out this year in France, Germany, Australia and New Zealand.

The solution also provides an anti-counterfeit that takes advantage of 2 barcodes. As barcodes can be counterfeited, Danone's solution is to use two barcodes. One appears on the outside packaging. When scanned with a mobile app, it shows when the product was manufactured and its journey to the store. And another barcode is laser printed behind a tamper-resistant seal, which can be scanned after purchase. That confirms the authenticity, and if the same code has already been scanned, it will trigger an alert.

Several other baby food and milk producers are already using blockchain for food traceability. Nestlé and Carrefour[7] are tracking infant formula using the IBM Food Trust blockchain. Plasmon, an Italian subsidiary of Kraft Heinz, is exploring blockchain for baby food in association with the local agriculture ministry. TE-FOOD tracks organic infant formula for Vietnam's largest milk company, Vinamilk.

In 2018, Italian pasta and pesto maker Barilla[8] teamed up with IBM and Nestle teamed up with Microsoft. Each are testing out blockchain for traceability and transparency. The official representative of the manufacturer Barilla has already reported that if the pilot project code-named "basil pesto" is successful, the company will be ready to insert all its products in the blockchain: from cereals to tomatoes and milk.

Food freshness

Other aspects of food supply chains are ensuring food freshness.

Supporting Small Farms and the Circular Supply Chain

Supporting small farms and smallhold farmers is a priority for the State of California. Nearly 75% of California's farms are less than a 100 acres. Overall, the average farm size in California is 348 acres, much less than the US average of 441 acres. Notably, the "Central Valley", especially San Joaquin Valley, produces over half of California's agricultural output, and the majority of the 12.8% of US agricultural output. Most of the farms in San Joaquin Valley are small farms. In San Joaquin County, for example, the average size among its 4000 farms is 202 acres.

Several initiatives right now are exploring using blockchain technology to implement such connections. These include work done by Accenture on a "Tip-the-farmer"[9] pilot, and by IBM through FarmerConnect[10], allows a bag of coffee or unit of any agricultural product to not only be traced back to its origin, but also allow a small sum of money to be sent direct from consumer to producer, rather than indirectly through all the intermediary layers. They also create an efficient way for organized smallhold farmers to establish an ongoing relationship with the supplier, in a manner previously only available to large brands.

A further way in which blockchain technology might empower small farmers is remaking the relationship between farmers and farming co-ops. One project, AgUnity, described their project this way:[11]

"Our solution is to enable trust between farmers and co-operatives by providing a smartphone and our blockchain app to farmers in the developing world. This app enables farmers to easily record all transactions in an immutable ledger, and to plan better, buy and sell together and cooperate to share resources. In our pilot projects in Kenya and Bougainville, we increased farmer incomes by on average

3x from a single season to the next. The AgUnity App subsequently becomes the exclusive platform on which all their finances are managed, and we provide access to goods and services such as solar lighting, from which AgUnity earns a royalty (effectively becoming their eBay or Amazon).

It's true that we could have built a standard database for the documentation of farmer's transactions with farming co-operatives / other third-party partners. However, the issue we're tackling is around a lack of trust between a farmer and a co-op, so we would effectively be asking them to trust in the same system that typically leads to corruption and graft, except that they have to trust AgUnity who they know even less well than their existing partners. The use of a blockchain enables us to explain to farmers that once a transaction is agreed to by both parties, no one, not the farmer, not the co-op, not even AgUnity can ever change this record. It also provides an additional layer of security to ensure these transactions cannot be hacked by third-parties who may wish to transfer receipts from the farmers to themselves. So in short, no, we couldn't do what we do without the use of a blockchain!'

California policymakers could support small farms in their exploration of the use of blockchain technology by identifying opportunities for pilots for California specialty crops and organic produce where such "tip-the-farmer" initiatives could help increase margins and sustainability. California policymakers could also look at their oversight of the agricultural co-op space and look for opportunities to remake their accounting and operations using blockchain technology.

Regulating the Cannabis Supply Chain

The cannabis industry is growing quickly in California, and the pressure to properly test and certify the supply is greater than perhaps anywhere else in agriculture. The regulatory landscape in California is evolving quickly.[12] In addition to provenance tracking, proper testing by labs and labelling in ways that consumers can trust at the point of purchase is essential. This testing and certification is not unlike those emerging in the pharmaceutical supply chain; however unlike pharmaceuticals, these labels have to be understandable and trustable by average consumers.

Already there is a burgeoning startup community in the blockchain and cannabis space, and they are working with larger and larger partners. One example, TruTrace, "is launching its StrainSecure product in partnership with Deloitte. The system employs blockchain technology to track cannabis from seed to sale, in order to guarantee that customers and retailers know the history of the product" according to a Cointelegraph article from September 2019.[13] Furthermore, putting testing results directly on a blockchain, visible to all, can help reassure wholesale or retail buyers that the product they are holding has been independently tested, rather than trusting a simple label on a product. At least one company is focused on this, called CBD LabChain.[14] All this also enables regulators to have a real-time view into the supply chain data and perhaps even would automate reporting and auditing, avoiding delays or the risk of incorrect reporting.

The cannabis industry is also struggling with the need to conduct business without banking services, as federally-regulated banks are prohibited from providing services to such businesses. This requires dispensaries and suppliers and farms to handle and transport large amounts of cash, at substantial operational risk and cost. If instead money could flow through the supply chain using tokens, whether cryptocurrencies like Bitcoin or specially-issued tokens pegged to the US dollar, such unsafe cash handling operations may be avoidable. This is an approach being taken by HempCoin[15], PotCoin[16], and others, though it might not require a cannabis-industry-specific payments solution.

California policymakers could direct the California cannabis licensing authorities to accept blockchain-based verification and reporting mechanisms for the cannabis supply chain. This might require certifying specific blockchain projects who pass a set of standards for operation and authenticity. California policymakers could also consider authorizing participants in the cannabis supply chain to use payment mechanisms that implement stringent industry KYC processes but also avoid tripping US regulatory concerns.

Labor Rights and Social Services for Farm Workers

California's agricultural economy is substantially dependent upon lower-income and seasonal workforces, many of whom move between locations depending upon the crop and time of year, and sometimes across national borders. Often these workers lack formal identification, a Social Security ID number, or knowledge of available social services, and are vulnerable to abusive employers. And when obtaining those social services, a lack of formal identity can make it difficult to develop a care record, while also opening up the service providers to the potential for abuse. And yet this population may be resistant to exclusively government-tracked systems due to a lack of trust.

There are a number of projects looking at the use of blockchain-based identity, in particular the application of user-managed or "self-sovereign" digital identity systems backed by blockchain technology, as a way to provide both identity cards and social services to vulnerable populations. There is a substantial amount of research into this work in the Netherlands, from a project on ensuring GDPR conformance in the provision of services and assessing fines conducted by TU Delft and Ledger Leopard[17], to more generalized efforts like the non-profit ID2020[18] and the for-profit Tykn.tech.[19]

One promising project for the monitoring of labor abuses in challenging environments is being conducted now by Coca-Cola and the U.S. State Department in conjunction with the Blockchain Trust Accelerator[20] regarding Coca-Cola's supply chains in the Asia Pacific region. This project employs "blockchain and smart contracts to deliver greater transparency and record-keeping regarding laborers and their contracts [...] The group hopes, however, that a clear trail of evidence will make compliance a more likely outcome."

California policymakers could encourage the development of privacy-centric (CCPA-compliant at least) identity registration in the agricultural and migrant workforces, along with training and education programs to explain to use these systems and how they operate differently from drivers' licenses or social security numbers. California policymakers could also look into using blockchain technology as a platform for employers to submit labor compliance reporting data for the benefit of not just regulators but also workers and worker advocates.

Finally it's worth noting that migrant workers who cross national borders are likely to be large users of remittance services, often provided by operators who demand cash and levy substantial transaction fees. Remittances via cryptocurrencies or stablecoins may slash those transaction costs and complexity. Safe and appropriate adoption of such technologies could also be included in training and education.

Other Applications

There are lesser but still substantial aspects to the agricultural business in California that merit special attention for blockchain activity by policymakers and regulators:

- **Ports and customs**. In every cross-border provenance-tracking or even shipment-tracking use case to which blockchain tech could be applied, a substantial amount of value comes from expediting the shipment through various layers of unavoidable bureaucracy at the outgoing and incoming ports and customs authorities. In Tradelens, a cargo tracking blockchain set up by Maersk and IBM, claims that this paperwork can be 20% of the cost of shipping.[21] Typically, ports and customs authorities operations run lean and do not see IT as a strategic enabler, but instead at best as a necessary evil. With appropriate encouragement and funding from California authorities perhaps they could become a pro-active participant in cutting red tape and cost for getting California agricultural products to international markets.

- **Water rights**. There is at least one initiative in the central valley[22] that is looking at using blockchain technology to facilitate the tracking and trading of water rights between property owners, so as to better manage the limited overall supply of water from aquifers and create financial incentives to reduce water consumption. California could lead here by participating in such pilots and providing certification services.

- **Environmental monitoring**. Access to data about water availability and cleanliness is essential to ensuring a safe food supply and predicting, while other environmental data like air quality or soil tests can also be essential to agricultural performance and avoiding fraud in land sales. Use of distributed ledgers, particularly publicly accessible ones, to access this data but also guarantee the integrity and availability of this data, might help improve agricultural production and business outcomes as well as the environment. For some more thoughts on this see 8 ways blockchain can be an environmental game-changer.[23]

There are potentially other use cases we have not considered or seen suggested, but we believe even a subset of the above could represent substantially positive outcomes for the State of California, in capabilities and cost savings for its administration and in improved operations and safety for its citizens.