Blockchain technology in food industry ecosystem

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Abstract: Food industry is unique from the point of view of Efficient Consumer Response (ECR) which is a supply chain management initiative specific to the food industry and reflects organizations’ efforts to achieve quick response to reaching to market and ultimately consumer using Electronic Data Interchange, RFID (Radio Frequency Identification and bar codes. This paper would focus on looking at pros and cons of evaluating traditional traceability (is an important link in protecting public health since it allows health agencies to more quickly and accurately identify the source of contaminated food, fruit or vegetables believed to be the cause of an outbreak of foodborne illness, remove them from the marketplace, and communicate to the supply chain) matrix versus newly introduced disruptive technology called blockchain. This report outlines various components of traceability and its relation to other parts and methodologies in ensuring food product authenticity the paper further outlines detailing of blockchain technology its various types, implementation with examples and application in food industry. The concluding part of paper compares traditional vs. blockchain methods in regard to cost benefit analysis and implementation perspective of blockchain. The paper through reasoning and arguments justifies that how blockchain bases systems of food traceability are more suitable from speed, confidentiality and ease of implementation perspective as compared to traditional electronic traceability and current systems. From limitation perspective this paper highlights how lack of interoperability is currently the biggest one obstacle preventing system-wide, farm-to-fork food product traceability

Keywords: Blockchain Technology, Food Industry, Ecosystem, Applications, Limitations, Costs, and Benefits related to the use of blockchain technology in the food industry

1. INTRODUCTION

Since beginning of 2008 Blockchain has been making waves as technology disruption making insightful and meaning improvement in human lives. Blockchain definitely has huge role and application to play in food industry too. It looks currently blockchain is been oversold by tech industry promising more than they can deliver. This paper would look into presenting in most practical way the myth and reality about use of blockchain in food traceability value chain. The main theme of this paper is comparing and contrasting current alternative technologies and methodologies currently being used and their comparison with understand cost benefit analysis for using and implementing blockchain in food industry.

About Traceability in Food Industry: Traceability is best defined by (Olsen &Borit 2011) who defined as “The ability to access any or all information relating to that which is under consideration, throughout its entire life cycle, by means of recorded identifications”. Traceability applies to any sort of object or item in any part of the life cycle “That which is under consideration” is normally a batch (i.e. a unit of food or material used or produced by a food business operator (FBO)) or a trade unit (i.e. a unit of food or material sold by one partner, transported to, and received by another FBO).
scientific world literature, the common term for “that which is under consideration” is a Traceable Resource Unit (TRU) (Kim et al., 1999). The TRU is then “the unit that we want to trace” or “the unit that we record information on in our traceability system”. Traceability can be either internal or external to organization in reference. The internal refers to recording and storing information within organization and later disseminating. Internal Traceability also refers to good procedure and practices followed by organizations. Internal Traceability also refers to Chain Traceability within the links of the organization especially in regard to the way information is recorded and transmitted.

![Internal versus chain traceability](TraceFood_2008.png)

**Figure 1 Internal versus chain traceability Source (TraceFood 2008)**

Components of Traceability System(figure 1): In this system we make sure that information recorded in link one must be made available to next and other links and lost during transmission, capturing or recording. So for analyzing the properties of a traceability system there has to be clear distinction among the following components:

- The links, systems and processes that relate to the identification of the TRUs (Traceable Resource Units), which may include code, deciding on uniqueness and granularity of the code, and selecting how to associate the identifier with the TRU.
- The links, systems and processes that pertain to the documentation of the transformations in the chain, which includes recording of the TRU transformations1, the weights or percentages, and the related metadata.
- The recording of the attributes of the TRU, which can basically be anything that describes the TRU (e.g. attributes of the producing FBO, origin of the TRU, description of the TRU, measurements taken on the TRU, process parameters recorded when the TRU was produced etc.).
Figure 2. The Components of a Traceability System Source: (Olsen & Borit, 2018)

Traceability Systems Drivers: Various purposes/drivers for implementing a traceability system (figure 2) use different expectations in producers and consumers that do not always correspond to the traceability system in use. Characteristics of traceability systems, including drivers for implementing these are as per below table 1:

| Purpose/Driver | Objective | Attributes | Standard | Example |
|----------------|-----------|------------|----------|---------|
| Safety         | Consumer protection (through recall and withdrawal) | Specified in food & fish safety regulations | Mandatory | US regulation |
| Security       | Prevention of criminal actions (through verifiable identification and deterrence) | Verification of selected attributes on package and/or food | Regulatory (2) | US Prevention of Bio-terrorism, regulation |
| Regulatory quality | Consumer assurance (through recall and withdrawal) | Specific attributes included in regulations | Voluntary (no common standard) | Brand & product protection |
| Non-regulatory quality & marketing | Creation and maintenance of confidence attributes | Specific attributes included in public standards | Voluntary (common standard (4)) | Organic fish, Eco-labelling |
| Food chain trade & logistics management | Food chain uniformity & improved logistics | Specific attributes required to food and services suppliers by contract | Private standards (4) | Own traceability systems (e.g. Wal-Mart) |
| Plant Management | Productivity improvement and costs reduction | Internal logistics and link to specific attributes | Voluntary (internal traceability; own or public standards) | From simple to complex IT systems |
| Documentation of sustainability | Natural resource sustainability | Specified in environmental protection regulations | Mandatory | FAO IPOA-ILU (8) |

2. RESEARCH OBJECTIVE

This is a conceptual paper involving exploratory research to analyze Cost, Benefit, limitation, implication, and application of Blockchain Technology in Food Industry. This paper compares in detail the main component of food industry i.e. traceability from traditional electronic versus proposed blockchain based perspective. Paper also highlights how traceability and its correlation with various methodologies and approaches ensures authenticity of food products. Paper also covers core principles, types of blockchain implementation and highlights the solution providers with current applications. Towards the end paper explores traditional versus blockchain functionality of food traceability.

3. METHODOLOGY:

This article is a conceptualization Paper which has been presented through rigorous literature review. The concepts of blockchain have been taken from my own book titled “Technology Disruption Reshaping the Market (ISBN: 978-620—0-28037-4) published by LAP LAMBERT Academic Publishing Founded in Germany in 2002)” 3, various white papers, online articles and extensive discussion with subject matter experts. The terms used and introduced with respect to traceability of food Vs electronic traceability is result of extensive insight into scientific publications and news reports in subject area. In fact Application, Implication & Limitation of Block Chain Technology in Food Industry traditional against blockchain based traceability is still at infant stage and would invite researchers and scholars to develop this area to save precious resource like food which is an important ingredient to human life. The Paper offers two important blockchain technology for meat and food spices (Taking one each non vegetarian & vegetarian products to draw parallelism and highlight blockchain introduction in food industry.
4. MAIN ANALYSIS:

4.1 Prevalent Investigative methods and Traditional Traceability:
In food industry there are claims normally made by intermediaries who normally process and transform food so to reach consumers/users in raw, semi raw, processed, ready cook and/or ready to serve form. Currently, there are number of important instruments and methods for testing, and verifying claims in regard to veracity in respect biochemical properties food which essential to human existence and growth and survival. Some of these methods are High Performance Liquid Chromatography, DNA Tests, Mass Spectrometry, Gas Chromatography, Nuclear Magnetic Resonance, NIR (Near Infrared Spectroscopy, Chemical profiling, Metabolite Profiling etc. All these tests help us ascertain biochemical properties of the food. Properties that to some degree can be verified by analytical methods include species, geographical origin (broadly), process involved like fresh or frozen, original and remaining shelf life, extent of additives mixed, organic/inorganic production using natural or fertilizers. The analytical methods mentioned and used in ascertaining properties definitely do not give any insight into detailed TRU including information like farm in which it is produced, farmer who produced it or route it is taken from farm to fork. Often stakeholders involved including publishers, handlers, practitioner, publishers often name these as traceability, which definitely is inaccurate. So some of the analytical tests often termed as part of traceability whereas, fact is traceability information is neither verified nor authentic bluffing all the lawful claims of real owners and defaulters who often under camouflage escape in case of eventuality.

4.2 Chain of Custody Vs Traceability:
Chain of Custody is defined as control and responsibility at each step of supply Chain in respect of Input and output, including all parameters and documentation. CoC (Chain of Custody) is often confused and interchangeably mixed with traceability. There are several different models for implementing CoC systems, including identity preserved, segregation, and mass balance, however major difference between Traceability and CoC is defined in the following table 2.

Table 2. Major Points of Differences between Traceability & Chain of Custody (CoC)
[Source: (Borit& Olsen, 2016)].

| Traceability | Chain of custody (CoC) |
|--------------|------------------------|
| Objective    | To associate recorded data with TRUs; to document what happens |
| Of what?     | To prevent mixing that violates the CoC requirements; to document that no such mixing has occurred |
| The traced unit | With respect to some particular property which the CoC is in relation to, often origin or ecolabel status |
| Mix/join units | The units with the same CoC identifier |
| After mix/join | Only the units with the same CoC identifier |
|              | Considered same unit and receiving the same CoC identifier |

Status (e.g. fresh or frozen), presence of additives, some aspects of organic production, remaining shelf life, and some others, depending on the type of food item. While the list of food item properties that can be verified analytically is extensive and growing as the methods and technologies improve, it is worth noting that this is only a small subset of the properties recorded in a traceability system. Analytical methods cannot tell you who the owner of the TRU is, or the name of the farm or farmer, or the route the TRU took in the supply chain, or whether the production was ethical of fair trade, or similar. While practitioners and publications sometimes refer to these types of methods as “methods for traceability”; that is inaccurate, at least in relation to most definitions of traceability (including the one chosen here), because they do not deal with “recorded identifications”. What these methods can be used for is to verify some of the claims in the traceability system. It is important to keep in mind that a traceability system is made up of statements that are claimed to be true, but we do not know for sure
that they actually are true, so that is something we need to check.

This means that analytical methods are very important when we are dealing with traceability, but these methods do not in themselves provide traceability. What they do provide is a way of verifying most of the claims relating to biochemical attributes of the food item in question. While these claims are only a subset of the total number of claims in a traceability system, they are among the most important ones, because if there is a food safety problem related to a food item, it will be detectable through application of analytical methods, and food safety, as we have seen, is a strong driver for implementing a traceability system.

4.3 Transparent Traceability (T²)
In Supply Chain Transparency is critical and is referred to as extent to which product and process related information is among participating members in supply chain. Transparent Traceability is also key element in building trust among stakeholders of Supply Chain (Hofstede, 2004; Renn, 2008). Transparency in Supply Chain also refers to requested product related information by concerned supply chain stakeholder with an assurance of no loss of information due to noise, delay, misrepresentation (Hofstede, 2004). It is important to know at this stage that transparency and traceability are not same. In fact, traceability sets the framework for transparency, (Egels-Zandén et al., 2014). Normally a good traceability system is capable of providing information sought by stakeholder with just very minor loss of delay and noise, however, distortion does contain mostly unverified claims thus in order to have transparency good data verifying mechanism has to be part of system. In a supply chain good traceability can provide information and overview of content, raw material, ingredients, product and processes involved but to have transparency one needs many more components. In nutshell traceability is generic, whereas, transparency is specific, and provides record of what one is doing to supply chain. In food industry transparency deals with general public Vs decision makers at large.

4.4 B² (Block By Block) Understanding Blockchain Technology
From the beginning of the Century people have been sharing information through Internet, especially in the era of Social media sharing has increased in manifolds. Blockchain a revolutionary technology, which is spreading like a wild fire has made sharing information as (IoV) Internet of Values. Through Blockchain people are able to not only exchange information, but exchange and transfer any ownership of a priced moveable and immovable assets (Through digital documentation), or transfer financial securities, without having to use a third asset of value also on a peer-to-peer basis, in a more transparent and secured way.

As of today there are entities that not only own the process but also control the transactions as intermediaries causing delay and financial losses to transacting parties in the form of fees and charges, and thus making transactions unnecessarily expensive.

As of now one can say that there are mainly two types of Blockchain Technologies. (B2) Bitcoin Blockchain that enables Bitcoin (a digital currency) transactions. The other form of blockchain is (EB) EthereumBlockchain, which is a programmable. This is far more adaptable than the (B2).

4.5 Irreversible Yet Localized
One important feature in Blockchain is that any data that is stored on the Blockchain remains there forever - the record is, therefore immutable and cannot be erased. This means that the data stored on the Blockchain offers absolute level of transparency that does not exist today in the modern world. It means that if one owns something, and when its ownership and value is transferred to other at a certain time, there will always be a record of my previous ownership on the Blockchain. This also guarantees that the record cannot be manipulated, for example, that no one else can alter the record, which is why within the industry, Blockchain is often described as the ultimate TM (Trust Machine.)
Another important feature of Blockchain technology is that it's localized. But what does that really mean? In Blockchain context, localized means that no single person, or a company, or a government, or an entity, owns the data. Originally Blockchain, is a growing list of records, called blocks that are linked using cryptography. Each block contains a cryptographic hash (#) of the previous block, a timestamp, and transaction data (generally represented as a Merkle tree). By design, a Blockchain is resistant to modification of the data. It is "an open, distributed ledger that can record transactions between two parties efficiently and in a verifiable and permanent way". For use as a distributed ledger, a Blockchain is typically managed by a peer-to-peer network collectively adhering to a protocol for inter-node communication and validating new blocks. Once recorded, the data in any given block cannot be altered retroactively without alteration of all subsequent blocks, which requires consensus of the network majority. Shown in figure 3 is working model of blockchain:

![Figure 3. Schematic Diagrams explaining How Blockchain Works](image_url)
Figure 4. Blockchain under the Hood: How does Blockchain Actually Work? Blockchain is interdisciplinary

Figure 5. How Blockchain is interdisciplinary in Nature
(Source the Blockchain Technology by MoolySagiv Tel Aviv University)

Blockchain is interdisciplinary in nature (Refer figure 5) and depends on network “The assets that Blockchain can track can be “hard” assets such as personal property or real estate, or they can be “soft” assets such as intellectual property.” It is important to know why this technology is considered better over traditional technologies, and the answer is “Blockchain as technology has potential to solve two of the Internet’s basic complications:

Firstly “The reality that information can be easily copied without any effort, which undervalues it, and the loss of confidence that results when economic relationships transfer into Internet”. Secondly “The pressing need and reason for using Blockchain Technology is its marginal nature, which is best suited
for today’s economy and society”.

Blockchain working has been diagrammatically explained in above in figure 4. The diagram explains block by block structure and also explains logical sequencing followed. This logic and flow is best suited for food industry in most appropriate manner.

Thus Blockchain offers following advantages, “Autonomy” (Works as per rule and no need for central decision making body), “Transparency” (offers an audit trail that can be consulted at any time by all Blockchain members, “Automation” (The rules set upstream by Blockchain members via smart contracts allow for automatic settlement) Security (owing to the stacking of the blocks), “Client accountability” (each participant has rights and obligations with regard to the Blockchain community). The main advantages (i.e. Automation, Autonomy, Client Accountability, Security and Transparency) of Blockchain as technology is given below in figure 6 for reference and understanding.

1. Automation: rules set upstream by Blockchain members via smart contracts allow for automatic settlement.
2. Autonomy: Blockchain works according to the ruleset by its members. There is no need for a central decision making body.
3. Client Accountability: each Blockchain participant has right and obligation with regard to the Blockchain Community.
4. Security: Operating data input on the Blockchain is deemed secure owing to the stacking of the block.
5. Transparency: Blockchain offers an audit trail can be consulted at any time by all Blockchain members.

4.6 “Blockchain can be divided into three categories and these are Public (all parties involved are able having right to use the database, store a copy, and incorporate it by making available their computing)” “Consortium (these are available/open to the public at large but not all data is offered to all stakeholders. User rights differ and blocks are authenticated based on before/predefined rules.

Figure 6 Advantages of Blockchain Technology Source: Blockchain a Catalyst for New Approaches in Insurance by PWC
Consortium Blockchains are therefore "partly distributed" and "Thirdly, Private (these are where a nodal expert achieves the rights to admittance or amend the database. All three explained categories are shown in figure 7 below. The system can be easily incorporated within information systems and offers the added benefit of an encrypted audit trail. In private Blockchains (Table 3), the network has no requirement to encourage enactors/miners to use their computing power to run the validation algorithms)."

Figure 7. Categories of Blockchain Source: Blockchain a Catalyst for New Approaches in Insurance by PWC

Table 3. Main types of Blockchain segmented by permission model

| BLOCKCHAIN TYPES | READ            | WRITE          | COMMIT                  | EXAMPLE                                      |
|------------------|-----------------|----------------|-------------------------|-----------------------------------------------|
| OPEN             | Public permissionless | Open to anyone | Anyone                  | Bitcoin, Ethereum                             |
|                  | Public permissioned | Open to anyone | Authorised participants | Supply chain ledger for retail brand visible by public |
| CLOSED           | Consortium       | Restricted to an authorised set of participants | Authorised participants | Multiple banks operating a shared ledger |
|                  | Private permission "enterprise" | Fully private or restricted to a limited set of authorised nodes | Network operator only | External bank ledger shared between parent companies and subsidiaries |
4.7 Misconceptions about Blockchain

4.7.1 Pseudonymous

Contrary to popular belief, in general, Blockchain technology does not allow its users to be totally anonymous. Rather, public Blockchain platforms tend to be pseudonymous: user identities can be anonymous but their accounts are not, as all of their transactions are visible to all other users refer figure 9 above for details. On these platforms, user accounts can be created without any identification or authorisation process. This allows users to use a pseudonym. Permissioned blockchains can require a user’s identity to be verified before they are able to access or use the blockchain. Further blockchain is also multilayered with three layers namely application, network and protocol layers as shown in figure 8 above.

4.7.2 Well “almost” immutable...

While rare, it is possible for the Blockchain to be compromised if nodes pool their resources and collude to approve incorrect ledger entries. However, the larger the network, the more difficult it becomes to carry out this attack. In most systems, it would cost the attacker many more resources to carry out the attack than they would gain from the attack itself. Additionally, some private blockchains allow for central authority nodes to change information on the ledger. Advances in quantum computing (supercomputing) threaten some current cryptographic security measures, but there is equally the likelihood that Blockchain’s security will evolve with quantum computing capabilities. As per (Chopra A. & Sankaran V 2019) Blockchain a sound as technology acceptance in other areas.
4.8 Applying of Blockchain Technology in Food Industry (BaaS, SaaS, PaaS, IaaS, WebEx)

4.8.1 Brief about Providers of Blockchain Technology as of Today:
Blockchain is open source technology thus gives freedom to use, extend and amend the way it suits application provider and the downside of such open source product is that one has to comprehensively understand the original source code for better implementation. Blockchain being open ended has resulted into emergence of number of established players each having their own strength.

4.8.1.1. BaaS (Blockchain as a Service):
BaaS can be mapped to identification of SaaS (Software as a Service) which is typical distribution model, where third party hosts an application’s functionality i.e. service through cloud/internet. There are number of such service providers among big names e.g. Google Apps, Salesforce, Cisco WebEx and Dropbox, such services also known as Service on demand S/W typically requires subscription or registration. The other variant is PaaS (Platform as a Service) and IaaS (Infrastructure as a Service) blockchain too follows this ideology, thus doesn’t warrant developing blockchain from scratch. Some of the big cloud providers such as Amazon (with AWS), Microsoft (with Azure), and IBM (with BlueMix) are starting to offer blockchain as a service on their cloud platforms. Users adopting BaaS solutions will benefit from not having to deal with the problems concerning configuration, setting up a working blockchain, and not needing hardware investments.

4.8.1.2 Amazon AWS blockchain solutions:
Amazon offers end-to-end BaaS solutions with a wide range of blockchain frameworks for developing blockchain applications. Examples of frameworks are Hyperledger Fabric, Hyperledger Sawtooth, Ethereum, and Corda. Amazon offers developers a one-click deploy of the underlying blockchain and connectivity to supplemental applications.

4.8.1.3 Microsoft Azure Blockchain Workbench:
Microsoft offers modular, pre-configured networks and infrastructure. Development of blockchains can be done by the blockchain workbench. The workbench is a collection of Azure services and capabilities designed to create and deploy blockchain applications to share business processes and data with other organizations. Microsoft provides the infrastructure scaffolding for building blockchain applications, allowing developers to focus on creating business logic and smart contracts. Other Azure services can easily be integrated. Examples of blockchain solutions offered are Corda, Ethereum, and Hyperledger Fabric. A solution architecture for supply chain track and trace is also offered.

4.8.1.4 IBM BlueMixBlockchain:
IBM offers BaaS on their BlueMix cloud platform. IBM blockchain solution and services are built on Hyperledger technologies which provide the framework and tool set. IBM claim to have successfully implemented over 400 blockchain solutions, and their best practices can be found in their enterprise ready blockchain services. There are other variants such as Blockchain first (A blockchain first implementation works directly with the blockchain tools and stack) Development platforms (Several development platforms exists that allow for fast development of a blockchain implementation); Vertical solutions (Vertical blockchain solutions are industry specific, and are based on private blockchain or ledger infrastructure) and APIs & Overlays (This approach uses the blockchain as an asset, ownership or identity-binding infrastructure, and it is typically used for a specific purpose).

4.8.1.5 Brief on Blockchain Technology in the Food Sector
In market there are both test and trial applications of blockchain in food industry especially in traceability area however, industry lacks common technology on which different blockchains can connect (Ciaian, 2018). It is important to know that Most existing blockchain systems for traceability management have been developed since 2015 (Galvez et al., 2018). Table 4 below gives brief of some of the important initiatives in blockchain technology pertaining to farming and agricultural food supply chains along with blockchain technology implementation objectives.
Table 4. Few Important Applications of Blockchain Technology in the Farming & Agricultural Supply Chain

| Goods/Products | Initiative/Project/Company Involved | Objectives |
|----------------|------------------------------------|------------|
| Agri-food      | AgriOpenData (Galvez et al., 2018) | Allow quality and digital identity to be certified |
| Agri-food      | Supply Chain Traceability System for China Based on RFID & Blockchain Technology (Galvez et al., 2018) | Trusted information throughout the agri-food supply chain |
| Beef           | “Paddock to plate” project, BoekEdger;ID.com (Kamaliris et al., 2018) | Foodtraceability |
| Beer           | Downstream (Kamaliris et al., 2013) | Foodtraceability |
| Chicken        | Gogochicken, Grass Roots Farmers Cooperative, OriginTrail (Kamaliris et al., 2018), ZhongAn (Ciaian, 2018) | Foodtraceability, food safety concerns of urban consumers |
| Coffee         | FairChain coffee: Sext350 in partnership with Moyee Coffee (Ciaian, 2018) | Traceability, transparency of the value added |
| Fish           | Provenance (Galvez et al., 2018) | Auditable system |
| Fresh food     | Ripe (Galvez et al., 2018) | Enabling data transparency and transfer from farm to fork |
| Fruits         | FruitChains (Galvez et al., 2018) | Public, immutable, ordered ledger of records |
| Grains         | Agridigital (Kamaliris et al., 2018) | Financial |
| Large enterprises | IBM (Galvez et al., 2018) | Food tracking project |
| Mangoes        | Walmart, Kroger, IBM (Kamaliris et al., 2018) | Foodtraceability |
| Olive oil      | OlivaCoin (Ciaian, 2018; Kamaliris et al., 2018) | Financial, small farmers support |
| Orange juice   | Alber Heijn & Refresco (International Supermarket Nave 2018) | Show customers how and by whom products are made |
| Pork           | Walmart, Kroger, IBM (Kamaliris et al., 2018) | Foodtraceability |
| Pork           | Arc-net (Galvez et al., 2018) | Brand protection and security through transparency |
| Scotch Whisky  | CaskCon (Ciaian, 2018) | Investing in maturing Scotch Whisky |
| Soybean        | HSBC & Cargill; ING & Louis Dreyfus Co. [Hochfelder, 2019] | Help authenticate products as well as eliminate the “paper trail” of verification at every stage of the supply chain |
| Sugar cane     | Coca-Cola (Kamaliris et al., 2018) | Humanistic |
| Turkeys         | Cargill inc., Mendrix Genetics (Ciaian, 2018; Kamaliris et al., 2018) | Foodtraceability, animal welfare |
| Wine           | Chainwine (Galvez et al., 2018), Winecoin (Ciaian, 2018) | Increase performance, revenue, accountability, and security |

5. COMPARATIVE ANALYSIS OF BLOCKCHAIN VS TRADITIONAL FUNCTIONAL BASED TRACEABILITY SYSTEMS

To do best comparative analysis of Blockchain Vs Traditional Traceability one need understand following example taken from food industry i.e. if someone needs to serve chicken at the time of dinner then one has number of options in terms of its serving including time, type, of addons, presentation, cutlery etc. etc. The same when we see from Blockchain perspective it is set of recorded transactions in the form a block linked to other blocks and each block refers to previous block in chain. Thus, practically it makes impossible to make changes in immediately preceding blocks. And if changed it would be known immediately to all with identification. For a blockchain expert blockchain is simply structured data in a set which is similar to linked list where, hashes rather than pointers are used to refer to the previous link in the chain. In chicken example if you do not have set structure then what one has is not a blockchain. Then what about serving options? Any expert on blockchain would explain that blockchain is simply online implementing the distribution of multiple copies of the databases or blockchain through mechanism of consensus in a synchronized manner with signing process using public and private keys for the purpose of identification through encryption enabling
process. The fact is all mentioned additional enablers in blockchain are options but implementation must. Other implementation options could have been made, and the fundamental data structure would still be a blockchain. A programmer on a standalone offline computer could write a blockchain implementation based on a single version of the blockchain, with no consensus mechanism needed, no signing process needed, and no encryption needed. In principle this should be called a blockchain, because the underlying data structure for the implementation as well as the data recorded would be identical to a (single copy of) an online public blockchain, implemented in the traditional way with a consensus mechanism, a signing mechanism, and encryption using public and private keys. This precisely is the USB/uniqueness of blockchain compared with traditional electronic traceability mechanism which is based in RDB (Relational Data Base) as basic principle. In short difference between two underlying systems is this data structure. This is, however, not how blockchain implementations are usually described or analyzed. Rather than comparing blockchain against non-blockchain implementations, most analyses compare online against offline implementations, or distributed against centralized, single copy implementations, or encrypted against non-encrypted signatures. As per (Collak 2018) it takes Wall Mart to track pack of mangos just two seconds using blockchain, however using non blockchain time taken can be more than six and half days. Table 5 compares blockchain vs. traditional traceability in food industry in respect to characteristics and implementation options.

Table 5 Compares Characteristics and Implementation Options under Blockchain Vs. Traditional Traceability in Food Industry

|                         | Traditional electronic traceability system | Electronic traceability system based on blockchain technology |
|-------------------------|-------------------------------------------|-----------------------------------------------------------|
| Underlying database     | Relational database (usually)              | Blockchain                                                |
| Immutable database?     | Possible by setting ‘append only’ flag on database, but very unusual | Yes                                                       |
| Single copy of database?| Normally, yes. Traditional databases often use client-server network architecture, where a single, master copy of the database is stored on a centralised server. | No, normally multiple copies (but strictly speaking this is an implementation option) |
| Consensus mechanism?    | Needed if there are multiple copies of the database, unusual | Yes (but strictly speaking this is an implementation option) |
| Online? Cloud-based?    | Not uncommon for large companies, and for modern chain traceability systems | Yes (but strictly speaking this is an implementation option) |
| User authentication     | In a client-server implementation, the server authenticates a client’s credentials | Based on cryptography with private keys and public keys (but strictly speaking this is an implementation option) |

On looking at each element of above table it is very much clear there is absolutely no comparison. Rather it is appropriate to compare characteristics and implementation options individually and point out advantages and disadvantages of each separately as follows:

**Appropriateness of Database**

When comparing between tradition Vs. blockchain it is important to know blockchain deals with transactions and in food supply chain transformation of food is similar to transaction in blockchain, whereas, tradition databases normally store anything and it is based on status i.e. both state and value of data. Thus, blockchain is more appropriate for food data storing as compared to traditional.

**5.1 Data Conformity & Quality**

Any recorded data has various attributes which include quality, conformity wrong recording of data and both these are of concern in both types of systems however chances of deliberate fraud is less likely in blockchain.
5.2 Invariability, Reliability and Limpidity
There is noticeable difference between Blockchain & traditional database when it comes to data invariability, reliability and limpidity, as by design blockchain technology is immutable and in traditional database overwriting is possible and it is uncommon practice to keep version logs thus it maintains latest recorded state of each data proving blockchain to be having edge over traditional data bases.

5.3 Trust
Normally trust is not a matter of evaluation and system in consideration treats it differently e.g. in traditional traceability trust is in system designer/owner and database and any glitch refutes to the owner of database. In Blockchain trust is a function of legitimacy of design itself. However, going by blockchain there is no disadvantage attributable to system. The very built in blockchain quality of “not needing to trust any single organization” is not really applicable in the food sector.

5.4 Rapidity and Efficacy
Implementation in Blockchain as of now is slower than that of traditional system because of supporting functionality of normal database and also for blockchain there is need to authenticate signatures using cryptography and consensus algorithms during updates. This is over and above the inefficiency related to the built-in redundancy in the blockchain, where there are multiple copies of the database, and where all transactions since the creation of the blockchain are stored and accessed. Over a period of time this problem would overcome making blockchain equally good as traditional database making it also equally suitable for traceability of food.

5.5 Robustness
Redundancy is subset of Robustness. So Robustness occupies higher spot than redundancy. Robustness deals with functions incidents, errors, safety and losing of data during power cuts, incidents, server crashes or H/W failure etc. In traditional systems all these are taken care by external processes resulting into minor to severe data loss. Comparatively in blockchain extent and degree of robustness is built-in and can be recreated by traversing the recorded transactions, and for the database, which is normally online, and duplicated many times.

5.6 Interoperability
As the name suggest is exchange of information across various systems. In traditional electronic traceability there are number of options and RDBMS (Relational Data Base Management Systems) giving ease of structuring. And implementation, on the other hand blockchain is more homogenous in that they all store transactions rather than data element values, they are all online, they are all immutable, they all employ cryptography for verifying identity etc. The fact that blockchain systems are more homogenous makes them more interoperable, and in fact many of the reported blockchain success stories are based on the improvement in operability and data sharing along the supply chain rather than on any of the blockchain attributes in itself. For traditional traceability systems to become (more) interoperable would depend on widespread adoption of standards both for Electronic Data Interchange (EDI) and for data content; unfortunately, there are too many competing standards in this area, so the current level of interoperability is fairly low. Thus in food’s supply blockchain proves to be better option than traditional electronic traceability.

Looking at table it is evident that there are five parameters (Shown in Grey Color) which favor traditional electronic traceability. There are two parameters one each supporting Traditional Electronic System (Speed and efficiency) and Blockchain (Interoperability) both are shown in Green Color and both are of significant importance. The Section shown in light red color are challenges or disadvantages of systems. So it recommended that while choosing between two in regard to traceability in food supply chain one should look at the importance of systems qualities and then decide e.g. data transparency, integrity and for robustness one should favor block chain and for those
looking for speed, and data confidentiality then traditional electronic traceability is more suitable.

The significance and usefulness of improved interoperability should not be undervalued. While interoperability is technically possible for traditional traceability systems, it is difficult to get a large and diverse group of companies to agree on what standards and data formats to use. It is probably easier to get a large and diverse group of companies to agree to all use blockchain-based systems, and then significantly improved interoperability will be a much-desired side effect of that decision.

Table 6. Comparative Cost Benefit Analysis of Blockchain with Tradition Traceability System

| Comparison criteria                  | Traditional electronic traceability system                                                                 | Electronic traceability system based on blockchain technology                                      |
|------------------------------------|-------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Suitability of database            | Records (claimed) variable states, versatile                                                                 | Records transactions, well suited for recording transformations                                  |
| Data quality and veracity          | Data provider must check and vouch for data quality and veracity                                             | Data provider must check and vouch for data quality and veracity, but fraud frequency may be lower, as risk of getting caught is higher |
| Immutability, integrity and transparency | Data elements can be overwritten; needs additional recording (transaction log or similar) to document this | Only the transactions are recorded, which means a higher level of integrity and transparency of the claimed values |
| Confidentiality                    | Easy to integrate tiered levels of access                                                                   | Can be done, but to some degree it goes against the philosophy of what a blockchain implementation is meant to support |
| Trust                              | Based on trust in the food business and the brand                                                            | Still based on trust in the food business and the brand, but trust may be higher because of higher degree of data integrity and transparency |
| Robustness                         | Duplication, back-up, and other means of providing robustness must be provided by external processes        | Robustness and duplication of data is built into the system                                       |
| Speed and efficiency               | As good as you can get                                                                                       | Significant overhead related to duplication, error checking, consensus mechanisms, and calculating the state of variables based on transactions |
| Interoperability                   | There is a plethora of systems, implementations, and database structures, there are a number of standards for TRU identification and Electronic Data interchange, and there are very few standards defining how the recorded data elements should be named and measured. This means that system interoperability (exchange of data) is a big problem. | Blockchain-based systems are less diverse; they all record transactions (transformations) rather than state values, and they are all immutable. Interoperability and data interchange between blockchain-based food traceability systems is easier than between existing systems, any many of the success stories reported is because a higher degree of interoperability has been achieved. |

View Point on How Regulators May Favor Blockchain Over Traditional System(Table 6 & Table 7)
Table 7. Cost Benefit Analysis of Blockchain from Regulator Perspective

| Comparison criteria          | Traditional electronic traceability system | Electronic traceability system based on blockchain technology |
|-----------------------------|--------------------------------------------|------------------------------------------------------------|
| Suitability of database     | Authorities can only access claims in relation to state of variables | Authorities can access the entire set of transformations that led to the current state, which makes it easier to see the origin of the stated claim |
| Data quality and veracity   | Authorities need separate and external checks to test the data quality and veracity | Some degree of quality and veracity is provided by the blockchain-based system itself |
| Immutability, integrity and transparency | It is difficult for authorities to know if recorded data has been subsequently overwritten | The immutability of the database means that the authorities know that the data has not been overwritten |
| Confidentiality             | Not an issue for authorities                |                                                            |
| Trust                       | Not really an issue for authorities (except for trust in data quality and veracity, which is better in a blockchain-based system) |                                                            |
| Robustness                  | Not an issue for authorities                |                                                            |
| Speed and efficiency        | Not an issue for authorities                |                                                            |
| Interoperability            | Lack of interoperability makes it more difficult to identify discrepancies, and to do mass-balance accounting which is sometimes necessary to identify fraud | Better interoperability and better access to comparable data from different systems makes it easier to identify discrepancies, and to do mass-balance accounting |

For regulators features like transactions recording, and that too, not only variable states, even immutable database, interoperable systems are more important than efficiency, confidentiality and speed which are more pro supplier oriented.

6. CONCLUSION

It is evident that if we overlook speed and confidentiality (important for Commercial stakeholder in food supply chain) blockchain technology is more suitable (For Regulators and end users). The most favorable parameters which favor blockchain are interoperability and data sharing. But for the benefit of society and human at large data access from Farm to Fork is key and is easy to implement using blockchain because of its main support of interoperability. It is important to reiterate that blockchain-based implementations may not solve all, or even most of the problems associated with traditional electronic traceability systems includes:

1. Data quality and veracity
2. Food fraud.
3. Need for standards

To avoid future disappointment, it is important that both food businesses and solution providers are aware that these challenges will continue to exist also in blockchain-based implementations.

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