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Blockchain in Supermarkets: Mitigating the Problem of Organic Waste Generation

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***Abstract*—This work presents a proposal for a solution to the specific problem of organic waste generated by supermarkets and understood as t merchandise of organic and perishable composition that could not be marketed during its validity period. The goal of this research is to propose a solution based on Blockchain technology in Chile, which would allow an immutable, decentralized, and validated transaction record to be kept. Such a record would enable supermarkets to trace the life cycle of those products that make up organic and perishable merchandise in a transparent, reliable, and scalable way. To this end, the problem is modeled using the Blockchain Hyperledger Fabric platform (an open-source platform started by the Linux Foundation), which is fed with relevant information and data on the status of a representative set of organic merchandise products. At the same time, a qualitative approach is proposed to gather the opinions of executives and logistics operators through semi-structured interviews, and considering a convenience sample. With a sample of 6 executives, it is understood how the proposal is perceived and its applicability in supermarkets and distributors. The data show that both obtaining information and making decisions about it are achieved in a distributed and collaborative way, allowing for reliable and agile traceability, thereby mitigating the low quality of the information provided by the actors that make up the supply chain. This service is perceived as desirable by both customers and operators. The model enables not only horizontal communications between suppliers, distributors, and consumers, but also vertical ones, and thus, ultimately, makes the company's income statement more efficient.**

***Keywords*—Blockchain; organic merchandise; generation of garbage in supermarkets; hyperledger fabric; traceability.**

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I. Introduction

According to the study of technological trends, Blockchain is positioned in the post-inflated expectations stage (Fig. 1) as presented in the Gartner curve [1,2], and continues to grow. A similar comparison can be made looking back at the 90s World-Wide-Web internet hype. As a technology, the internet also went through a post-inflated expectations phase, which culminated in the well-known Dot-com financial bubble. However, after this relatively short period we observed how its recovery became exponential. For supermarket supply chains in Chile, Blockchain applied to organic merchandise is a powerful opportunity for managing all its different processes.

Considering SCOR 12.0 [3], i.e., Planning, Resources, Manufacturing and Distribution, Returns, Availability as a reference model, we observe that Blockchain can plausibly be used in the same way. With Blockchain, supply chain stakeholders have reliable information, which enables them to react proactively upon changes in supermarket stock. The USA, under the Obama Administration, passed the Food Safety Modernization Act, which establishes traceability requirements for supply chains [4], and further stresses the importance of having the necessary technological enablers to meet regulatory frameworks in an agile fashion. Traditionally, computer systems that support supply chains manage information flows sequentially, consolidating reports and metrics periodically (e.g., every 24 hours,) and at the end of the process, as illustrated in Fig. 2.

Moreover, Blockchain technology proposes an architecture where data is Decentralized, Verifiable and Immutable [5]. The assumption is that there is distrust among stakeholders (reason for which contracts exist in the first place), and that data is updated, consolidated and validated, as the data is being generated. It is no longer necessary to perform costly consolidation requests to centralized data servers, that, in addition, are likely to give discrepancies.

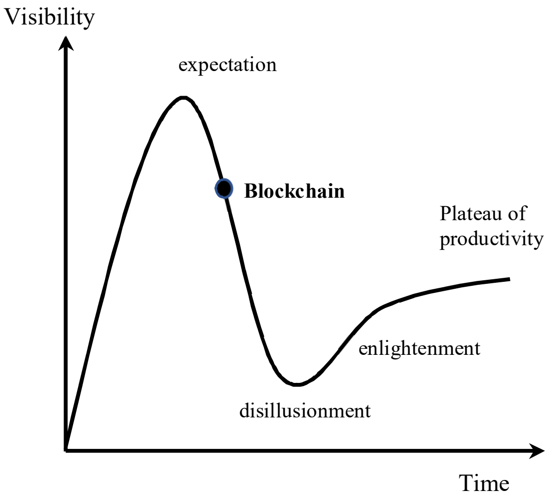

Fig. 1 Hype cycle for emerging technologies [1], [2].

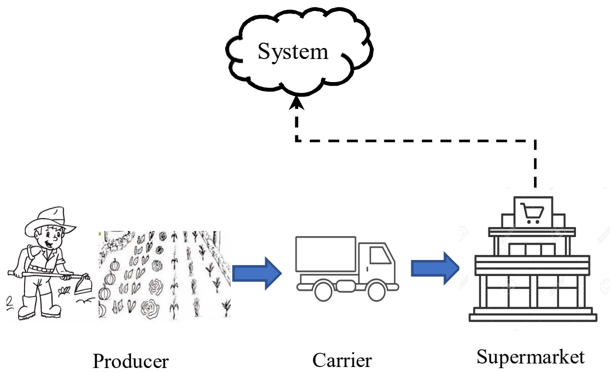

Fig. 2 Traditional supply chain information flow.

The Blockchain system as such oshiperates with robust cryptographic mechanisms which, added to the so-called "Byzantine tolerance" towards failures [6], make data reliability a naturally inherent feature. The chart in Fig. 3 represents a normal flow that runs with the Blockchain Hyperledger Fabric platform of the Umbrella project [7], where a transaction is promoted to definitive, and afterwards is stored in a distributed database. Comparison of results are done first, conducted in parallel and independently in different nodes, requiring identical results for all cases. The identical result state is what is referred to as Blockchain consensus, which is a sine qua non condition for a definitive entry.

For stakeholders operating with Blockchain and intervening in the supply chain, the information is now truly symmetric. Information flows effectively reflect faithfully what is occurring in the value chain [8]. The data structure managed by Blockchain itself, called Ledger, is managed and represented by immutable transaction blocks (Fig. 4); referenced by hash keys. Linked to each block is a metadata called Block Header (e.g.: Fig. 4, (Block Header n: Bn)), which contains a hash to the previous block. This metadata also contains a Merkle Root, which synthesizes all transactions included in the block, and allows all transactions included in the block to be succinctly referenced. Again, as in the case for an accounting entry, transactions are registered sequentially and incrementally. It is not possible to retrospectively perform modifications without leaving some trace, hence its immutability. The complete transaction history is registered providing full transparency to the process. Blockchain uses a mechanism called Consensus, where, for a transaction to be viable and become part of the history of transactions carried out by the Ledger, it must have reached a result on the Ledger that is identical in all the nodes that form part of the Blockchain validation network.

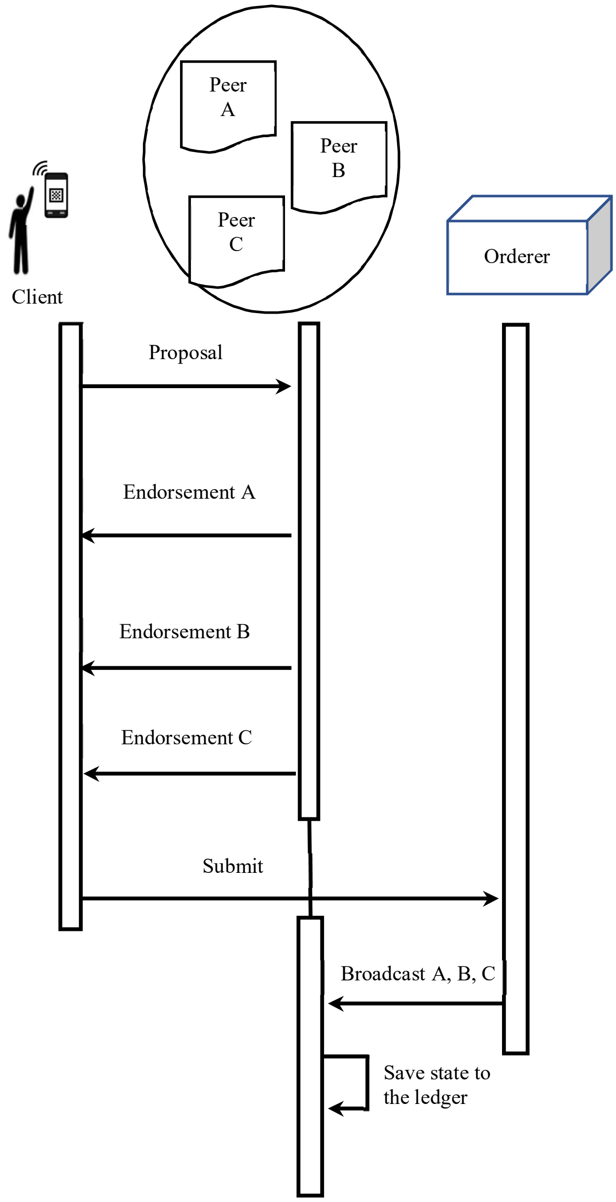

Fig. 3 Blockchain information flow chart.

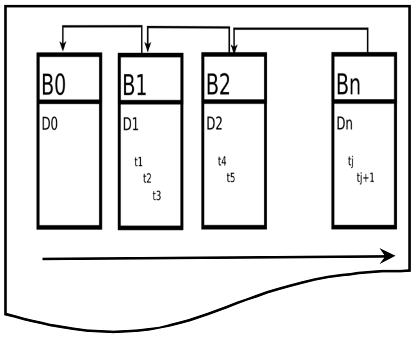

Fig. 4 General data structure for Blockchain.

A. Technologies used and their evolution through time

Blockchain in its more general sense can be dated back to a technology known as Distributed Ledger Technology (DLT) [9], which was characterized for having the following 3 elements, that were naturally inherited by Blockchain:

- Data Model.
- Transaction language.
- Protocol (commonly called consensus).

Without a doubt, Bitcoin is a milestone worth mentioning as it was one of the first to appear on the scene. As such, Bitcoin is a Blockchain used as currency whose authenticity and validity are given by a transparency scheme, incentives and computational efforts that achieve a simple but secure system. The idea for Bitcoin is that, in theory, anyone can generate one. Through methods of brute force trial-and-error, a bitcoin can be created, if sufficient time and CPU power are available. This is what is referred to as "mining bitcoin". And it is precisely in this last detail where the entry barrier lies; given that current CPU power requirements are so great, associated costs are huge, regardless of the combination of necessary infrastructure and energy. An example is the case of Iceland [10] that, thanks to its low temperatures, manages to attain savings in cooling costs.

B. Models or types of representation in Blockchain

From a public or private standpoint, Blockchain can be classified as:

- "Permissionless Public Ledger": Anyone with sufficient CPU resources is free to operate with it, Bitcoin being the most representative case.
- "Permissioned Public Ledger": Can only be operated by those who have authorization.

There are multiple examples of implementations, such as Hyperledger Fabric and Hyperledger Sawtooth. The difference resides mainly in where emphasis is placed. Hyperledger Sawthooth was designed to interact with business rules that operate in a traditional system, while in Hyperledger Fabric business rules are part of the Blockchain.

C. Incentives Economy

As mentioned before, consensus is achieved through a mechanism or protocol which enables an agreement between nodes. For the case of Bitcoin ("Permissionless Public Ledger"), we have what is referred to as incentives economy [11]. This solved an old problem known as "The Byzantine Generals Problem". The solution to the problem used a bold proposition: using cryptography as a means where a message would be able to withstand an attempt of fraud or breach, while at the same time allowing the issuers and receivers to have a mechanism that provides sufficient assurance of the legitimacy of what is being communicated.

D. How has Blockchain been adopted in the rest of the world?

Leaving aside cryptocurrencies or other financial solutions, Blockchain throughout the world is steadily being adopted in the food industry and in its supply chains.

There are experiences with the fishing industry in New Zealand and Norway, who are currently facing an issue where 70% of fish are incorrectly labelled (either by error or fraud), which means that the origin and processing of fish that are consumed do not have a known origin or processing location that is sufficiently transparent, and do not guarantee the sustainability of the industry. Now in these countries, using radio frequency devices (RFID) or QR codes, consumers can effectively verify in a supermarket or gourmet restaurant the provenance and processing of the fish that is going to be consumed. ConsenSys is a company dedicated to developing Blockchain and works together with the WWF and Seaquest [12] for the tuna fishing industry in the south Pacific.

E. How is Blockchain addressed in Chile?

For the case of Chile, there are experiences in implementing solutions using Hyperledger Fabric [13] at the Santiago stock market. Blockchain was used in this case for a Securities Lending System. The project was sponsored by IBM, who is the main business contributor for the Hyperledger Fabric project. The spirit of the project was to obtain higher participation of this asset class, within the total volume of assets that are transacted on the exchange. Previously, the asset only reached 0.7% of total daily transactions. The innovation seeks to provide more transparency and agility to process these transactions.

In the specific case of supermarkets in Chile, no cases of Blockchain implementations exist. What supermarkets have is stock management software built with a centralized architecture that, due to its nature, represent a "single point of failure", being susceptible to internal and external vulnerabilities against deliberate cyberattacks. Chile has recently suffered important cyberattacks, perpetrated externally targeted at financial institutions that have had costs to the tune of several million dollars [14]. These conventional platforms, to be able to integrate stakeholders or external suppliers, need to make an intense effort in development and implementation. And even when these difficulties are worked out, there still is the habitual and costly IT process of consolidation at the moment of operating the platform, which, in turn, result in a high number of failures, as they are generated reactively and without considering the real-time costs in most cases.

As with consumers, they know little or nothing about tracing events produced in the organic products that they are consuming. Some assumptions are made, and in the best-case scenario they trust the responsibility logos that are scarce and have low standards. Thus, it becomes clear what Richard Thaler studied, Nobel laureate in economics in 2017, who explored the consequences of consumer decisions being constructed on limited rational assumptions, social preferences and lack of self-control [15].

Regarding labelling in Chile, very few brands print on their egg cartons the certification of origin logo e.g., “Certified humane”. The question that follows then is: Can Blockchain technology provide a solution to the following problems? (Which are, in addition, long-standing issues for the retail supermarket sector): Traceability; Integration; Decentralization; Reliability (Immutability and anti-fraud); Food Waste (Organic waste).

The importance of traceability for organic merchandise has been and continues to be a relevant issue, for consumers and suppliers alike. If we consider that supermarkets are the prevalent retail modality for commercializing and distributing this type of merchandise in Chile, it is only natural to think that product traceability is a key part in the global scheme, which covers the complete distribution chain, including consumers. This invites us to ask ourselves the following: Can blockchain technology provide an agile traceability solution for perishable merchandise and help to reduce excessive merchandise waste in retail stores and supermarkets?

After covering the theoretical background, it is worth mentioning that the main driver to carry out the study has been to apply Blockchain technology to the supermarket sector in Chile, due to the excessive amount of merchandise that is not commercialized, which points to management issues caused by a lack of traceability and information, and final disposal, which creates organic waste from organic merchandise. Building an IT system leveraging Blockchain technology that enables flexibility in integration and reliability, to address issues of supply chain management is necessary. The system would allow to minimize potential stockouts as well as minimizing overstock and contribute to improve communication not only with supermarket suppliers and distributors, but also from and towards consumers, by providing a tool to trace organic products, creating trust in the process. This allows to feedback the supply chain with valuable information, enabling the chain to react in an agile way, reducing the levels of mediation and uncertainty, without having to wait for requirements that may have been estimated under unreliable demand assumptions.

With this in mind, this work aims to propose a minimum and viable solution (MVP) based on Blockchain methodology to trace the life cycle of organic and perishable merchandise in supermarkets, to inform product traceability to relevant stakeholder in the supply chain and mitigate the generation of organic waste.

II. Material and Method

Paradigm and design: A mixed methodology has been selected, based, from a qualitative perspective, on the implementation of a MVP, that seeks to model a solution for the problem at hand. A qualitative approach has been proposed to support its construction, based on semi-structured interviews from key stakeholders regarding the application that we propose [16], understanding the methodology as a systematic activity aimed at in-depth understanding of the perceptions from intervening parties regarding the need to assess the what-and-how product traceability and waste mitigation. The approach allows a deep understanding of the solution’s potential, applied in a specific geographical context, also considering the users’ possible resistance to the proposed system.

Target population for the study: From a qualitative standpoint, the study used a convenience sample of managers, suppliers and users from supermarkets in the commune of Las Condes, in Santiago, Chile, totaling 6 interviews. The typical case criteria led us to select managers, who constituted 50% of the sample, while the rest of the sample was comprised by supermarket area supervisors 17%, administrators 17% and consumers 16%. In total, 4 university degree professionals and 2 workers were interviewed, with an average age of 41 years, with a maximum age of 50 years and minimum age of 32 years. The average seniority was 10 years, with a minimum of 5 years and a maximum of 20 years. Of the sample, 80% has worked primarily in the supermarket sector. Quantitatively, the study used a 3-year historical database for tomatoes.

Environment: The study was performed in the commune of Las Condes, of Metropolitan Region in Chile. The commune has an approximate population of 280,000 inhabitants, which represents 1.6% of the population in Chile. The commune has 26 supermarkets [17], and the proposal was implemented considering one of them, which belongs to a chain that represents 28.1% in market share, based on total revenue [18]. Annual revenue for this type of chain totals 3.38 billion dollars, being the largest food distribution force in the commune.

Interventions: For discussion groups and interviews, a recorder was used together with a methodological tool to capture data, using a written document that participants used to follow the questions, which in turn guided the conversation. The questions were open-ended and considered the following 3 stages of the study: Stage 1: Characterization of the present and understanding of reality: Stage 2: High-impact proposals and Stage 3: Alerts on transformation.

The researcher simultaneously kept a field diary, which registered each of the observed situations that would require information collection and perceptions of the business environment during trips to different business centers.

Instrument verification and validation methods: The instrument was validated by two independent Chilean experts, who suggested adjustments to provide consistency to the study design. To verify the information obtained from the interviews, these were reviewed by various professionals and a posteriori, the analyzed results were presented to the interviewees for validation.

Data analysis plan: Observation and study categories were established. Visits to business centers and observations were performed (non-participative) for each of the cases. Afterwards, the theory and the observations gathered in the field diary were contrasted. An explanatory hypothesis was established for each observation. The next step was to contact possible groups of people at levels and with different roles within the company, attempting to cover all levels of hierarchy. In the spirit of investigation and reflection, and by utilizing the questions as an interaction framework, two (2) discussion groups were organized, together with six (6) individual interviews which allowed to verify the stated hypothesis. Starting from this analysis, a perception analysis for key executives and directors was proposed for the company, regarding a possible development and implementation of a Blockchain-based MVP, to comply with the proposed objective.

Ethics: Informed and voluntary participation was fostered for participants in the study; measures were taken to guarantee confidentiality and to validate information with interviewees. No implicit nor explicit attempt was made to influence in the answers neither change the individual features, freedom to participate or decline to participate was respected without pressuring or offering benefits to participants in exchange for being part of the investigation.

III. Results and Discussion

The proposed MVP includes the following architecture comprised by the corresponding components (Fig. 5):

Endorser Node (Peer): Node that receives from a client application a petition to invoke, and executes 2 functions:

- Transaction validation.
- Execute Chaincode.

After executing these functions, the node proceeds to approve or deny the attempt to invoke.

Orderer Node: Responsible for maintaining consistency throughout the Blockchain, is who creates the block and delivers it to all the network.

Couch DB: Is a non-relational database, which stores approved ledger transactions.

Certificator Provider: Node that provides the necessary certificates enabling the “Endorser Node” and “Clients” to participate.

Chain Code Client: Is who contains the business rules known as Chain Code and who invokes them afterwards for verification by the Blockchain network.

A. Practical application case

Design of a client application that interacts with a blockchain network, belonging to the Hyperledger Fabric project to be operated by the Agricultural Producer, Logistics Operator and Supermarket. The client contains a set of minimum and necessary functions that enables each of them to input the necessary data to generate sufficient traceability for 1 agriculture product: tomatoes.

It is worth mentioning that interaction with the Hyperledger Fabric Blockchain network can be performed through other means such as RFID (Radio Frequency Identification) and other IoT (Internet of Things) devices, which have lower operational costs but require more specialized technology, which are in general more expensive.

B. Tomato application

What is presented next is a description of the 3 most representative user histories, which have allowed to implement a consistent MVP in the Hyperledger Fabric Blockchain network and a mobile web client. The corresponding modelling considers 1 type of product (“tomatoes”), which is produced by 1 producer, distributed by 1 logistics operator and finally, disposed by 1 supermarket (Fig. 6).

Each stakeholder in this simplified supply chain interacts via mobile web app where each corresponding milestone is registered, which are reflected in the following data structure (Table 1).

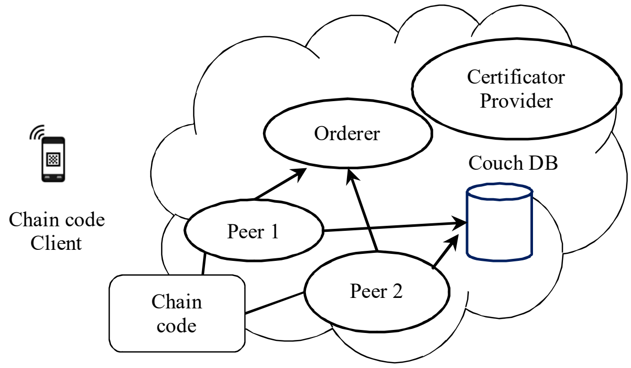

Fig. 5 Deployed architecture for use case.

User history 1: The producer has 200 kg of harvested tomatoes on March 12th, at the farm located in Limache. The relevant data to be entered in the App are:

- Position: latitude, longitude of the farm.
- Harvest date.
- Tomato maturity.
- Production weight.
- Paid/received price.
- Producer identification data.

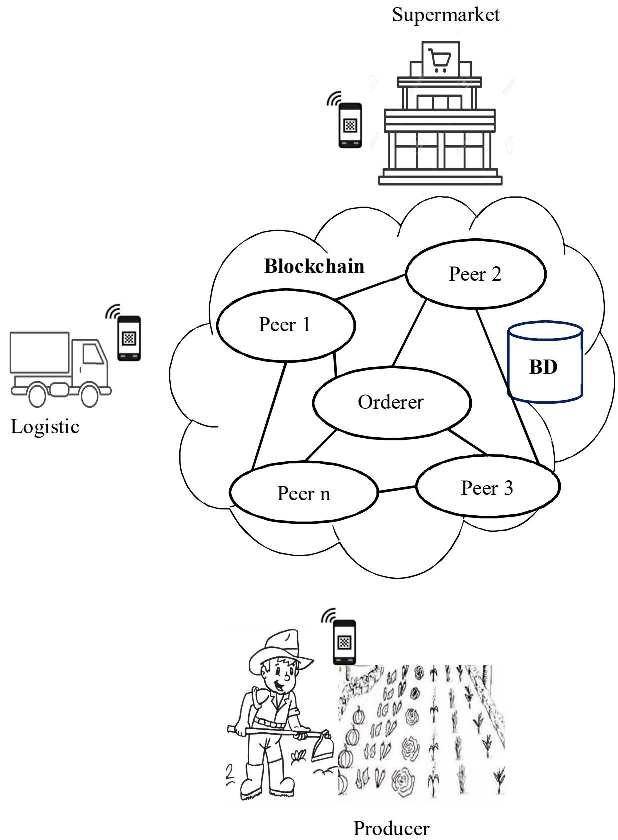

Fig. 6 Proposed Blockchain architecture.

User history 2: The logistics operator arrives at the tomato farm located at the coordinates (latitude, longitude) -33.0178,-71.3232), on March 15th of 2019 at 5:30 am, where the production is loaded and the mobile App registers the following data:

- position: latitude, longitude.
- date, time.

- production weight.
- holder: operator identification data.

User history 3: The supermarket receives the production and enters in the mobile App:

- Date.
- Weight.
- Supermarket position.

Regarding the necessary infrastructure to deploy the Blockchain network, container technology is required to permit visualization of the nodes in the network [19]. These nodes consist in Linux-type servers, that are specially provided by IBM to be used in Blockchain projects that utilize Hyperledger Fabric. The servers consist in 5 servers corresponding to:

- Certificator Provider: "a.example.com"
- Node 1: peer0.org1.example.com
- Node 2: peer1.org1.example.com
- Database engine (Couch DB).

TABLE I
MVP DATA MODEL

Product	
Product ID	string
Producer	string
Maturity	string
Unit Cost	integer
Unit Price	integer
Weight	float 32
description	string
Harvest date	date
Lattitude	float 32
Longitude	float 32
Holder	string

At the same time the commands, representatives, that allow to instantiate the platform result from using the Docker tool called "Docker Compose", which allows to execute multi-container applications.

An aspect worth highlighting in the operation by the final user is that consensus must be satisfied when uploading data to the cloud, a sine qua non condition prior annexation to the ledger. For instance, in the interaction between the producer and the logistics operator it is impossible for the positions of both at the moment of loading the production cargo on the truck to be different. This aspect confers a level of reliability to the product regarding fraud, and simplifies paperwork, which is prone to error. Moreover, the logistics operator and the supermarket are aware that the route is recorded in the ledger, impacting KPIs which, for example, measure carbon footprint. All data is agreed upon and entered incrementally, without the possibility of being altered arbitrarily.

Consumers have information on the history of the tomatoes they are about to consume, realizing their impact on the environment and of the subsequential decision of consuming or not this product.

C. *Discussion of results*

Based on the evidence obtained in Stage 1, characterization of the present and comprehension of reality, it is observed that all interviewees demonstrate sufficient understanding regarding their supply chains. There is coherence in their opinions, stating that organic waste creates discrepancies in estimating the final demand. However, when referring to organic waste management (non-commercialized merchandise products) different solutions start to appear or, failing that, it is disposed in landfills. Finally, on the consumer side, it has not been possible to confirm that consumers express an active concern for this issue.

This calls for reflection, and to address this gap we propose that the main stakeholders, supermarkets and consumers, must collaborate, share resources and efforts, to mitigate the generation of organic waste as a way to drive more sustainable practices, as studied in [20], which suggests taking an initiative involving all stakeholders in a supply chain to mitigate waste at all levels.

The high-impact proposal from Stage 2 shows that, although supermarket operators were relatively satisfied with their current organic waste management processes (non-commercialized merchandise products), they acknowledge the financial impacts, recognizing a real possibility in cost savings. This is coherent with the fact that approximately one third of global food production ends up as waste [21]. When questioned about Blockchain, interviewees were not up to date regarding the distribution and collaboration possibilities that the technology has to offer; however, after having been explained the benefits, the interviewees demonstrated interest in actively exploring the possibility of developing a project that explores this paradigm for a supermarket supply chain. It is exciting to have found a gap that provides space to initiate agile projects for solution development using Blockchain applied to organic merchandise.

Finally, regarding the findings from Stage 3, Alerts of Transformation, evidence shows that what triggered the most interest for supermarket operators was the possibility of having traceability with different suppliers, with whom they have contractual agreements. To a lesser degree of interest, operators mentioned that reliability and agility were relevant aspects and were welcome to have them.

Thus, the need to adopt this type of technology in Chile has been expressed, which contributes to improving the country image as to the commercialization of organic merchandise. A paradigmatic case that corroborates this point is the implementation at Walmart, United States, through the work proposed by Yiannas [22], stating that it is paradoxical, in a world where information is always accessible, that it cannot be traced, nor its reliability and integration be ensured (with respect to food products). Governments can contribute to generating favorable environments to encourage creating projects using Blockchain.

IV. CONCLUSIONS

This study shows that it is possible, through Blockchain technology, to provide a life-cycle traceability solution for perishable merchandise, particularly in the retail sector, contributing to the participation and trust of all stakeholders who are part of the supply chain. Indeed, the data shows that through a mobile app (RFID may have been used as an alternative or complement), it is possible to trace what is consumed without major issues. Intermediaries can proactively demonstrate their actions directly. And final consumers received this new experience positively. In other words, all stakeholders in the supply chain have high-quality, accurate information regarding expiration status, as well as its traceability, available at all times. This enables decisions (e.g.: purchases, discount application) to be more exact and, consequentially, to reduce unnecessary waste.

In this way, this proposal contributes to improving, with sufficient confidence, communication, not only from suppliers to supermarkets but also inversely, and from the last link in the supply chain: consumers. Improving the business profile to the eyes of current client requirements.

Proposing the following actions for the gaps found in the different stages: Promoting greater coordination in organic-waste management by supermarkets. Generating awareness plans in the population that illustrate the problem and its environmental consequences. Designing a digital product using Blockchain for a set of organic products, in order to provide traceability to consumers, on the origins of the merchandise, as well as in the opposite direction: to deliver visibility to the producers of what happens with their production. In addition, using resources such as marketing and user experience, we seek to align some economic results with the obtained digital design, to provide support from the economic point of view. Generating, by Governments, public policies that encourage retail chains to use technologies such as Blockchain, as well as to raise consumer awareness.

Finally, this type of proposal, in the short term, will allow to generalize throughout the entire spectrum of organic and perishable merchandise in a supermarket. This constitutes a challenge, and will require scaling-up, considering agility and agile methodologies. It will also require investigation and implementation of software architectures that allow to incorporate all the products, as well as the implementation at the Blockchain level (Hyperledger Fabric) the necessary channels that allow transparency, and in turn protect the different contracts that may have been created without affecting their privacy. On the other hand, from a governmental and regulatory standpoint, how to make the industry plausible to be audited by the State, using this technology, remains pending. The retail industry, using Blockchain, would achieve a level of transparency and joint coordination whose effects would spread both locally and regionally, and, why not, also globally. A last relevant aspect not addressed in this study is the relative energy consumption of the Blockchain infrastructure in general versus using a traditional solution.

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