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SIBRAAR - BRAZILIAN AGRO-TRACEABILITY SYSTEM

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ABSTRACT

The aim of this study is to implement a blockchain-based traceability system for monitoring sugarcane products produced by Granelli Mills. This system is designed to ensure data integrity and provide a reliable audit trail by leveraging the inherent immutability of blockchain technology. In cases where data tampering is suspected in the database, the blockchain can be accessed and compared to the database to identify any discrepancies. The system integrates traditional databases with blockchain technology, which serves as an effective method for storing the hash codes of blocks that contain brown sugar production data. These hash codes act as keys to access the corresponding production data stored on the blockchain. Each production batch is uniquely identified by a hash code that is generated and recorded on the blockchain. This hash code also forms part of a unique URL that allows consumers to access detailed product and production information for that specific batch. Granelli Mills uses this hash code to generate a QR code, which is printed on labels attached to packages of brown sugar and demerara sugar. The QR code simplifies access for consumers: by scanning it with a smartphone, they are directed to a web page displaying the relevant batch information. The Sibraar system serves as an effective example of how blockchain can be used to enhance traceability and transparency in supply chains.

Keywords: Blockchain; brown sugar; data immutability; data tampering; information security.

INTRODUCTION

Innovation has been a defining force in recent decades, driving continuous technological revolutions across various sectors — agriculture included. As the industry evolves, the importance of product reliability and quality has become paramount, especially for distribution on both national and international scales.

By leveraging innovative and secure network systems, it is now possible to track and record critical information seamlessly. These advancements enable real-time monitoring and negotiation of goods flow and payment management without depending on a centralized control system. This decentralized approach reduces transaction costs, minimizes losses, and simplifies complex interactions between agribusiness stakeholders.

Blockchain technology, in particular, offers a powerful solution for recording traceability data — including product origins, producer details, production sites, pesticide usage, and import/export records. Such transparency enhances insights into product sustainability and origin, ensuring greater accountability and consumer trust. The immutability of blockchain data significantly enhances product quality assurance and builds confidence among all parties involved, from producers to end consumers (SILVA *et al.*, 2019).

The origins of blockchain date back to 1990 when Stuart Haber and W. Scott Stornetta, working at Xerox, sought to address the vulnerability of digital documents. After discovering how easily files could be manipulated or deleted, they developed a method to encrypt data, making it virtually immutable and tamper-evident. Despite its early promise (HABER AND STORNETTA, 1990), blockchain remained relatively obscure until 2008, when Satoshi Nakamoto repurposed the technology in creating Bitcoin (NAKAMOTO, 2008).

This study presents the implementation of a blockchain-based traceability system for monitoring sugarcane products produced by Granelli Mills. The system is designed to ensure data integrity and provide a reliable audit trail by leveraging the inherent immutability of blockchain technology. Maintaining accurate and trustworthy information on product quality, production processes, and sugarcane origins is critical to meeting the expectations of both consumers and the broader retail market.

METHODS

Blockchain Technology

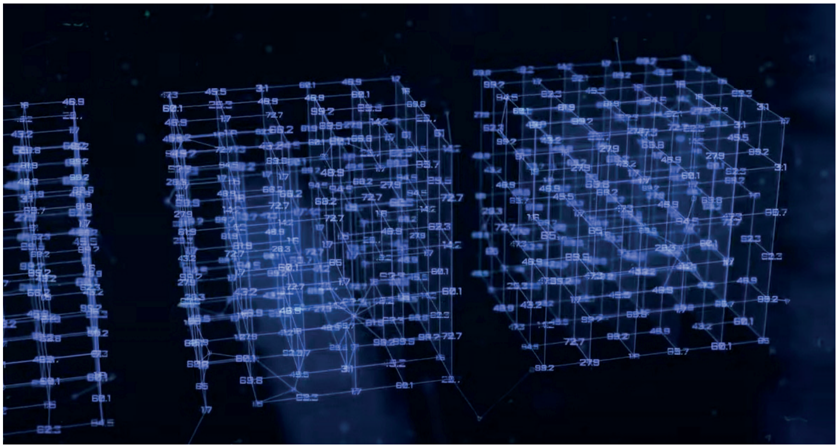
Blockchain is a technology consisting of interconnected blocks of data recorded sequentially, as illustrated in Figure 1. This technology, developed by HABER AND STORNETTA (1990), enables the identification of changes made to digital data, including text, audio, images, or videos. They implemented a chain of blocks to provide this identification, where each block contains not only data but also the hashcode of the previous block.

A hashcode is generated by a cryptographic algorithm that transforms any block of data, regardless of its size, into a fixed-length series of characters. Its primary function is to ensure data integrity, as any alteration to the data block results in a change to the hashcode. Consequently, if any data is modified, the cryptographic algorithm will generate a new hashcode that differs from the original.

Since each block contains the hashcode of the preceding block, a potential hacker attempting to tamper with data in a specific block would need to modify the hashcodes of all subsequent blocks. This is because the content of each block comprises the current data along with the hashcode of the previous block. This interconnected structure makes it practically impossible to alter data once it has been recorded on the blockchain, effectively rendering the recorded data immutable.

NAKAMOTO (2008) leveraged the immutability of blockchain technology in the implementation of Bitcoin. However, this characteristic is also highly valuable for a wide range of other applications, including healthcare, supply chain management, goods and asset traceability, e-commerce, and more.

Figure 1 – Blockchain.



Source: Adapted from Souza, 2021.[1]

In Ethereum blockchain networks, the implementation of applications relies on smart contracts. These are event-driven computer programs that autonomously respond to events based on a set of pre-defined rules, without any human intervention. This characteristic is what makes them appear intelligent. Additionally, smart contracts serve the purpose of storing data, which causes blockchain and smart contracts to resemble distributed databases (TSENG *et al.*, 2020). However, they lack certain database functionalities, such as concurrent access control, backup and restore tools, and referential integrity, among other features.

Brazilian Agro-Traceability System (Sibraar)

The core feature of the Brazilian Agro-Traceability System (Sibraar) is its use of blockchain technology to ensure data immutability. The system is structured around three main processes: Upload, Write Blockchain, and Web Application. These processes are illustrated in the Data Flow Diagram in Figure 2. The following paragraphs explain each process in detail.

[1] https://www.youtube.com/watch?v=dkElPTevoR4

The data flow begins with the Upload procedure, in which Granelli Mills uploads data about a newly produced batch of brown sugar to the system's database. Next, in the Write Blockchain procedure, the batch data is recorded on the blockchain using a simple, generic smart contract. During this process, the blockchain automatically generates a unique hash code—a 64-byte representation that serves as a compressed digital fingerprint of the block's contents. This hash code is also stored in the system database.

After the data is recorded, the system generates a unique URL for the batch. This URL includes a fixed component (the website domain) and a variable component (the blockchain-generated hash code).

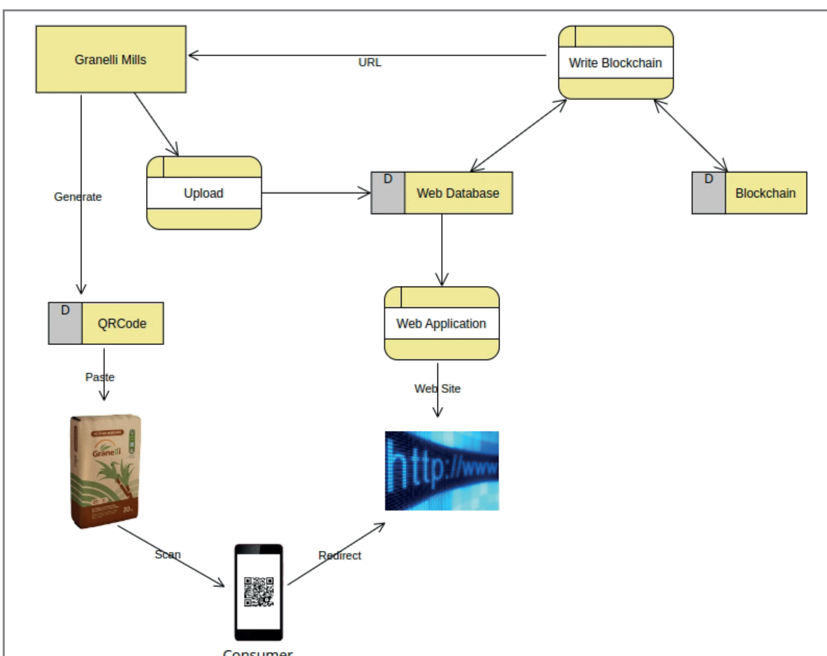
The final process, Web Application, allows users to access the data by visiting the URL generated in the previous step. Granelli Mills also receives this URL and uses it to generate a QR code. This QR code is printed on product labels and affixed to the brown sugar packages.

The data flow concludes when consumers scan the QR code on the package using a smartphone. This directs them to the product's dedicated webpage, where they can view detailed information about the specific batch. Because the data is recorded on an immutable blockchain, any tampering of the database can be detected by comparing it with the original blockchain record—ensuring transparency, trust, and product integrity.

Whenever there is suspicion of data tampering in the Web Database (Figure 2), it is sufficient to access the blockchain and compare the two to identify any discrepancies. The integration of databases with blockchain technology has already been implemented in various applications (CELESTI *et al.*, 2020; ABHIJITH *et al.*, 2021). This integration is justified as it provides an effective method for storing the hash codes of blocks that contain production data for brown sugar batches. Since hash codes cannot be accessed through a smart contract, a database is essential for their storage. Any application based on a smart contract will require access to a database to store these hash codes, leading to the necessity of two data reading operations, which can burden the system and negatively impact performance. Additionally, using a database to make data available online offers advantages in managing transaction interruptions, such as sudden power outages. Databases feature mechanisms like COMMIT and ROLLBACK, along with referential integrity, which make them less susceptible to data corruption compared to blockchain databases, especially in the event of system crashes.

A generic smart contract allows for system customization across different production chains. The Write Blockchain procedure utilizes Application Program Interfaces (APIs), meaning it does not require modification for each new product or industry. Instead, it is only necessary to adapt the APIs that facilitate data transfer to the recording process on the blockchain and the web application responsible for making the data accessible online. The APIs and this system architecture allow users to choose the type and manufacturer of the database. In this work, MongoDB, a NoSQL database, was the choice. Because it is a semi-structured database allows the inclusion of new data fields without the need to carry out any maintenance in the database, being, therefore, more flexible. Thus, in the future, if Granelli Mills wishes to enter a new data field. Such as the name of the sugarcane producer. This new data inclusion will not interrupt the operation and availability of the system.

Figure 2 - Sibraar's Data Flow Diagram.

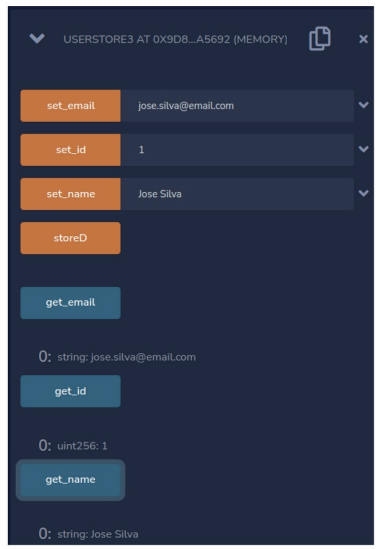


Source: Authors themselves.

Smart contracts incur computational costs, meaning that more complex applications require more weis (a smaller fraction of ether). Programmers should take this into account and aim to create smaller applications. Figure 3 illustrates two applications that record the same data. The left screen displays a compact application with aggregated data (a), while the right screen shows an application that records the same data organized by field (b).

Figure 3 - Example of applications, with aggregated data (a) and with data separated by field (b).

(a)



(b)

Source: Authors themselves.

While data organized by field is more appropriate for responding to queries on a website than aggregated data, it is important to consider the transaction cost differences in blockchain systems. The variations in compilation costs are highlighted in yellow in Table 1:

Table 1 - Compilation costs aggregated data and data separated by field.

Aggregated Data	Data Separated by Field
{ "Creation": { "codeDepositCost": "258200", "executionCost": "300", "totalCost": "258500" }, "External": { "data()": "infinite", "get()": "infinite", "set(string)": "infinite" } }	{ "Creation": { "codeDepositCost": "370800", "executionCost": "405", "totalCost": "371205" }, "External": { "get_email()": "infinite", "get_id()": "1079", "get_name()": "infinite", "set_email(string)": "infinite", "set_id(uint256)": "20264", "set_name(string)": "infinite", "storeD()": "infinite" } }

Source: Authors themselves.

The cost difference in recording transactions can be noticed by looking at Tables 2 and 3, highlighted in yellow:

Table 2 - Write Transaction Data with Aggregate Data.

status	true Transaction mined and execution succeed
transaction hash	0xd4cca684cfe71b878d9106e1a28efddb712376c7df8f1a2f1bff15ba27164d6c
from	0x5B38Da6a701c568545dCfcB03FcB875f56beddC4
to	SimpleStorage.set(string) 0xD7ACd2a9FD159E69Bb102A1ca21C9a3e3A5F771B
gas	105717 gas
input	0x4ed...00000
decoded input	{ "string _data": "1, Jose Silva, jose.silva@email.com" }
decoded output	-
logs	[{ "from": "0xD7ACd2a9FD159E69Bb102A1ca21C9a3e3A5F771B", "topic": "0xd9f-cb1e086b52ae76f593cda3b41303ed8056c6bcb77add9407da44cd11d18da", "event": "stData", "args": { "0": "0x5B38Da6a701c568545dCfcB03FcB875f56beddC4", "1": "1, Jose Silva, jose.silva@email.com", "_from": "0x5B38Da6a701c568545dCfcB03FcB-875f56beddC4", "storeD": "1, Jose Silva, jose.silva@email.com" } }]
val	0 wei

Source: Authors themselves.

Table 3 - Write Transaction Data with Field Separated Data.

status	true Transaction mined and execution succeed
transaction hash	0x838c7912a95600446c0067d9e160a243cf4f94f3f6114c1a30dc7f3a2e168785
from	0x5B38Da6a701c568545dCfcB03FcB875f56beddC4
to	UserStore3.storeD() 0x9d83e140330758a8fFD07F8Bd73e86ebcA8a5692
gas	36031 gas
input	0xeaa...4f986
decoded input	{}
decoded output	-
logs	[{ "from": "0x9d83e140330758a8fFD07F8Bd73e86ebcA8a5692", "topic": "0x8d-43d26f48b1feccd7a56659072d03a05a69eb7a33736ce631f15d7a3330e993", "event": "usData", "args": { "0": "0x5B38Da6a701c568545dCfcB03FcB875f56beddC4", "1": "1", "2": "Jose Silva", "3": "jose.silva@email.com", "_from": "0x5B38Da6a701c568545d-CfcB03FcB875f56beddC4", "_id": "1", "_name": "Jose Silva", "_email": "jose.silva@ email.com" } }]
val	0 wei

Source: Authors themselves.

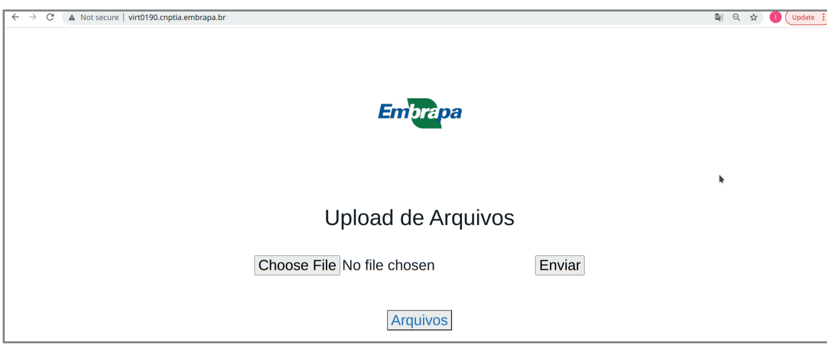
Blockchain is well-suited for decentralized and distributed applications; however, it does not support complex applications effectively. As a result, programmers must be mindful of both the cost associated with smart contract applications and the maximum code size for smart contracts.Unlike database applications, there is no limit on code size. Therefore, by using a database to store data organized by field alongside a simple and generic smart contract for registration and auditing, it becomes feasible to manage complex supply chains, such as those in the meat industry, which involve stages like breeding, rearing, fattening, slaughtering, and marketing. A solution that attempts to embed all business rules within a single smart contract would require breaking down that complexity into several smaller smart contracts. This highly complex application would incur significant computational costs, leading to increased electricity consumption and raising concerns about sustainability.

RESULTS

Sibraar is an auditable traceability system that leverages blockchain technology to ensure data integrity. The system stores production data for manufacturing batches in both a traditional database and on the blockchain. In cases where data tampering is suspected—such as the omission of a farm involved in illegal deforestation—the corresponding blockchain record can be consulted to verify whether any discrepancies exist. Figure 4 shows the upload page used by Granelli Mills to input production batch data into the system.

Each production batch is uniquely identified by a hash code generated and recorded on the blockchain. This hash code forms part of a unique URL that consumers can use to access detailed product and production information for that specific batch. Granelli Mills uses this hash code to generate a QR code, which is printed on labels affixed to packages of brown sugar and demerara sugar. The QR code simplifies access for consumers: by simply scanning it with a smartphone, they are directed to the product's web page containing the batch data (as shown in Figure 5).

Figura 4 - Upload Page for Granelli Mills.



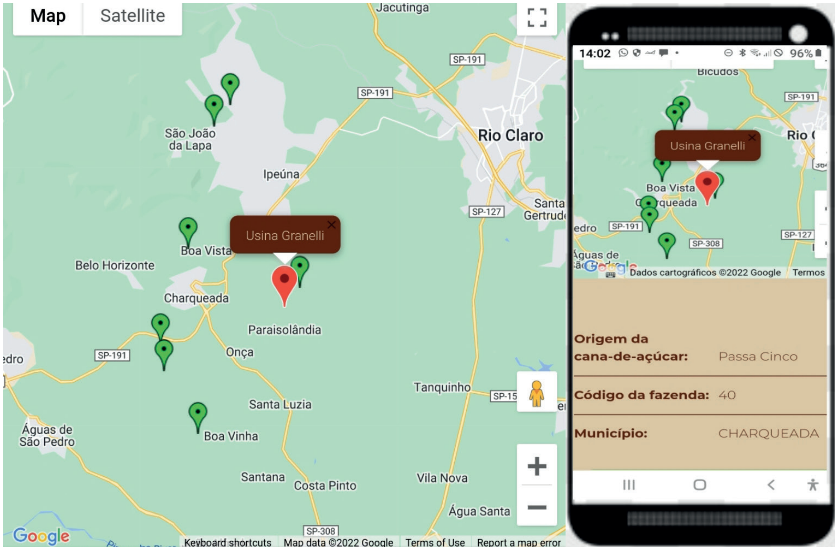
Source: Authors themselves.

Figura 5 - Granelli Mills Brown's Sugar Web Page.

Source: Authors themselves.

In addition to the product data, it is possible to consult various production batch data, such as information about the quality of the product (sugar Brown), such as color, humidity, and absence of contaminants. It is also possible to consult the chemical composition, nutritional information, target audience, and raw material origin (Figure 6). Figure 6 shows the sugarcane farms, identified by green pins, that supplied sugarcane for the batches specified on the brown or demerara sugar packages. Still, in Figure 6, Granelli Mills appears on the map highlighted with the red color pin. Through this map, consumers could know that sugarcane did not originate in areas of recent deforestation, mainly in the Amazon rainforest.

Figura 6 - Sugarcane Traceability Screen.



Source: Authors themselves.

CONCLUSION

This work introduces Sibraar, an agro-traceability system designed to track Granelli Mills' brown sugar. The system utilizes blockchain technology solely for audit purposes, as storing hashcodes in a dedicated database is always necessary. Using this database for the web application reduces computational costs and enhances sustainability.

To mitigate the risk of data tampering in web databases, it is crucial to record data in the blockchain and saving their corresponding hashcodes. These hashcodes enable the verification of data integrity during future queries because they are essential for accessing the immutable information stored within blockchain blocks, making blockchain ideal for audit processes.

In Sibraar, the smart contract generically stores all aggregated data from production batches, irrespective of content or volume. This operation simply records batch data without imposing specific structural formats. For integration with the web application, a web database was employed because the data needs to be organized in a tabular format (such as vectors or matrices) to ensure the proper placement of each field on the webpage.

Integrating blockchain technology with a web database simplifies smart contracts and mitigates the risk of elevated computational costs. This advantage is demonstrably apparent during compilation and blockchain update transactions, ultimately contributing to lower data processing requirements and reduced electricity consumption.

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