Storing Data of Sugarcane Industry Processes Using Blockchain Technology

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Advances in information and communication technology (ICTs) have reduced physical, political and cultural barriers among nations. Furnished with equipment and sensors, and without connection limit, world population exercises globally its power of choice, creating reality out of Big Data, where high data and information volume on tendencies and demands reflect, among other features, cultural and psycho-social manifestations. Organizations involved with science and technological innovation are increasingly being required to invest heavily in tools and processes that support forecasting technological needs and on future demands on goods and services— which are more and more diffuse and dynamic — is essential for research and innovation organizations. This document describes specifically an agricultural industry context that is marked by the age of Big Data, generating high data volume that needs to be organized, stored and processed for generating knowledge, more specifically, this work deals with storing data of sugarcane processes using blockchain technology for control processes and tracking purposes. This work presents a prototype of the use of blockchain within the scope of a government project developed between the Embrapa - Brazilian Agricultural Research Corporation, and the Coplacana - Sugarcane Planters Cooperative located in the state of São Paulo, Brazil.

Palavras-chave: Ethereum platform, Sugar and Alcohol Production, Renovabio, Tracking System

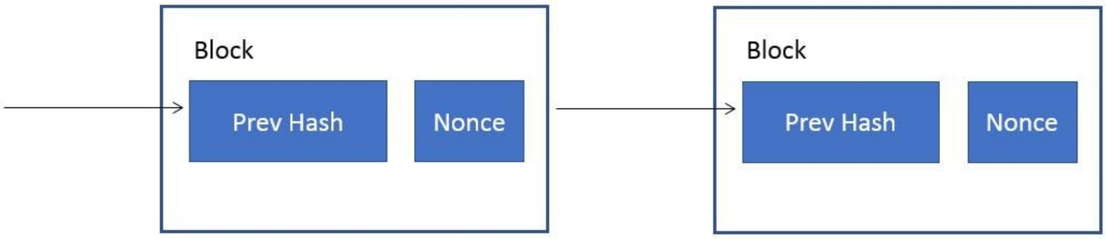
1. Introduction

The world now lives the age of Big Data, when it is possible to generate, collect and store overwhelming amounts of data, the raw material of knowledge. A plethora of emerging technologies help organizations to create value from large data sets, which allow for, e. g., inferring behavior and consumption patterns, and individually adjusting design and logistics for products and service delivery, with huge benefits in operational and economic efficiency. Looking forward, private sectors will use Big Data to multiply access to services and goods. The public sector will use Big Data for supporting formulation, improvement and implementation of public policies in sensitive areas such as medicine, public health, food production, and environment. In agriculture, the age of Big Data will impact genetic improvement, weather forecasting, precision agriculture, knowledge on market dynamics, among others (EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA, 2014). In agribusiness, the reality of Big Data, associated with new technologies such as blockchain, may facilitate distributed registers of agricultural product tracking operations, and commodities transactions, aiming at decentralization as a security measure.

Blockchains are distributed and shared records and databases, and their function is to create a global index of all transactions occurring in a given market. This technology is behind cryptocurrencies such as bitcoin, ether, ripple, among others, but their usage as transaction conduits goes even further. By conception and design, it is a technology that allows—and asks—for the setting of cooperative partnerships in a participating network, in one or more markets, or even in different locations.

The current forms of blockchain are based on the works of NAKAMOTO (2008), a “reclusive” scientist who expanded and made public the current concept of cryptocurrency. According to this definition, data blocks are responsible to carry information between a buyer and a seller during financial transactions in a manner available for everyone, much like a cash book. The pieces of information in this book are called blocks, and their set is called blockchain. Such transactions are validated by digital signatures, then the data set goes through a hash generating function, and the sequence created is inserted in the next block (Figure 1).

Figure 1 - Blockchain representation



Source: adapted from NAKAMOTO (2008)

Data validation, specifically for cryptocurrencies, presents another step called Proof-of-work (PoW). PoW was created by DWORK and NAOR (1992) as a way to avoid email spamming. Although it consists of requesting a task that has high computational cost it is easy to verify.

Bitcoin PoW means inserting zeros at the hash start, based on the inclusion of a certain number called "nonce" at the block end. When the "nonce" is changed, the whole hash is changed. By trial and error, various numbers are tested until the amount of zeros specified for the hash start is obtained. The PoW solution authorizes the creation of a new block. As a reward, the person who accomplishes the proof-of-work receives a definite set of cryptocurrency.

Currently, using blockchain technology goes beyond cryptocurrency; it is used in public infrastructures (NOMURA RESEARCH INSTITUTE, 2016), election processes (HEGADEKATTI, 2017) and safety food chains (KAMATH, 2018). Blockchain reduces transaction costs and complexity between companies by creating efficient and highly secure networks, in which practically any value can be monitored and traded, without depending on a central control point. In finance, the use of blockchain networks improves compliance and transaction security reducing time and cost. In commerce, such networks can facilitate supply chain management and allow for commodity and payment flows to be tracked and recorded in real-time.

This work presents a prototype of the use of blockchain technology to store data of the sugarcane industry for control processes, supply chain management and, tracking purposes. This was done within the scope of a government project developed between the Embrapa - Brazilian Agricultural Research Corporation, a state-owned research corporation affiliated with the Brazilian Ministry of Agriculture, and the Coplacana - Sugarcane Planters Cooperative located in the state of São Paulo, Brazil (SEI-Embrapa 21184.001539/2019-63).

2. Materials and Methods

This technical communication presents the implementation of a blockchain-based system for the sugarcane processing industry. This proposition uses the Ethereum platform (ETHEREUM PROJECT, 2019); the code was developed at Remix integrated development environment (REMIX, 2019), which allows for the assemblage of transactions through Solidity programming language. In Ethereum platform, the chained blocks carry a certain content along with a digital hash signature, so that the next block always contains the previous block's hash function and its content, and thus generates its hash:

Block 1 = content = hash 0

Block 2 = content + hash 0 = hash 1

Block 3 = content + hash 1 = hash 2

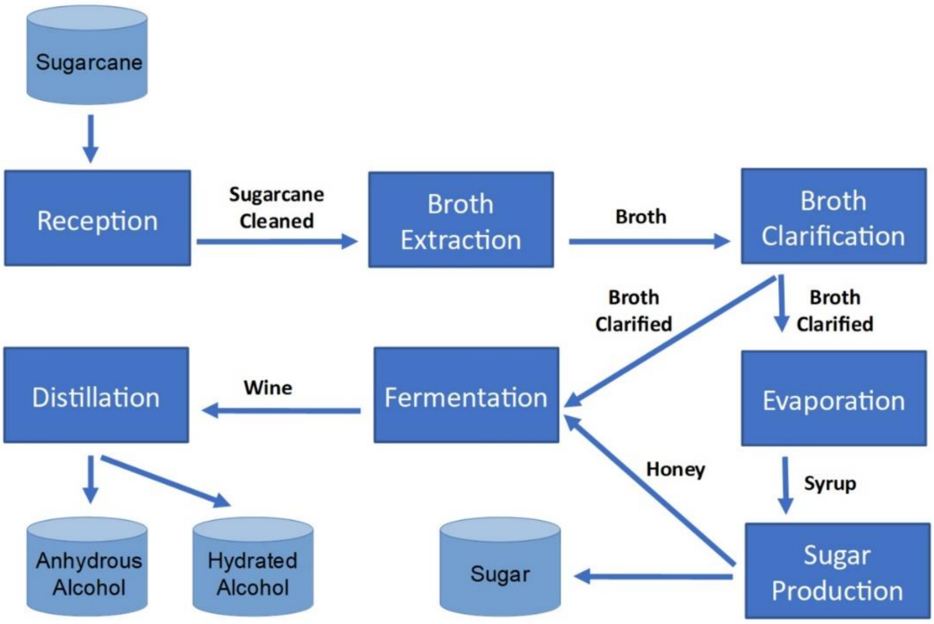
All block information is written and recorded in a ledger and, once written, cannot be erased. Eventually, in case any content in the block is changed, the hash function will also be changed. It is important to highlight that, in a standard blockchain, there are mining knots composed by parties that check whether the written block is valid. Every time a participant validates a block, it receives a reward in the platform's digital currency; in the case of Ethereum, the currency is ether. This reward is the payment for the processing cost of mathematical calculations that ensure the block cryptographic hash is valid. However, validation could be carried out by a system hosted in a government infrastructure that does not requires rewards of any kind for validating and storing transactions.

The code (contract) is stored in the blockchain and is executed as part of each transaction, where each stored data is a cryptographic hash function, a mathematical function considered impossible to reverse, that is, of recreating its input value from its output value. For cryptographic security, Ethereum uses the Secure Hash Algorithm V. 3 (SHA3) function instead of the SHA-2 cipher standard.

The purpose of this work is to demonstrate the use of blockchain to store data about the steps involved with the sugarcane processing in sugar and alcohol mills. The data stored can be used for knowledge generation about controlling processes for cost reduction, supply chain management and, improvements in sugar and alcohol qualities. Figure 2 shows the flowchart of the sugarcane processing industry, which is divided into seven main steps, in a manner that permits observing the inputs and outputs of each process.

The process starts with the sugarcane Reception procedure, in which the sugarcane is weighted and washed. The result is the sugarcane cleaned which passes through the Broth Extraction procedure. Once the broth has been extracted, it is sieved, chemically treated, heated, decanted and filtered in the Clarification procedure. In the next step (Evaporation procedure), part of the broth clarified is evaporated to make a syrup. The syrup undergoes cooking, crystallization, centrifugation and drying in the Sugar Production procedure to produce sugar and honey. The honey and part of the broth clarified go through the Fermentation procedure to produce wine[1]. Finally, in the Distillation procedure, the wine is distilled to produce hydrated and anhydrous alcohol.

Figure 2 - Sugarcane Processing Flowchart

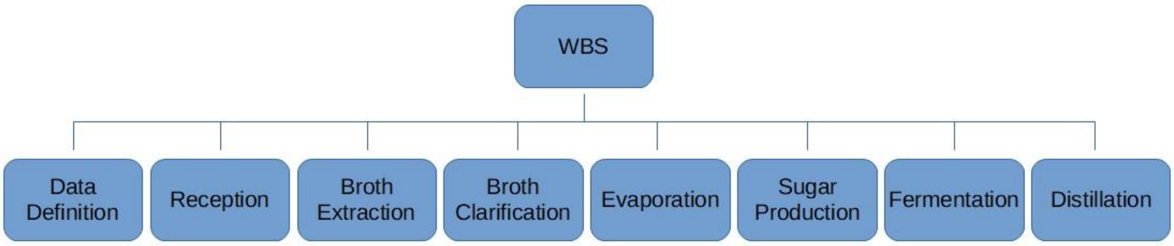


Source: Adapted from DAL BEM et al. (2003).

The blockchain is a distributed database that can be used in various applications using smart contracts. Smart contracts (BUTERIN, 2014) are computer programs which control digital currencies and assets according to the application rules in blockchain technology. In this work, a smart contract store and track data about sugarcane lots processed in sugar and alcohol production. The smart contract is represented by the Work Breakdown Structure (WBS) (HAUGAN, 2001) in Figure 3.

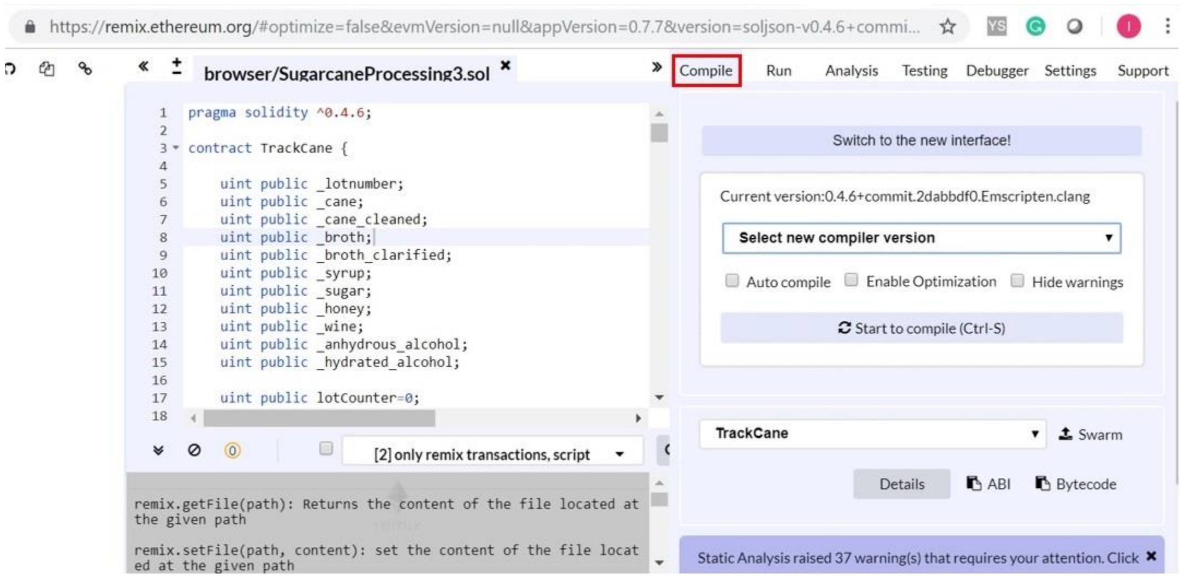
[1] Sugarcane wine (RAVANELI, 2011) is the sugarcane fermented must (ALCARDE et al., 2003).

Figure 3 - WBS of the Sugarcane Processing Smart Contract



The smart contract named TrackCane, written in Solidity language version 0.4.6., was deployed at Remix IDE[2]. Figure 4 shows the Remix IDE interface at the Compile tab, just for illustration.

Figure 4 - TrackCane Smart Contract at Remix IDE



Except for the Data Definition procedure, all the other procedures are the same as the seven processes used for sugarcane processing. The Data Definition procedure is a section in the smart contract used to declare and set values to variables (Figure 5) and structures[3] (Figure 6). In this work, the smart contract receives all input data into variables, before storing them in the structure. The use of a structure facilitates to map and retrieve information just using the sugarcane lot number.

[2] Details about the use of Remix IDE (REMIX, 2019) can be found at YANO et al. (2018).

[3] Structures are sets of variables which can be of different data types under a single name (SIMON, 2017).

Figure 5 shows eleven variables defined to store production data in the smart contract, from lines 5 to 15. Each variable has a function to set its value. The setlotnumber function is an example of these functions, from lines 20 to 25. It sets the lot number to the lotnumber variable. Thus, there are another ten functions like that, and all these functions have a corresponding button provided by Remix IDE on the Run tab after smart contract deployment (Figure 8). Figure 6 shows the structure of the data to be stored, from lines 41 to 54, and the mapping command for its association to the sugarcane lot number for retrieving purpose.

Figure 5 - Part of Data Definition procedure in the smart contract

```
trackcane.sol
1  pragma solidity ^0.4.6;
2
3  contract TrackCane {
4
5      uint public _lotnumber;
6      uint public _cane;
7      uint public _cane_cleaned;
8      uint public _broth;
9      uint public _broth_clarified;
10     uint public _syrup;
11     uint public _sugar;
12     uint public _honey;
13     uint public _wine;
14     uint public _anhydrous_alcohol;
15     uint public _hydrated_alcohol;
16
17     uint public lotCounter=0;
18     bytes32 newKey;
19
20     function setlotnumber(uint slotnum) public returns(uint) {
21
22         _lotnumber = slotnum;
23
24         return _lotnumber;
25     }
```

The other seven procedures effectively store the data into the structure. Figure 7 presents the commands executed by the Reception procedure:

1) from line 77 to 79 do a verification if the lotnumber, cane and cane_cleaned were inserted;

2) line 81 increments a lot counter;

3) line 82 creates a unique key (canekey) which will be mapped to a lotnumber used to retrieve the data stored;
4) from line 83 to 86 stores the msg.sender, i.e., the user responsible for this operation (active account in Figure 8), lotnumber, cane and cane_cleaned indexed by the canekey;
5) line 87 maps the lotnumber to the canekey;
6) line 88 maps the lotnumber to the lot counter (lotc) to facilitate find the lotnumber if the user forgets it;
7) line 73 and 89 the purpose of these lines are the declaration and execution of the event command (SOLIDITY READ THE DOCS, 2019). This command saves the stored data also into the transaction for tracking information and security reasons.

Figure 6 - Structure of the data stored in the smart contract.

```
    struct CaneReceived {
        address sender;
        uint lotnumber;
        uint cane;
        uint cane_cleaned;
        uint broth;
        uint broth_clarified;
        uint syrup;
        uint sugar;
        uint honey;
        uint wine;
        uint anhydrous_alcohol;
        uint hydrated_alcohol;
    }


    mapping(bytes32 => CaneReceived) public caneReceived;

```

The whole smart contract (trackcane.sol) can be downloaded from https://github.com/ihyano/trackcane.git (e.g.: git clone https://github.com/ihyano/trackcane.git).

Figure 7 - Reception procedure code

```
    event LogCaneReceived(address sender, uint lotnumber, uint cane, uint cane_cleaned);

    function Reception () public returns(bool success) {
        //if(msg.value==0) throw;
        if(_lotnumber==0) throw;
        if(_cane==0) throw;
        if(_cane_cleaned==0) throw;
        // make a unique key ...
        lotCounter = lotCounter + 1;
        newKey = sha3(msg.sender, lotCounter);
        caneReceived[newKey].sender = msg.sender;
        caneReceived[newKey].lotnumber = _lotnumber;
        caneReceived[newKey].cane = _cane;
        caneReceived[newKey].cane_cleaned = _cane_cleaned;
        lotn[_lotnumber].caneKey = newKey;
        lotc[lotCounter].lotNumCount = _lotnumber;
        LogCaneReceived(msg.sender, _lotnumber, _cane, _cane_cleaned);

        return true;
    }
```

3. Results

After compiled the smart contract can be deployed and used to store the data about sugarcane processing for sugar and alcohol production, using the Run tab (Figure 8). The Remix IDE provides five accounts for smart contract testing. The active account will be the user responsible for the operation (msg.sender). The Remix IDE also provides a button for each function for interaction with the smart contract (Figures 9, 10 and 11).

The simulation of the TrackCane Smart Contract starts with the Reception procedure, which depends on three variables: lotnumber, cane (sugarcane received) and cane_cleaned (the result of the washing process). The setlotnumber function sets the lotnumber (Figure 9), so as for setcane and setcane_cleaned functions to set the cane and the cane_cleaned, respectively (Figure 11). Figure 9 shows an example for insert the lot number 329, just clicking in the setlotnumber button.

After input the value 10 for cane and 9 for the cane_cleaned using setcane and setcane_cleaned buttons respectively (Figure 11). The Reception procedure can be executed, by clicking in the Reception button (Figure 10).

The Remix execution report of the Reception procedure shows the information about the status, hash, transaction fees (blockchain mining) and the stored data. Table 1 is a copy of the Reception procedure execution result presented by the Remix IDE.

Figure 8 - Run tab at Remix IDE, which provide five testing accounts

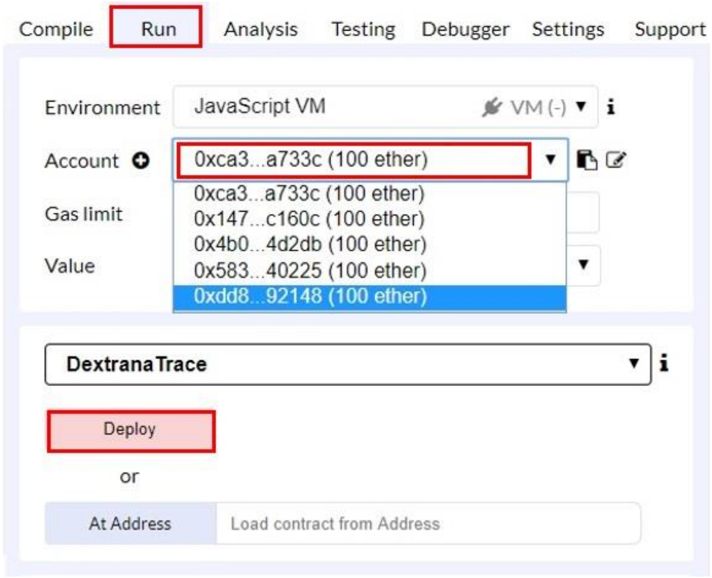


Figure 9 - Setting the lot number by setlotnumber function

Figure 10 - Reception Button

To complete the data about the sugarcane lot, the user has to perform the procedures BrothExtraction, BrothClarification, Evaporation, SugarProdution, Fermentation, and Distillation. Table 2 and Figure 11 show which data will be stored in which procedure of the smart contract. The same color-coded procedures (Table 2) and buttons (Figure 11) were used to highlight which functions record which data. The msg.sender and the lotnumber are included in all procedures because, since the steps of sugarcane processing occur at different times, this information is necessary to address the correct data to the correct lot.

Table 1 - Remix execution report of the Reception procedure

status	0x1 Transaction mined and execution succeed
transaction hash	0xc29f2636dbb438ec2d6f80cf04a2284fa121bfffc370004556e840c58f08da79
from	0xca35b7d915458ef540ade6068dfe2f44e8fa733c
to	TrackCane.Reception() 0x692a70d2e424a56d2c6c27aa97d1a86395877b3a
gas	3000000 gas
transaction cost	188464 gas
execution cost	167192 gas
hash	0xc29f2636dbb438ec2d6f80cf04a2284fa121bfffc370004556e840c58f08da79
input	0x24e...0460f
decoded input	{}

decoded output	{
	"0": "bool: success true"
	}

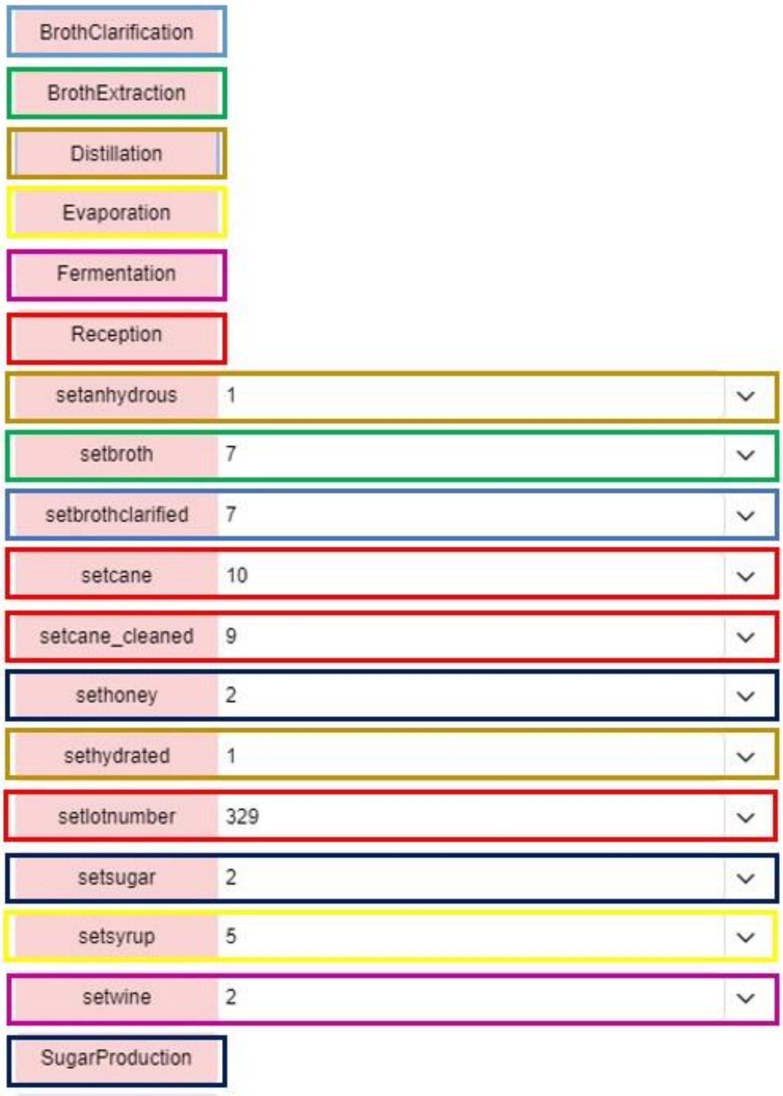
logs	[
	{
	"from": "0x692a70d2e424a56d2c6c27aa97d1a86395877b3a",
	"topic":
	"0x179f5abcfafed427b440b0c4a35f5f9a50417dbc8f675357696c62b1387728f8",
	"event": "LogCaneReceived",
	"args": {
	"0": "0xCA35b7d915458EF540aDe6068dFe2F44E8fa733c",
	"1": "329",
	"2": "10",
	"3": "9",
	"sender": "0xCA35b7d915458EF540aDe6068dFe2F44E8fa733c",
	"lotnumber": "329",
	"cane": "10",
	"cane_cleaned": "9",
	"length": 4
	}
	}
	]

value	0 wei

Table 2 - Procedure and Respective Input Data

Procedure	Input Data
Reception	msg.sender, lotnumber, cane, cane_cleaned
BrothExtraction	msg.sender, lotnumber, broth
BrothClarification	msg.sender, lotnumber, brothclarified
Evaporation	msg.sender, lotnumber, syrup
SugarProduction	msg.sender, lotnumber, sugar, honey
Fermentation	msg.sender, lotnumber, wine
Distillation	msg.sender, lotnumber, anhydrous_alcohol, hydrated_alcohol

Figure 11 - Input data and corresponding execution procedure highlighted by color code (red for Reception, green for BrothExtraction, light blue for BrothClarification, yellow for Evaporation, dark blue for SugarProduction, lilac for Fermentation and brown for Distillation).



All the data about the sugarcane lot will be stored at the CaneReceived struct. This data can be retrieved by a unique key (caneKey). The caneKey in its turn can be obtained using the lotnumber and the lotn mapping (Figure 12). Figure 13 shows the CaneReceived struct retrieved using the caneKey at the Remix IDE.

Figure 12 - caneKey obtained using lot number

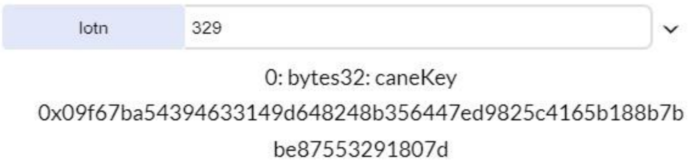
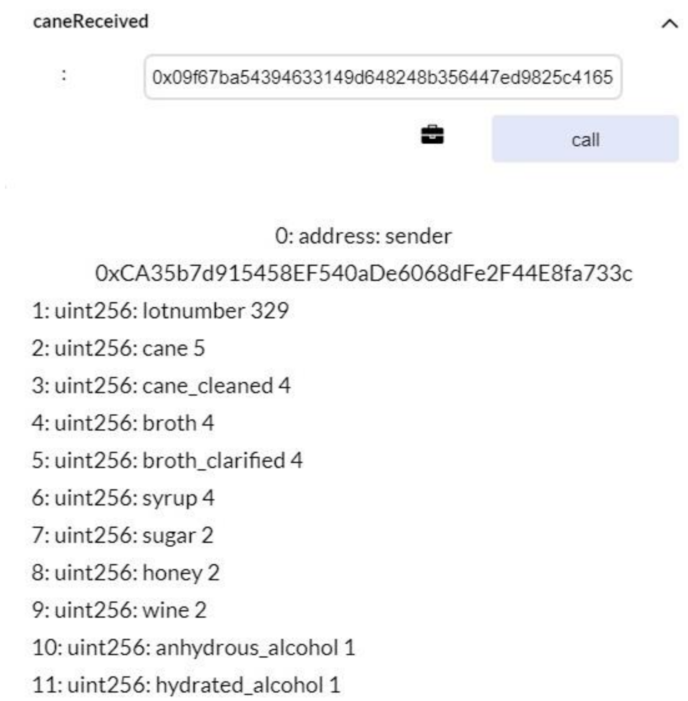


Figure 13 - Information about lot 329 retrieved by canakey



4. Discussion and Conclusion

This work presented a prototype of the use of blockchain to store and track information about sugarcane processing lots in sugar and alcohol production only in the mill environment. The adoption of this technology should be useful for this kind of application, in which the processing steps and the information about them occur at different times.

This proposal was based only on industrial processing because it is the core of the sugarcane production chain. The information stored in the blockchain can be used for continuous improvements in the sugar and alcohol manufacturer processes, supply chain management and, tracking system. This information system will be especially useful to enable plants to enter the Renovabio program.

The Renovabio is a Brazilian government´s program created to decrease carbon emissions from fossil fuels by enhancing the production of renewable biofuels (ethanol, biodiesel, biomethane, and biokerosene). Renovabio introduced a system of tradeable carbon savings credits (CBios) based on California's Low Carbon Intensity Program as an incentive payment for biofuels production (OECD iLibrary, 2020).

As a continuation of the Embrapa-Coplacana project, to put a blockchain of traceability into practice, Usina Granelli Ltda will be the first Coplacana´s member to implement the commercial version of the blockchain tracking system, which will be developed by the Safe Trace company. Similar to the system presented in this work, this new commercial version system will store data collected from the sugarcane field, passing through the broth extraction, treatments, fermentation, and distillation in the agro-industrial units (CANAONLINE, 2020).

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