VOL. 05 NO. 9,
AUGUST, 2024
E-ISSN 3026-958X
P-ISSN 3027-1169

African Scholar Publications & Research International
www.africanscholarpub.com

Journal of Science Innovation & Technology Research (JSITR)

Implementing a Traceability Model for Agricultural Supply Chain using Ethereum Blockchain Technology.

Adewoye Munir Adeniyi[a]; & Suleiman Salihu Jauro[b]

[a] *Department of Computer Science, School of Secondary Education (Science)Federal College of Education (Technical), Gombe, Nigeria.* [b] *Department of Computer Science, Faculty of Science, Gombe State University, Gombe, Nigeria*

Corresponding Author: *ademunir@fcetgombe.edu.ng*, *ssjauro@yahoo.com*.

Abstract

The world's population depends heavily on the agricultural sector for its sustenance. However, its supply chain's efficiency, security, and transparency are becoming more and more of a problem, lack of price transparency contribute to hike in commodity price by different factors. This research uses Ethereum Blockchain technology to implement a well traceability system in order to address these concerns. The study makes use of the Remix Integrated Development Environment (IDE) and Solidity smart contracts to build an unchangeable and transparent ledger of the completely agricultural supply chain. Smart contracts represent various actors, like seed vendors, distributors, farmers, retailers, and consumers, facilitating safe and transparent data recording. The research has many advantages, including improved transaction flow and the development of integrity and trust along the completely agricultural supply chain. While supply chain participants gain from increased efficiency, security, and safety of the agricultural produce eliminating third party, consumers gain the ability to verify the authenticity and origin of agricultural products. Nevertheless, there are obstacles like using a virtual machine rather than deploying the contract on an actual Blockchain due to financial concerns.

Keywords: Traceability Model, Agricultural Supply Chain, Price Transparency, Ethereum Blockchain and Smart Contract.

Introduction

The supply chain in agriculture is essential in guaranteeing security of food and quality of the modern, globalised world. However, there are several issues with openness, trust, and traceability in this complex network of producers, distributors, and consumers. There is a greater need than ever for a trustworthy and unchangeable system to trace

and verify the path taken by agricultural products from farm to fork due to worries about food safety, authenticity, and sustainability. Here comes Ethereum Blockchain, a decentralised ledger technology that possesses the ability to completely change the traceability of the agricultural supply line (Tian, 2016).

Technology has given birth to an authentic digital database called Blockchain. Blockchain is an unchangeable digital ledger for monetary transactions which can be configured to record almost anything of value, beyond financial transactions (Tapscott & Tapscott, 2016). That was the reason why individual value depends and varies according to their perspectives; for instance, according to business perspective Blockchain is a decentralised ledger where participants alternately log details about the creation, sale, and use of goods and services. (Xiong et al., 2020). From technical view; (Li et al., 2020) Blockchain comprises several independent nodes and functions as a distributed database system. In other words (Alobid et al., 2022) viewed Blockchain as an interconnected network of computers shares a distributed database (Sheth & Dattani, 2019) pointed out that Blockchain is an independent, distributed record-keeping system that facilitates quick, dependable transactions without being monitored by a central management.

In a wider perspective, Blockchain can be applied to a different area of lifelong aspects. It applies to Education, Banking industry, Health, Government, Application development, Application consensus protocol, Application in internet of a thing (IoT), Agriculture. This study will focus on agricultural sector. Blockchain can be applied in agriculture sector in four major areas: the first one is the agrarian insurance. Farmers can safeguard themselves financially from production losses resulting from natural disasters by purchasing agrarian insurance, which is an essential instrument for risk management in business (Hatch, 2009), while smart agriculture the second one. The application of technological tools like sensors, artificial intelligence, positioning systems and IoT on farms to improve crop/animal quality while optimizing the human labour used and yield is known as "smart agriculture." aa(Rajeswari et al., 2017). The third is the chain of "food supply chain" which refers to the processes that describe how food from a farm ends up on our tables. (Canfora, 2016). The last area is the online sale of agricultural goods, Agricultural product e-commerce is a way to streamline farm operations, cut down on cycle times and administrative costs, and enhance customer and business partner relationships (Zeng et al., 2017).

Most notably fascinating and contentious research area regarding technology right now is Blockchain. In 2008, a Japanese named Satoshi Nakamoto implemented the applications of Blockchain in the financial services for the first time (Mirabelli & Solina, 2020). To make Blockchain more robotic smart contract technology was embedded. This provide the protocol that govern the transaction that brought it uniqueness and trustworthiness, this feature make Blockchain a technology of today. Several investigations have been carried out and some are still going utilizing Blockchain in it wider perspective studies (Galvez et al., 2018); (Mann et al., 2018);(Song et al., 2019); (Matsenko & Voronenko, 2020); (Prashar et al., 2020); (Sunny et al., 2020);(Centobelli et al., 2022);(Marchese & Tomarchio, 2022);(Nuansanong & Kiattisin, 2021) and (Raman et al., 2021). Some researcher specified their findings using Ethereum Blockchain, like (Caro et al., 2018); (Hellani et al., 2021); (Ehsan et al., 2022);

(Lopez et al., 2022) and (Tsoukas et al., 2022).Similarly, additional research on Blockchain and smart contracts has been done., (Salah et al., 2019); (Demestichas et al., 2020); (Gopalakrishnan et al., 2020); (Shahid et al., 2020) and (Alves et al., 2021). In Nigeria few study was conducted on Blockchain studies mostly were survey studies (Jimoh et al., 2019); (Abayomi-Zannu et al., 2020) and(Hamma-Adama & Labaran, 2021), but little is known in area application of new technology like Blockchain and smart contract. It can also be noted that all studies were conducted on a particular Agricultural produce, not on Agricultural supply chain and traceability. Study like (Bako et al., 2019) suggest the use of Blockchain and smart contract.

Literature Review

Many related work to agricultural supply chain traceability using Blockchain are reviewed including some other areas of supply chain traceability. Massive popularity has being gained by Blockchain in different sectors like health, banking and finance etc. It is growing gradually in agricultural sector. (Agrawal et al., 2021), employ Blockchain with tailored smart contracts and transaction rules to develop a framework for textile and clothing industries.

The Blockchain framework was provided for the implementation of supply chain traceability in the textile and clothing industries. This is as result of persistent issues of data lopsidedness as well as poor vision. That is challenging for customers to obtain product information that could ensure the authenticity of the product or encourage moral purchasing behaviour. Also mention that research should be diverse into different areas of study, and it is necessary to create sector-specific smart contracts to satisfy the distinct requirements of different stakeholders.

(Adithi & Dakshayini, 2022), proposed a system using the Blockchain technology's Hyperledger fabric framework. By simply providing a product's ID to the proposed system, in just 0.015 seconds, it has effectively traced the entire chronicle of food crops and seeds. It creates an open ecosystem that permits for farmers to acquire premium seeds, profitable yields, and a happy life. (Tsoukas et al., 2022) created a blockchain-based food supply traceability system using Smart contracts on Ethereum and Tiny Machine Learning. Assuring data consistency, workflow automation, and interoperability across surveillance systems from several vendors, the framework is constructed with a Blockchain-based backend. The work helps two areas: security, since the anomaly detection device discourages bad actors, and transparency and traceability of food products. RFID and Blockchain-based technologies are used by (Tian, 2016) to tackle China's expanding food safety problem. The system was capable of collecting, circulating, and sharing data using RFID technology, and Blockchain-based technology maintains the accuracy of data communicated with everyone involved at all levels using a farm to table tactics. RFID tags, which frequently appear on item packaging, can be used to offer to consumers a number of agri-food attributes, including the variety, name, place of origin, level of fertilization, and use of pesticides. An accessible, self-organizing, trustworthy, and ecological smart agriculture system that incorporates all ecosystem members is made possible via the combination of the Blockchain technology and the IoT. In order to lessen the reliance on human involvement for effectiveness of the system, the proposed system

aims to employ IoT gadgets in place of manual documentation and confirmation. The system will monitor only food safety concerns (Lin et al., 2018).

At the heart of processing on the traceability of soybeans in the agricultural supply line, an approach is proposed that uses the generic Ethereum framework moreover smart contracts to monitor, observe and conduct business transactions without middlemen. Presentations include information on the system architecture, design, diagrams of sequences, interactions, entity-relation diagrams, and implementation techniques. The application of the suggested solution for tracking and tracing the supply chain for soybeans is demonstrated (Salah et al., 2019). The development of a suggested system built on the Ethereum Blockchain and smart contracts was motivated by a lack of clarity and quality. It has been found that Blockchain holds the ability to enhance the nation's financial status by decreasing bribery and raising manufacturer and consumer contentment. The management of supply chains is made more transparent and efficient by doing away with the middleman. This model allows for the tracking of the product's shipment, the verification of the item's origin, and the saving of transaction proof (Ehsan et al., 2022).

(Vijay et al., 2022) proposed system called Grain chain which was built using Hyperledger fabric. Grain chain is an entirely permission-based, decentralized Blockchain application that allows participants to transact with one another. It also makes it easier for user to monitor the product from harvest to table. Any supply chain implementation can utilize the permissioned Blockchain technology framework known as the Hyperledger Fabric. The system is only capable of handling grains. Future research should investigate how to introduce a rating system to producers, distributors, and retailers to enable users to view the rating prior to selling their item.

Table 1: Summary of the Related Work

Authors	Traceability	Safety and Security	Smart Contract	Price Transparency
(Tian, 2016)	Yes	Yes	No	No
(Lin et al., 2018)	Yes	Yes	Yes	No
(Ehsan et al., 2022)	Yes	Yes	Yes	No
(Tsoukas et al., 2022)	Yes	Yes	Yes	No
(Adithi & Dakshayini, 2022)	Yes	Yes	Yes	No
(Vijay et al., 2022)	Yes	Yes	Yes	No
(Salah et al., 2019)	Yes	Yes	Yes	No

Most of the reviewed articles about the supply chain for food only address the security of food and safety they also discuss food quality and better customer experience. Others discuss prevention of counterfeit drugs and data security, but none of them discussed price transparency as shown in table 1 above.

There is need for research to close that gap, by proposing a model solution to the problem of agriculture supply chains. Blockchain would be useful in the agriculture sector for monitoring

the source and path of produce. This is crucial for farmers and consumers alike, because it gives consumers peace of mind knowing where their produce is coming from and enables farmers to sell for better prices throughout the supply chain. This is a significant factor to consider when considering the increasing lack of trust in the source of the produce sold in markets. Also price transparency is another factor and a problem that is affecting the entire stakeholder in the agricultural sector. This problem of price transparency is not address in all the studies mentioned above earlier.

Materials and Methodology

Existing System

The traditional routine in agriculture is for the farmer to buy seed and other required chemicals/fertilizer from vendors, and proceed for farming. After harvesting the farm produce, it will be sold to the distributors, after that, then be sold to the retailers and finally to the consumer. These routing is shown in figure 1 below

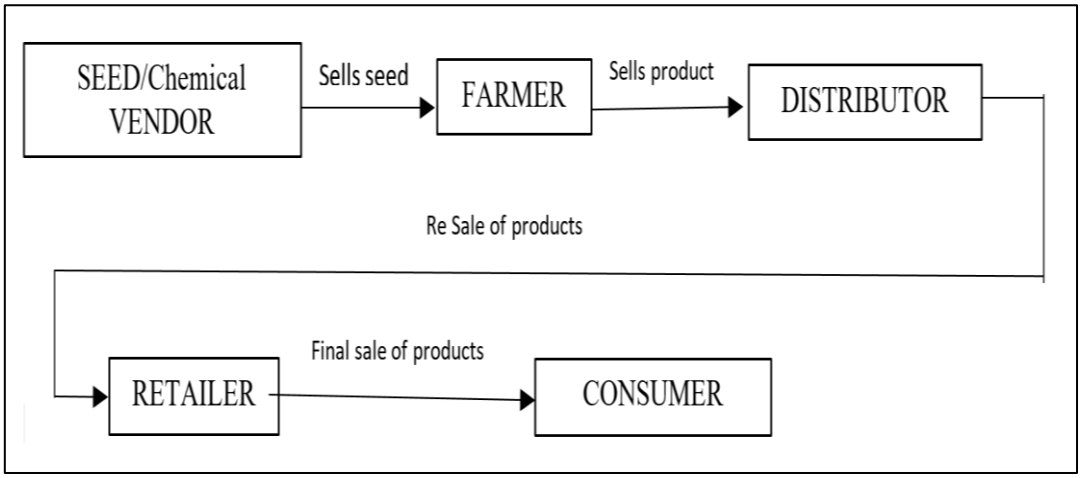


Figure 1: Traditional Agricultural Routing

The Proposed System Methodology

Figure 2 below explains the detailed operation of a Blockchain-based system. In step one, a transaction is requested by seeds/chemical company through smart contract, all the information of the product would be fed into the block, and in step two the famer make transaction which, include the descriptions of the farm product (Product Id and Product Name) it is broadcast to all connected miners (actors). When everyone has reached an agreement on this transaction, it is time to proceed. The third stage makes that of grain distributor, which confirms the transaction. Step four involves the development of a new cryptographically secure by the retailer's block. The new block is created with the existing blocks in steps five, which bring the consumer into the limelight, and the transaction is completed. With the use of smart contracts, all participants in the supply chain are linked together in a decentralized Blockchain, enabling the tracking of each transaction across the whole system. Anybody throughout the entire supply chain is able to track the goods.

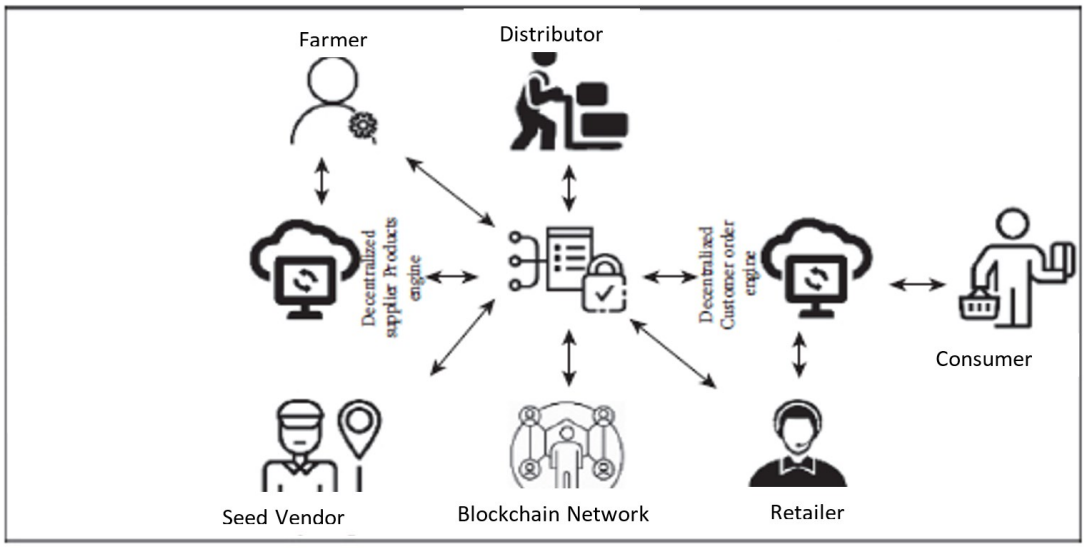


Figure 2: Proposed Agricultural Smart (Intelligent) Contract Supply Chain Network (Ehsan et al., 2022)

Flowchart of the Proposed Model

The flowchart diagram is used to describe the main processes and functionality of the Agricultural supply chain traceability. It models the user's action for using the system. The people that will interact with the proposed system are called actors (miners). The purpose of having flowchart diagram is to identify the scope of the proposed system.

Actors

- Seed Vendor
- Farmer
- Distributor
- Retailer
- Customer

The supply chain includes Seed Vendor, Farmer, Distributor, Retailer and customer, all of them represent the direct actors.

Deploy the contracts

Deploy the contracts SeedVendor, Farmer, Distributor, Retailer, and Consumer to Blockchain network platform.

Interaction with the Seed Vendor Contract

A function addSeed will be called to provide the required parameters (vendorId, seedId, seedName, chemicalId, chemicalName, chemicalUses) to add a seed to a specific vendor. Then call the setVendorPermissions function, providing the vendorId, farmerId, and a boolean value (canSell) to set the permission for a vendor to sell to a specific farmer.

Figure 3 shows the flowchart for the interaction of the farmer with seeds vendor to purchase seed and chemicals after having the permission to purchase from the vendor. Information of seed vendor and available product will be displayed (seeds and chemical like herbicides, pesticides etc. and fertilizer).

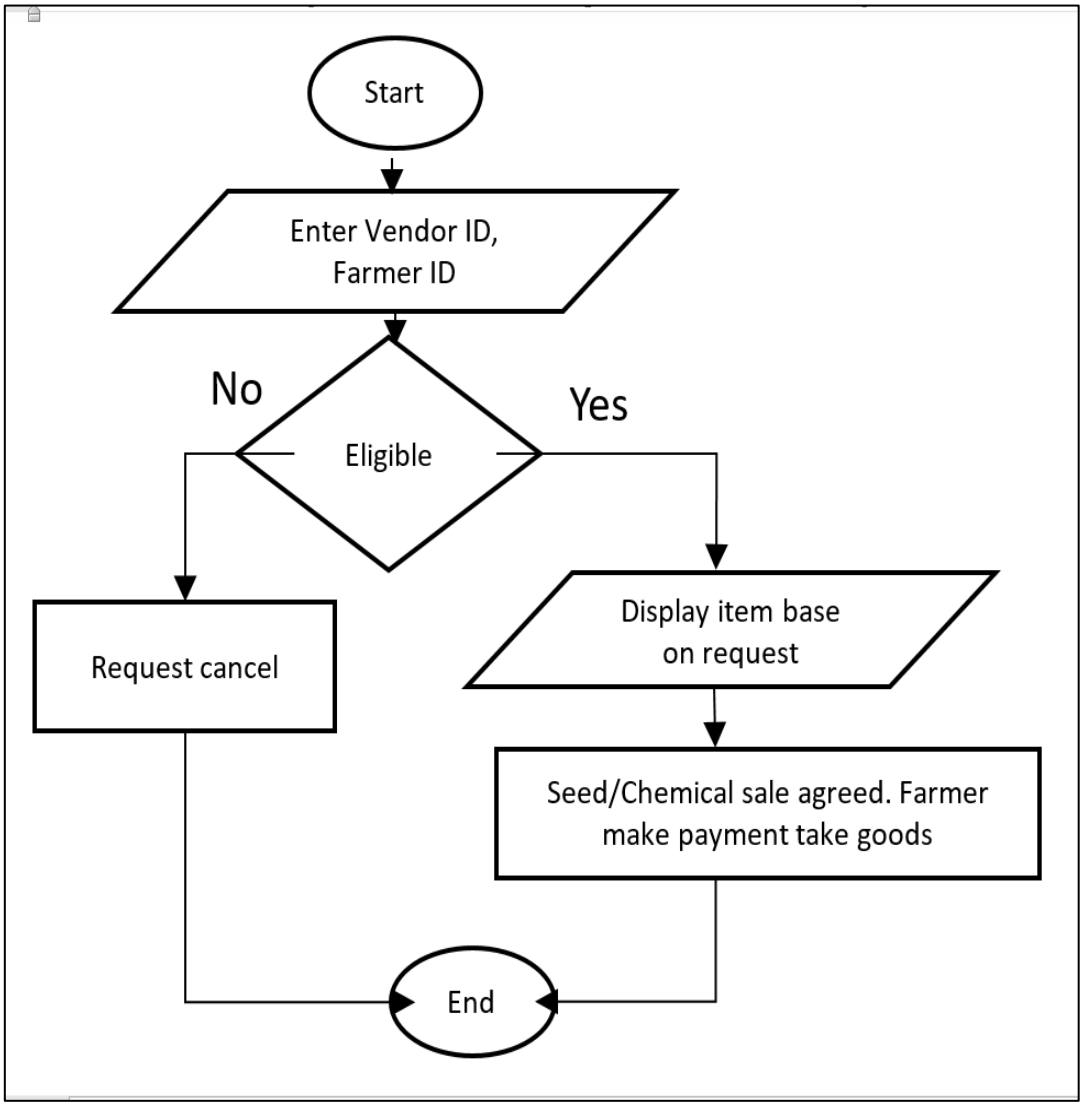


Figure 3: Farmer Transacts with Seed Vendor

The entire remaining actor's function flowchart is almost same as that of between seed vendor and farmer, that is farmer and distributor, distributor and retailer, except that of consumer.

Interact with the Consumer contract

A function purchaseProductis called, for providing the consumerId, itemId, and the name of the product to purchase and associate it with a consumer. Product information can be retrieve by calling the searchProductById function, and then the itemIdwill be provided to retrieve the product information based on its ID as shown in Figure 4 below.

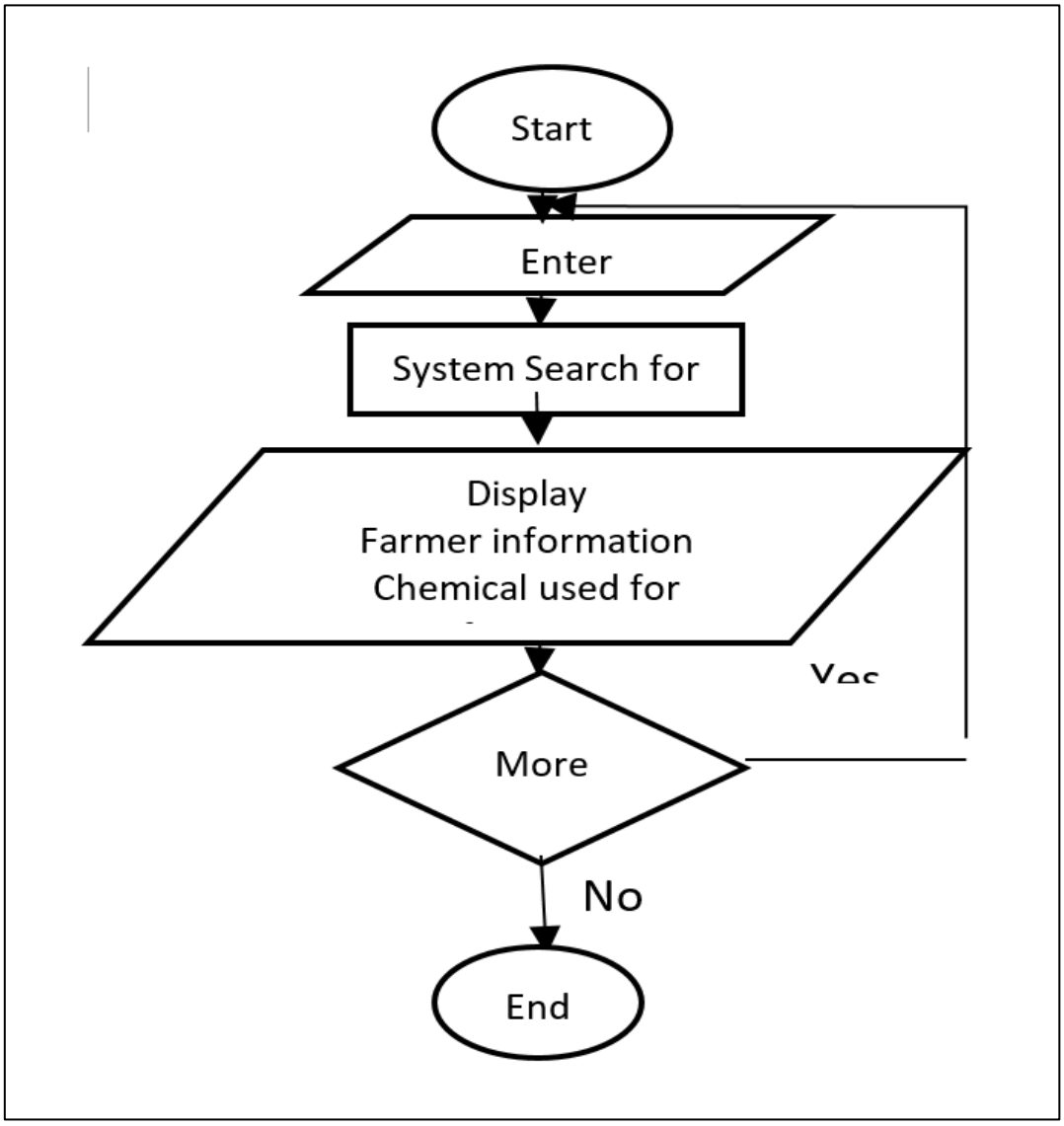


Figure 4: Consumer Search for Product Information

Proposed System Implementation

Hyperledger Fabric can mostly be programmed using Unix Operating System with following programming languages; Golang, Java, Go, Python, Solidity and it is permission Blockchain, while Ethereum can be coded on Remix browser mostly online using solidity, this can be done on any Operating System and it is permission less Blockchain. Ethereum Blockchain is the choice for the proposed system, using Remix and solidity for coding.

Implementation Flow

Supply chain in agricultural is the distribution of produce harvested by farmer through to consumer. Farmer buy seed from seed vendor, and then he cultivate the farm and sow the seed. After harvesting the farm produce, he will upload all information of the produce (name, ID,

fertilizer/chemical) used to grow the produce and information of the seed vendor too. Transaction concerning to this document will be documented by the Blockchain. Distributor will check and go through the information regarding farmer and his produce he will then place a buying order if he is eligible to buy from the farmer and the farmer is eligible to sell to that distributor.

The Distributor will collect the purchased harvested produce and upload all information to the network of Blockchain and documented. Retailer reviews the recorded information of distributor and the goods and place order if he has permission to buy from that distributor and that distributor has permission to sell for him, after the transaction is sealed, the retailer will collect the goods. Consumers can only buy from retailer. The retailer upload information of the goods in Blockchain network for consumer to review and make a choice for purchase. Information about the produce from the seed bought from seed vendor by the farmer up till the end of all processes can be search by customer. All these recorded information of the produce and that of actors on the Blockchain cannot be alter or modify this bring about transparency. Two actors have permission to communicate with each other. In this model, the consensus mechanism used is Proof of Authority (PoA). The actors' ability to transact with one another is determined by their consensus; this is known as the transaction flow among actors.

Deployment and Testing

Launch a Remix IDE on browser and create a new file by typing the name with .sol extension as shown in Figure 5 below. The name of the file is displayed in two places, under contracts in the file explorer, then on the text editor tap to differentiate different environment.

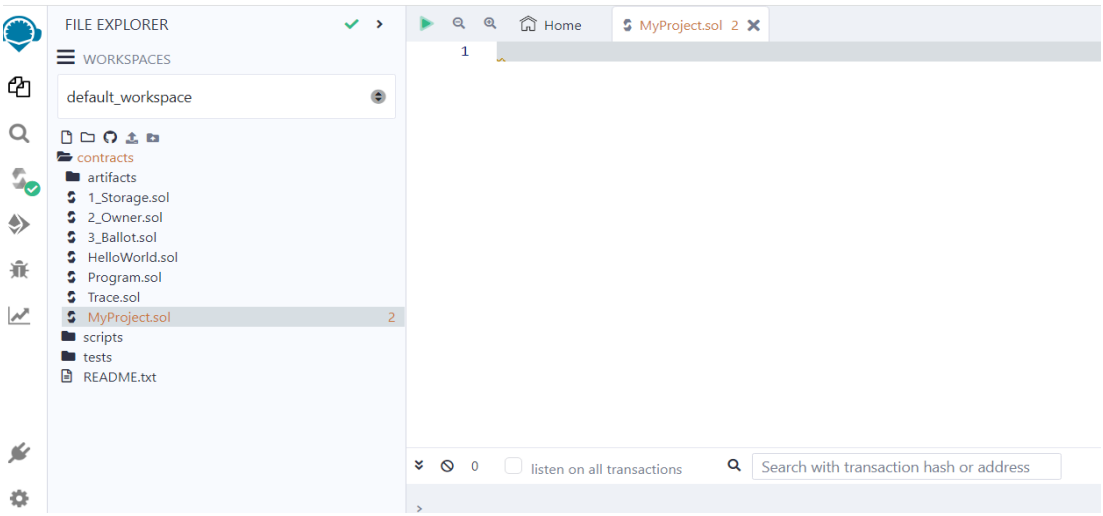


Figure 5: New file in Remix IDE

After coding then the it will be compiled by solidity compiler as display in Figure 6 below. If there is error in the coding it will not be compiled just complain of the error, but if the code is error free, it will be compiled and show a green mark on the solidity compile button. After a successful compilation then the system will be deployed for testing.

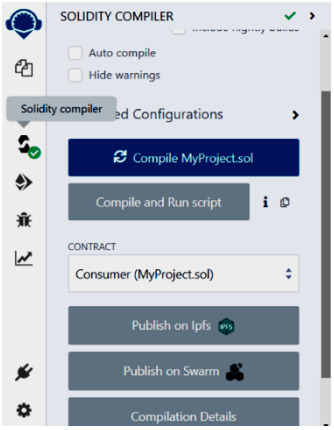


Figure 6: solidity Compileer window

The implementation will moved to the next stage which is deployment and running of the transactions. Deploy and run transaction button will be clicked as shown in Figure 7 below. The deployed smart contract will be defined and each actor instance will be deployed and executed.

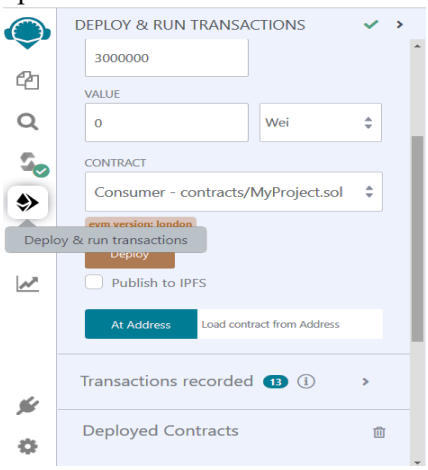


Figure 7: Deploy and Run Transaction window

Figure 8 show all the deployed contract of all the five actors which are now ready for transaction to take place. Transaction can only take place between two permitted entities, anyone that is not having permission to transact will not make transaction with others. Permission is set to be true with ID of those that are permitted to transact.

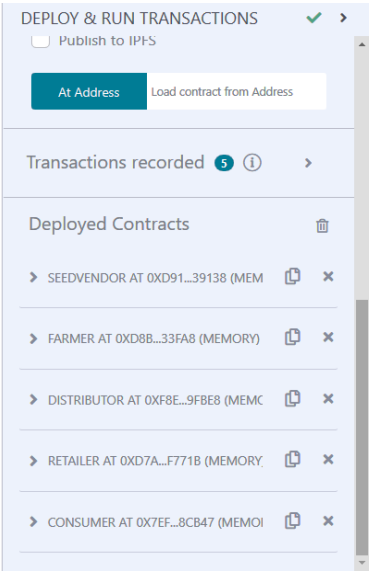


Figure 8: Deployed Contract of the Five Actors

Random data was created to test the proposed system chosen maize as the agricultural produce to test the system. The farmer bought maize seed, pesticide and fertilizer to grow the maize, the system keep track of the transaction including prices of what he purchased. After harvesting he will park them in sack, the system does not keep track of harvesting process and procedure but keep track of how many sack were harvested. A distributor that has permission to buy from this farmer and the farmer has permission to sell for that distributor, the system keep tract of how many sack of maize he bought, the price he bought them and the price to be sold. The retailer too undergo same process as that of distributor, then the consumer can only by from retailer which there is no restriction between them, any consumer can buy from any retailer. Then he search for information of the history of the maize. A block created for each transactions,.

Data Model

The process of creating diagrammatic flow in and out of data in the smart contract is call data modeling. The data modeling is aimed at producing consistent structured data for high quality of running of the proposed system. The figure 9 below shows how the Blockchain actors are

being created with their attributes for high quality performance. A customer has the ability to confirm the product's origin. The agricultural industry will be able to expand and have an impact on agricultural products thanks to the suggested supply chain model. By using Blockchain technology, consumers will be able to track every product they buy from farm to table. The final consumer will feel more confident with this model. In figure 10, the suggested sequence diagram is displayed.

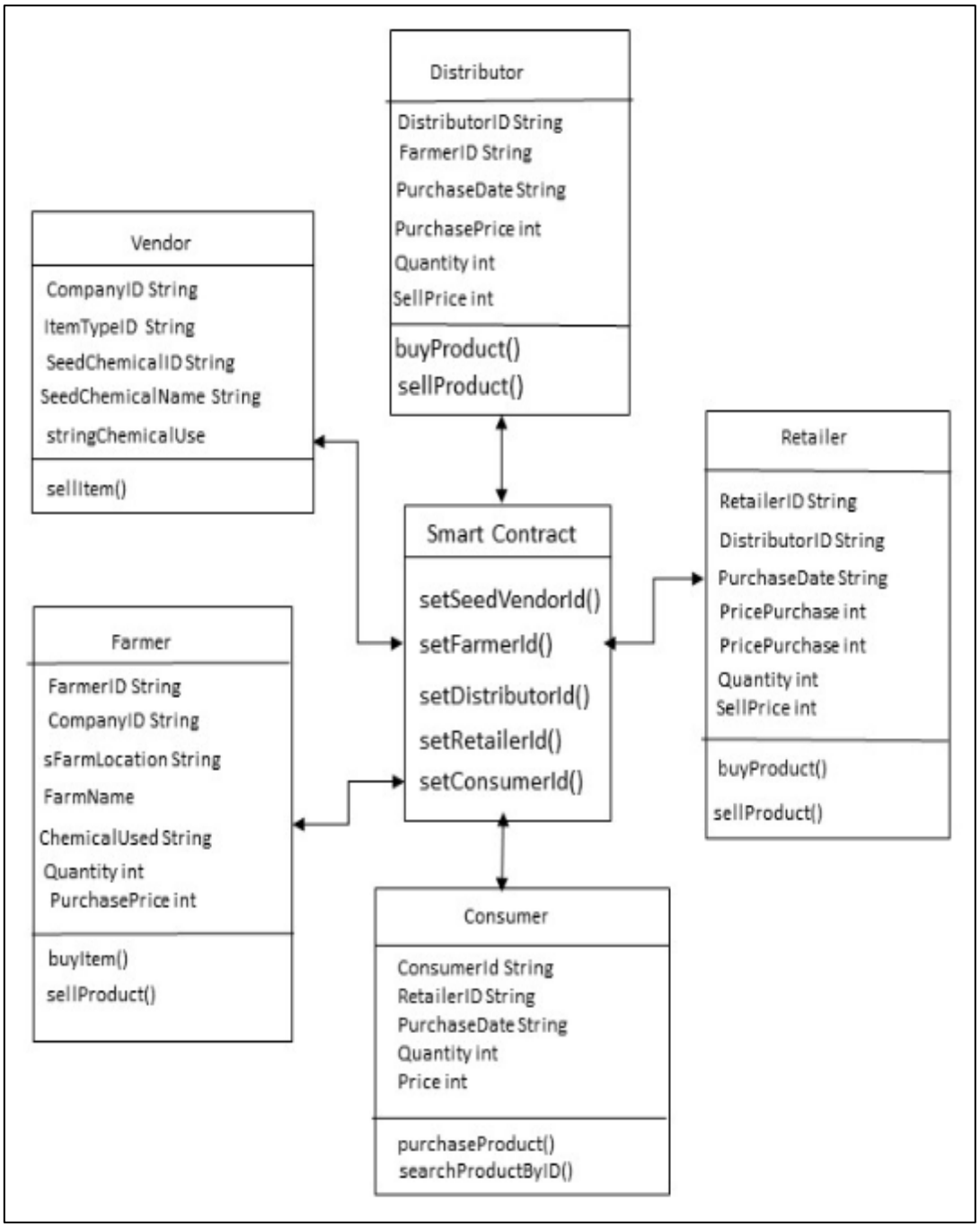


Figure 9: Diagram of Blockchain data Model

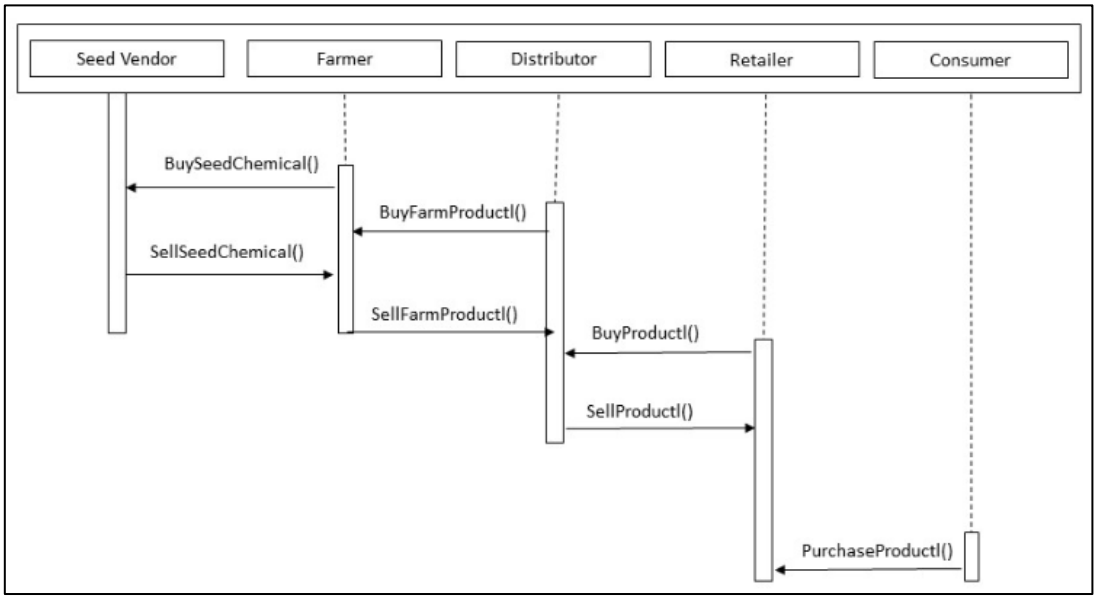


Figure 10: Sequence diagram of the Proposed System

Results and Discussions

The result of the propose agricultural supply chain traceability system, which is building the actual model using Ethereum Blockchain Technology. The system consist of five actors namely Seed Vendor, Farmer, Distributor, Retailer and Consumer. The system deployed on a virtual machine named Remix using Solidity language to code it.

Result Flow

Supply chain in agricultural is the flow of produce from grower to customer. When seed vendor contract was successfully deployed, a block was created as shown in figure 11 below and figure 12 display that of farmer successful deployed contract. The farmer buy seed from seed vendor if he has permission to do so.



Figure 11: Seed Vendor Deployed contract



Figure 12: Farmer Deployed contract

The permission is set that a particular seed using its ID number can be sell to farmer and a particular Farmer using his farm ID can buy from a particular seed vendor. If the permission is true, the transaction will take place but if the permission is false, the transaction will declined. The permission is shown in figure 13 and figure 14, the seed vendor permitted to sell seed and that of farmer permitted to buy from seed vendor respectively. After harvesting the farm produce, the farmer will upload all information of the produce (name, ID, fertilizer/chemical) used to grow the produce and information of the price of the produce.

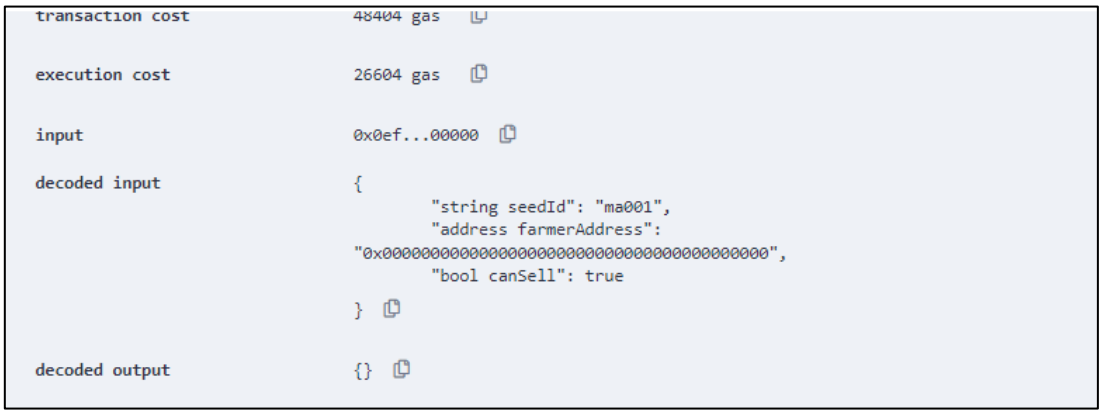


Figure 13: Vendor Permission to sell seed to Farmer

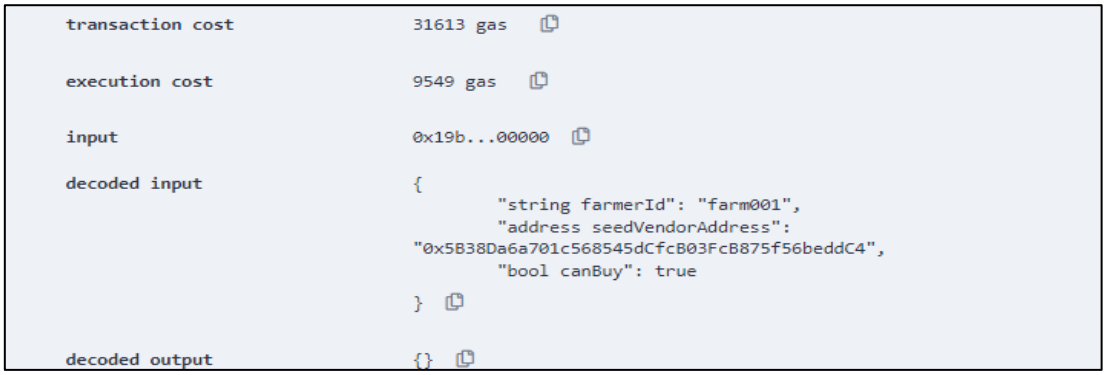


Figure 14: Framer Permission to buy items from vendor

The Transaction concerning the harvested produce will be documented on the Blockchain network as seen in the figure 15.

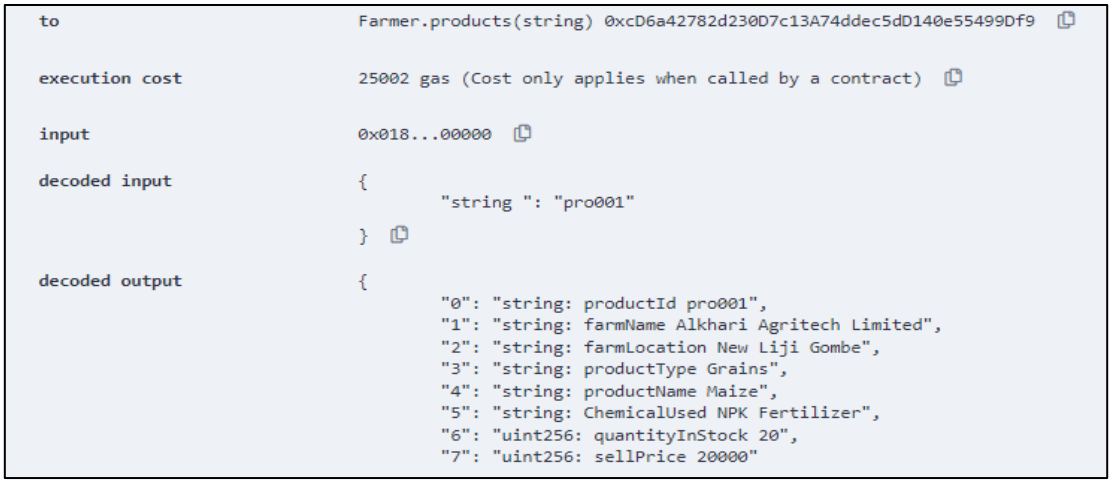


Figure 15: Farmer Harvested produce

Distributor will check and go through the information regarding farmer and his produce he will then place a buying order if he is eligible to buy from the farmer and the farmer is eligible to sell to that distributor. Thus, this permission is as result of consensus algorithm called Proof of Authority (PoA) that Blockchain adopted.

The Distributor will collect the purchased harvested produce and upload all information to the Blockchain network and documented as in figure 16, this include the price in which the goods will be sold.

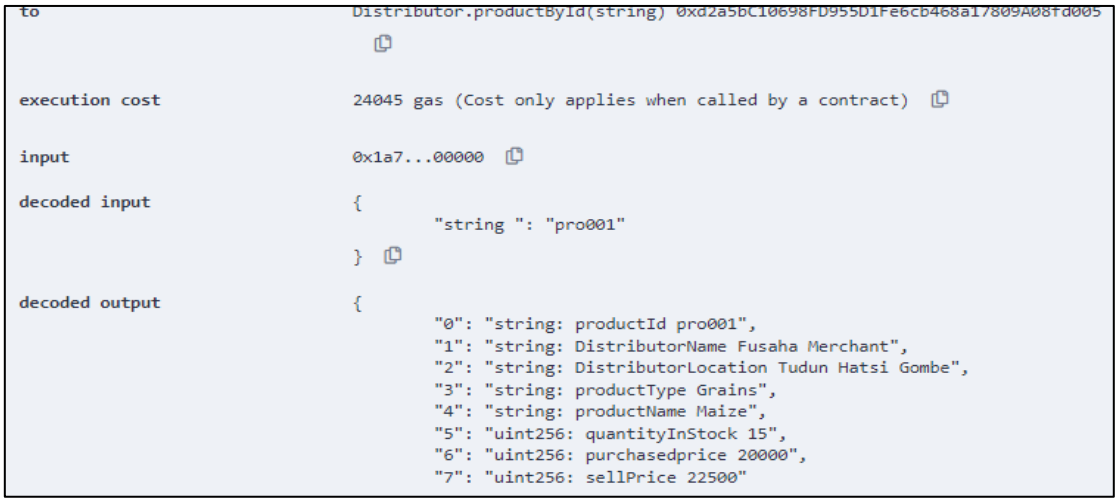


Figure 16: Distributor's goods information

Retailer will review the information of the distributor and the goods and place order if he has permission to buy from that distributor and that distributor has permission to sell for him, after the transaction is sealed, the retailer will collect the goods. Consumers can only buy from

retailers. No any actor can bypass to go and buy from others where there is no permission to buy or sell, retailer cannot go and buy from farmer directly the transaction will be reverted as shown in figure 17.

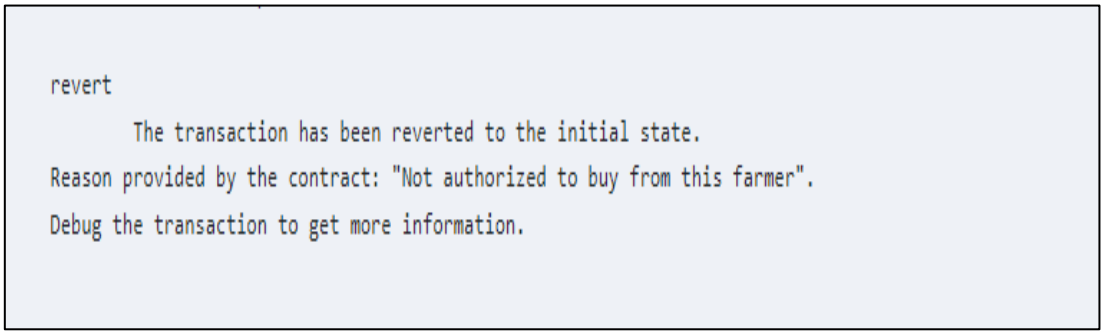


Figure 17: Reverted Transaction due lack of permission

The retailer upload information of the goods in Blockchain network for consumer to review and make a choice for purchase the retailer's goods information with the price purchased from distributor and sell price shown in figure 18.

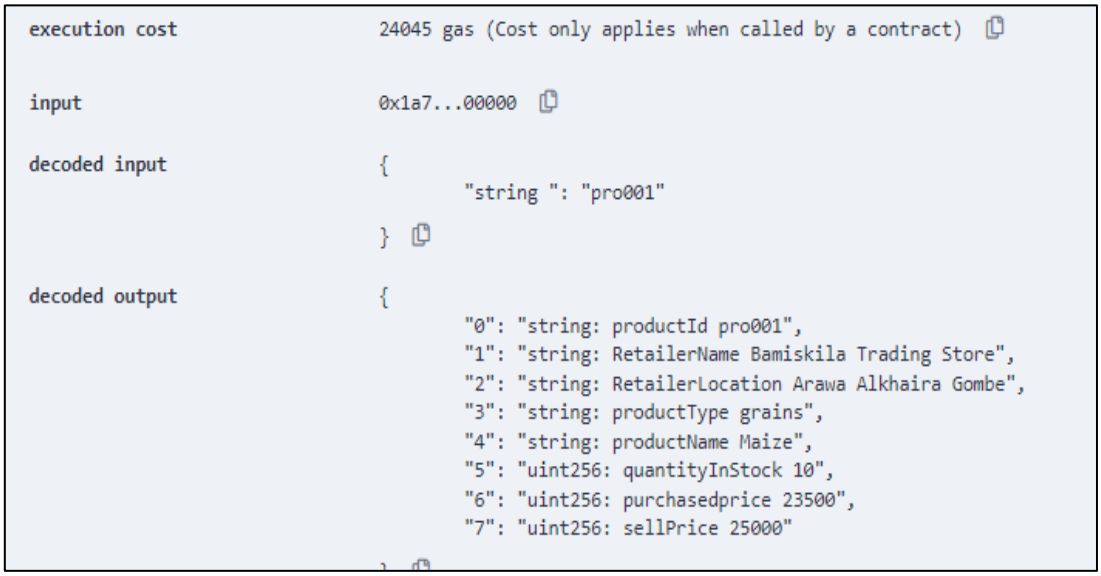


Figure 18: Retailer's goods information

Information about the produce from the seed bought from seed vendor by the farmer up until the end of all processes can be search by customer as shown in figure 19. All these recorded information of the produce and that of actors on the Blockchain cannot be alter or modify this bring about transparency. There is a permission of communication between two actors is as a result of Proof of Authority (PoA) which is a consensus mechanism in the Ethereum Blockchain technology. This consensus determine which actors allow to transact with each other. This is proper transaction flow among the actors.

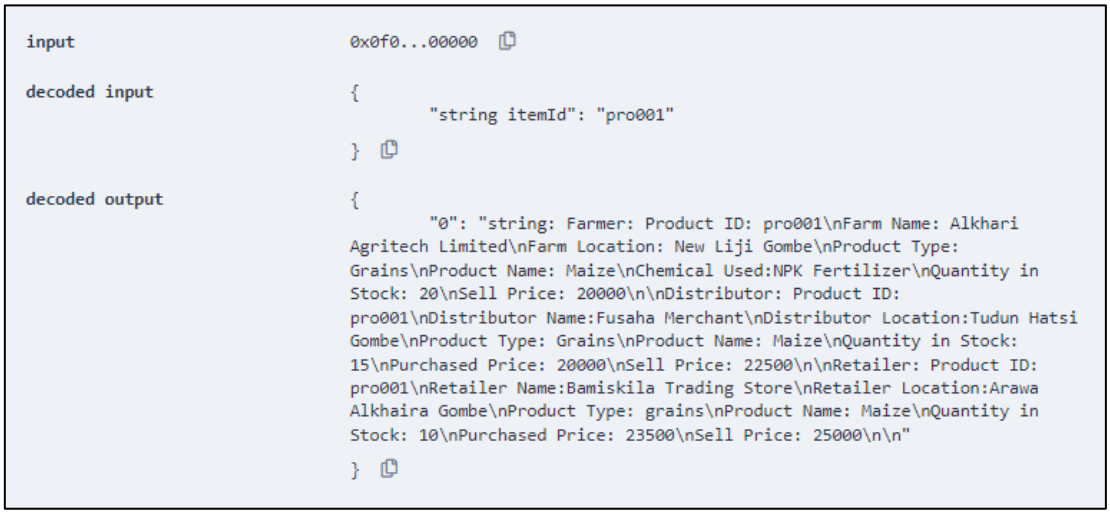


Figure 19: Result of Consumer's product search

Conclusion

Utilizing the Blockchain of Ethereum, Solidity smart contracts, as well as the Remix IDE, the research is attempting to implement agricultural supply chain traceability. This is a major step towards creating a more efficient, safe, and transparent agricultural ecosystem. In a world where food safety, transparency, and sustainability are of paramount concern, the integration of Blockchain approach appeared as a revolutionary remedy for the supply chain in agriculture. The research's main goals were successfully achieved. The development of smart contracts made it possible to include a variety of supply chain participants and guaranteed that each would have an unchangeable, safe platform for recording produce information. Once this information captured on the block, it turned into an enduring source of transparency, providing a thorough and unchangeable purchase price and sell price record of each agricultural produce's path from the farmer to the consumer, this guarantee price transparency.

Any actor cannot just make transaction with any other because he wish to unless permitted to do so by the system, which means a consumer cannot boycott retailer and move to purchase from farmer or from distributor, the system will stop the transaction after checking the eligibility of that transaction between the two parties. All the actors can view how much one purchase is goods and how much he want to sell the goods, this price transparency shows that other factors cannot lead to inflation of price of produce anyhow, this lead to transparency and trust in transaction.

Future work

The research focuses on consumer tracing the origin of the farm produce consumed, the price transparency, which enhance safety and security of the produce and transaction flow among the actors. Here are some suggestions for future work on this aspect:

1. To include tracking of produce transportation from one actor to another actor in the agricultural supply chain.

2. Creation of wallet for each actor that will allow automatic payment after agreement of the transaction using e-money.
3. Building of the system on actual Blockchain network like Mainnet, Testnetetc, to have real-life implementation.
4. Integration of Machine learning in Blockchain traceability in agricultural supply chain to enhance data analysis and prediction.

References

Abayomi-Zannu, T. P., Odun-Ayo, I., Tatama, B. F., & Misra, S. (2020). Implementing a mobile voting system utilizing blockchain technology and two-factor authentication in Nigeria. *Proceedings of First International Conference on Computing, Communications, and Cyber-Security (IC4S 2019)*, 857–872.

Adithi, G., & Dakshayini, M. (2022). *A Farmer & Consumer Friendly Traceable and Trustable Agro-Info DApp Using Block-Chain Technology*.

Agrawal, T. K., Kumar, V., Pal, R., Wang, L., & Chen, Y. (2021). Blockchain-based framework for supply chain traceability: A case example of textile and clothing industry. *Computers & Industrial Engineering*, *154*, 107130.

Alobid, M., Abujudeh, S., & Szűcs, I. (2022). The role of blockchain in revolutionizing the agricultural sector. *Sustainability*, *14*(7), 4313.

Alves, L., Carvalhido, T., Cruz, E. F., & da Cruz, A. M. R. (2021). Using Blockchain to Trace PDO/PGI/TSG Products. *ICEIS (2)*, 368–376.

Bako, H. K., Dandago, M. A., & Nassarawa, S. S. (2019). Food traceability system: Current state and future needs of the Nigerian poultry and poultry product supply chain. *Chem. Biomol. Eng.*, *4*(3), 40–44.

Canfora, I. (2016). Is the short food supply chain an efficient solution for sustainability in food market? *Agriculture and Agricultural Science Procedia*, *8*, 402–407.

Caro, M. P., Ali, M. S., Vecchio, M., & Giaffreda, R. (2018). Blockchain-based traceability in Agri-Food supply chain management: A practical implementation. *2018 IoT Vertical and Topical Summit on Agriculture-Tuscany (IOT Tuscany)*, 1–4.

Centobelli, P., Cerchione, R., Del Vecchio, P., Oropallo, E., & Secundo, G. (2022). Blockchain technology for bridging trust, traceability and transparency in circular supply chain. *Information & Management*, *59*(7), 103508.

Demestichas, K., Peppes, N., Alexakis, T., & Adamopoulou, E. (2020). Blockchain in agriculture traceability systems: A review. *Applied Sciences*, *10*(12), 4113.

Ehsan, I., Irfan Khalid, M., Ricci, L., Iqbal, J., Alabrah, A., Sajid Ullah, S., & Alfakih, T. M. (2022). A conceptual model for blockchain-based agriculture food supply chain system. *Scientific Programming*, *2022*, 1–15.

Galvez, J. F., Mejuto, J. C., & Simal-Gandara, J. (2018). Future challenges on the use of blockchain for food traceability analysis. *TrAC Trends in Analytical Chemistry*, *107*, 222–232.

Gopalakrishnan, P. K., Hall, J., & Behdad, S. (2020). A blockchain-based traceability system for waste management in smart cities. *International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, *83952*, V006T06A015.

Hamma-Adama, M., & Labaran, M. J. (2021). The Nigerian pharmaceutical supply chain: Blockchain adoption, counterfeit drugs and successful deployment of COVID-19 vaccine in Nigeria. *Journal of Scientific Research and Reports*, *27*(2), 20–36.

Hatch, D. C. (2009). Agricultural Insurance: A Focus On The Southhern Cone Observations and Criticail Sucess Factors. *Montvideo, Uruguay*.

Hellani, H., Sliman, L., Samhat, A. E., & Exposito, E. (2021). On blockchain integration with supply chain: Overview on data transparency. *Logistics*, *5*(3), 46.

Jimoh, F. O., Abdullahi, U. G., & Ibrahim, I. A. (2019). An overview of blockchain technology adoption. *Journal of Computer Science*, *7*(2), 26–36.

Li, X., Wang, D., & Li, M. (2020). Convenience analysis of sustainable E-agriculture based on blockchain technology. *Journal of Cleaner Production*, *271*, 122503.

Lin, J., Shen, Z., Zhang, A., & Chai, Y. (2018). Blockchain and IoT based food traceability for smart agriculture. *Proceedings of the 3rd International Conference on Crowd Science and Engineering*, 1–6.

Lopez, L. J. R., Babativa, J. M. C., & Reales, W. M. R. (2022). Blockchain apply to the supply chain of essential medicines for the treatment of Covid-19 in Colombia. *Informatics in Medicine Unlocked*, *33*, 101100.

Mann, S., Potdar, V., Gajavilli, R. S., & Chandan, A. (2018). Blockchain technology for supply chain traceability, transparency and data provenance. *Proceedings of the 2018 International Conference on Blockchain Technology and Application*, 22–26.

Marchese, A., & Tomarchio, O. (2022). A blockchain-based system for agri-food supply chain traceability management. *SN Computer Science*, *3*(4), 279.

Matsenko, O. M., & Voronenko, V. I. (2020). *Economic prospects for cooperation the European Union and Ukraine in the use of blockchain technologies*.

Mirabelli, G., & Solina, V. (2020). Blockchain and agricultural supply chains traceability: Research trends and future challenges. *Procedia Manufacturing*, *42*, 414–421.

Nuansanong, J., & Kiattisin, S. (2021). The electronic medical record exchange using a Blockchain technology. *Songklanakarin Journal of Science & Technology*, *43*(2).

Prashar, D., Jha, N., Jha, S., Lee, Y., & Joshi, G. P. (2020). Blockchain-based traceability and visibility for agricultural products:

A decentralized way of ensuring food safety in india. *Sustainability*, *12*(8), 3497.
Rajeswari, S., Suthendran, K., & Rajakumar, K. (2017). A smart agricultural model by integrating IoT, mobile and cloud-based big data analytics. *2017 International Conference on Intelligent Computing and Control (I2C2)*, 1–5.
Raman, R., Sushmitha, J., & Nalini, M. K. (2021). ``Asurvey paper on blockchaintechnologies in supply chain management,''. *Int. J. Res. Eng. Sci*, *9*(6), 79–86.
Salah, K., Nizamuddin, N., Jayaraman, R., & Omar, M. (2019). Blockchain-based soybean traceability in agricultural supply chain. *Ieee Access*, *7*, 73295–73305.
Shahid, A., Almogren, A., Javaid, N., Al-Zahrani, F. A., Zuair, M., & Alam, M. (2020). Blockchain-based agri-food supply chain: A complete solution. *Ieee Access*, *8*, 69230–69243.
Sheth, H., & Dattani, J. (2019). Overview of blockchain technology. *Asian Journal For Convergence In Technology (AJCT) ISSN-2350-1146*.
Song, J. M., Sung, J., & Park, T. (2019). Applications of blockchain to improve supply chain traceability. *Procedia Computer Science*, *162*, 119–122.
Sunny, J., Undralla, N., & Pillai, V. M. (2020). Supply chain transparency through blockchain-based traceability: An overview with demonstration. *Computers & Industrial Engineering*, *150*, 106895.
Tapscott, D., & Tapscott, A. (2016). *Blockchain revolution: how the technology behind bitcoin is changing money, business, and the world*. Penguin.
Tian, F. (2016). An agri-food supply chain traceability system for China based on RFID & blockchain technology. *2016 13th International Conference on Service Systems and Service Management (ICSSSM)*, 1–6.
Tsoukas, V., Gkogkidis, A., Kampa, A., Spathoulas, G., & Kakarountas, A. (2022). Enhancing food supply chain security through the use of blockchain and TinyML. *Information*, *13*(5), 213.
Vijay, P., Revathy, P., Ohja, S., & Sriram, N. (2022). Grainchain–Agricultural Supply Chain Traceability and Management technique for Farmers Sustainability Using Blockchain Hyper Ledger. *International Journal of Intelligent Systems and Applications in Engineering*, *10*(3), 141–146.
Xiong, H., Dalhaus, T., Wang, P., & Huang, J. (2020). Blockchain technology for agriculture: applications and rationale. *Frontiers in Blockchain*, *3*, 7.
Zeng, Y., Jia, F., Wan, L., & Guo, H. (2017). E-commerce in agri-food sector: a systematic literature review. *International Food and Agribusiness Management Review*, *20*(4), 439–460.