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Development of Traceability System for Seafood Supply Chains in Malaysia

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The growing concerns on seafood safety issues have promoted transparency of the food supply chain. Tracking tools are essential for consumers to understand the origin of food processing and for suppliers to detect flaws when contamination occurs. Blockchain technology is widely used in supply chains as it allows multiple parties to input and retrieve transactions without worrying about credibility. Track and trace management requires blockchain technology to ensure data accuracy and transparency. The research objective is to develop a food management tool for traceability in the seafood supply chain. As the foundation of the traceability tool, blockchain technology gives a decentralised structure and ensures the immutability of data collected. Python was chosen as the programming language for constructing the traceability tool, and a web interface for suppliers was created to input seafood data. Consumers can browse the entire supply chain of consumer products through QR codes on food packaging. The protocol is validated by using the tuna fish case study to fortify the blockchain and ensure the credibility and reliability of the supply chain. Consumers no need to question about the accuracy of data and transparency during data operation. The contamination tracing is validated by tracing the affected supply chain of frozen shrimp transported from an aquafarm, Shrimp Farm S/B, to a few retail sellers. There were six single chains, combining to form a complicated supply chain in the case study of shrimp. Consumers can view entire multiple chains in the supply chain information, from fishing vessels to selling units. When contamination happens at certain block, the affected block in the whole supply chain will be identified. The traceability tool developed keeps track of the entire seafood supply chain and, if any contamination occurs, immediate action can be taken. Immediate action to call back the seafood batch is necessary to avoid further losses and keep humans from consuming contaminated seafood. Future research may include the variables that cause seafood contamination, including the chemical hazard in traceability tools that comply with HACCP standards to ensure product safety before entering subsequent stages.

1. Introduction

Food authenticity and safety issues have become a concerning topic in the world. United States Food and Drug Administration (USFDA) had red-listed shrimp exported from Malaysia from 2019, as 18 shrimp samples were detected to contain chloramphenicol in 2018 (Arnold et al., 2020). Chloramphenicol has been used in shrimp farms to treat Early Mortality Syndrome (EMS), a disease that causes shrimp to die within 30 d of being put back into the growing ponds (Abdullah et al., 2013). Some European countries had rejected the exports of block frozen black tiger shrimp (*P. monodon*) from Malaysia due to the presence of the *Vibrio parahaemolyticus* bacterium (Olsen and Borit, 2018). There are two types of hazardous contaminants commonly found in seafood, chemical and microbial contaminants. Chemical contaminants such as mercury come from agriculture, household and industrial waste. Chemicals leach into an aquatic ecosystem and contaminated marine life. The contaminants can accumulate in the human body over time if constantly consumed the contaminated seafood and result in serious health issues (Thomas, 2009). In 2019, high concentrations of arsenic, cadmium, lead, and mercury were detected in shellfish from the Straits of Malacca (Azmi et al., 2019). The water is polluted due to the growing of the industrial activities in the port and estuary area. Contaminations also can happen during the transportation, storage, handling, and processing of seafood in the factory. By improving the supervision at each stage of the production chain, it would help improve the food quality of the seafood supplied and ease the

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management of the stakeholder, which is a win-win for both consumer and supplier (Fox et al., 2018). The seafood supply chain in Malaysia can be categorised into seven categories; resource, aquaculture, intermediate, processor, storage, distributor, and seller (Charlebois et al., 2014). In developing a traceability system, many key data elements need to be considered, for example, the legality of seafood caught, location, transportation, storage, and the process of handling seafood until sale (Manning and Soon, 2014). These elements are complex, with numerous data needed to be recorded, tracked, and analysed. There are a few technological challenges to be faced while developing seafood traceability systems (Olsen and Aschan, 2010). Small-scale fishermen or fish processors do the traceability themselves for regulatory compliance through paper records or spreadsheet data management. Limitation of paper-based traceability tools is to handle high complexity such as multiple branch supply chain and unable to deal with large amount of data retention and data tracing (Mgonja and Kussaga, 2012). The traceability system in Kresna et al (2017) have implemented interconnect system to show the documentation for each process in every single step and tuna fish condition. However, the data can be altered or deleted at any times will cause the inaccuracy data issue. In this era of globalisation, a global traceability system able to link all the processes and share data in the seafood industry is needed instead of an individual-oriented traceability system. Data transparency and accountability are crucial in the system as records in the traceability systems can be altered, deleted, or amended. This will decrease the accuracy and reliability of the data, which might end up being corrupted by food fraud and security issues (Burke, 2019). Blockchain technology is widely used in food traceability. Food traceability technologies are primarily used to solve cases concerning food safety and recalls issues (Pal and Kant, 2019). Blockchain is a decentralised transaction and information management technology that provides a platform for manufactures and consumers to record and exchange data. The value system is decentralised and transparent as every user in the supply chain with access right in the network can view the value recorded in each transaction (Atlam et al., 2018). The main objective of this work is to develop a food management tool for traceability in the seafood supply chain. In this work, an effective traceability tool with professionally managed data gathering, retention, analysis, and collaboration along the seafood supply chain can be utilised, while making sure the consumers' desires are always fulfilled. The designed traceability tools able to link with all individuals for data sharing decentralised by using peer-to-peer network. Several case studies for the traceability tools validation are required and will be presented. The potential benefit of this new traceability tools will be briefly discussed.

2. Methodology

The required input data for a seafood traceability tool was identified. The input data were used to develop the seafood supply chain superstructure. The seafood supply chain in Malaysia starts with resources and ends with consumers. In Malaysia, there is import and local harvesting of seafood as resources. Malaysia imports a lot of seafood, mainly consisting of sardines, Indian mackerel, and pomfret. The imported sardines are canned and then sold for the local market (Burke, 2019). The seafood supply chain in Malaysia can be categorised into seven categories which are resource, aquaculture, intermediate, processor, storage, distributor, and seller. Each category must provide data such as product, method, place, timestamp, handling method, process condition, and transit. A seafood traceability model was developed based on the model of blockchain using Python. There are five basic steps in developing a seafood traceability model. A Genesis block was set up and the flowchart of Genesis block is shown in Figure 1. Every block must have previous hash values, own hash values, transaction/data, nonce, and timestamp. Hash value is defined as the numeric value at a fixed length to represent a large amount of data. The Genesis block is the first block in the blockchain. Every block must have previous hash values, own hash values, transaction/data, nonce, and timestamp but there are no past hash values for a Genesis block. A single block was used to store input data and each block will have its unique ID, which is the hashes. The hash function is mapping the data with complex mathematical algorithms to a set up a hash. The SHA_256 hash function is used as an algorithm to generate hashes with a unique signature for each block.

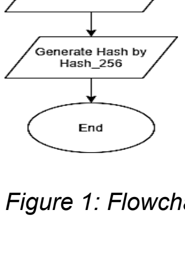

Figure 1: Flowchart of a Genesis block.

The second step is mining the block. Mining is the process of adding new valid blocks into a blockchain. In the new block, it contains the hashes of previous blocks to ensure the dependency and interrelation between the blocks. Figure 2 shows the flowchart of the mining process.

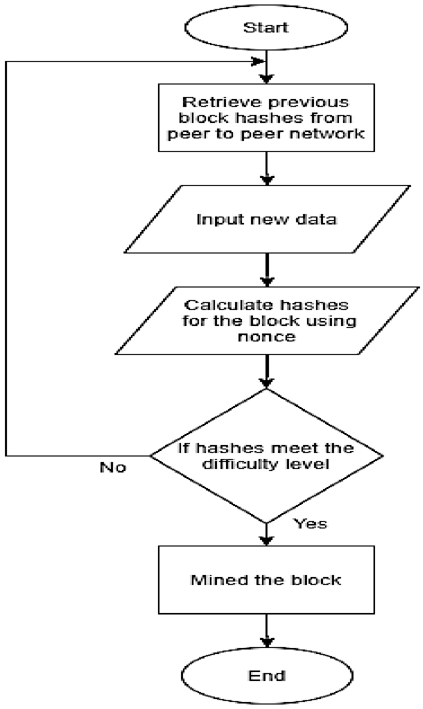

Figure 2 : Flowchart of the mining process.

A peer-to-peer network was set up to make a decentralized and trustable network. All the new individuals are registered as nodes in the system. The communication between each node is showed in Figure 3.

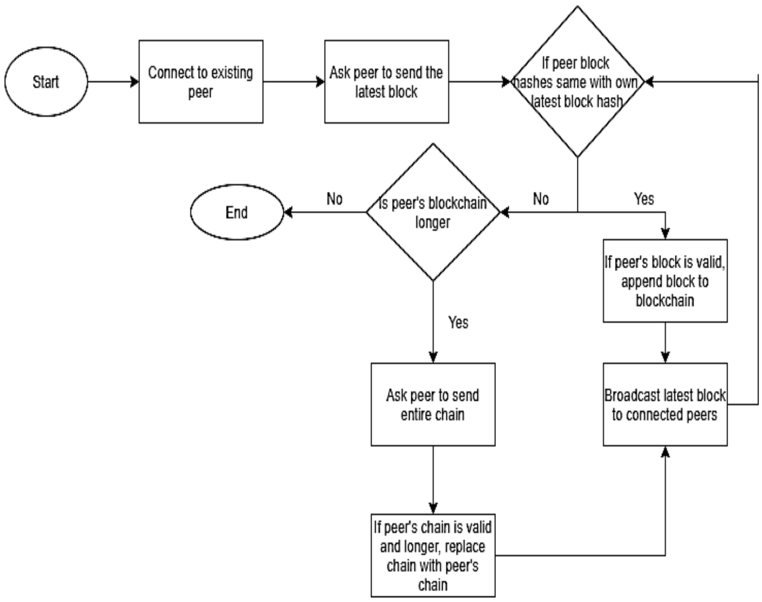

Figure 3 : Communication between nodes.

An interface was created to build interaction between individuals in the seafood supply chain and the seafood traceability model. Figure 4 shows the flowchart to build up crypto-database system.

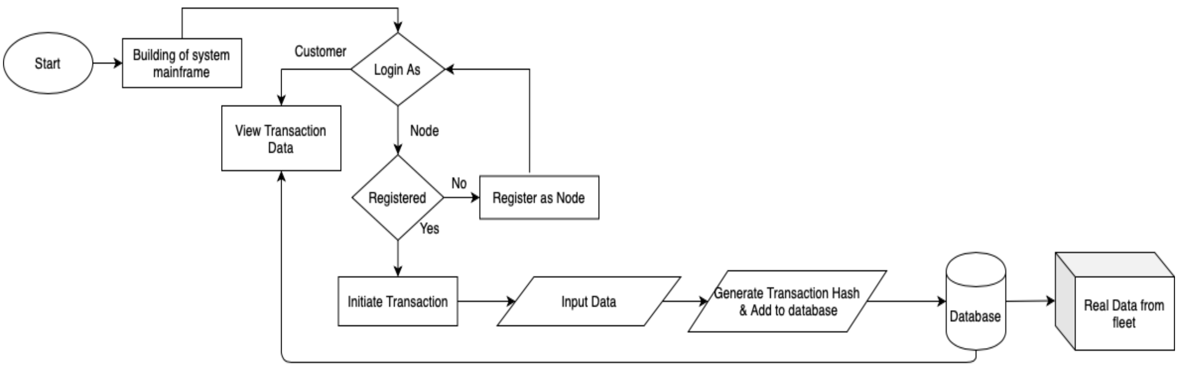

Figure 4: Flowchart of the crypto-database system.

A traceability tool was created to track back the affected chain when a contaminant is detected in the chain. The input data was collected from the database of interface and extracted for tracing. The data was stored in JavaScript Object Notation (JSON) format in the database.

3. Result and discussion

3.1 Protocol validation

The developed tool was applied to two case studies. The first case study is to generate a superstructure supply chain for tuna supply chain and determine contaminant tracing in single chain. The data used for validating was collected from Kresna et al (2017). This tuna supply chain involved processor, multiple distributors, and multiple retail seller, with a total six individuals. There are six blocks were created in the chain and each block has their own unique hash number, previous hash number and transaction data which showed in Figure 5.

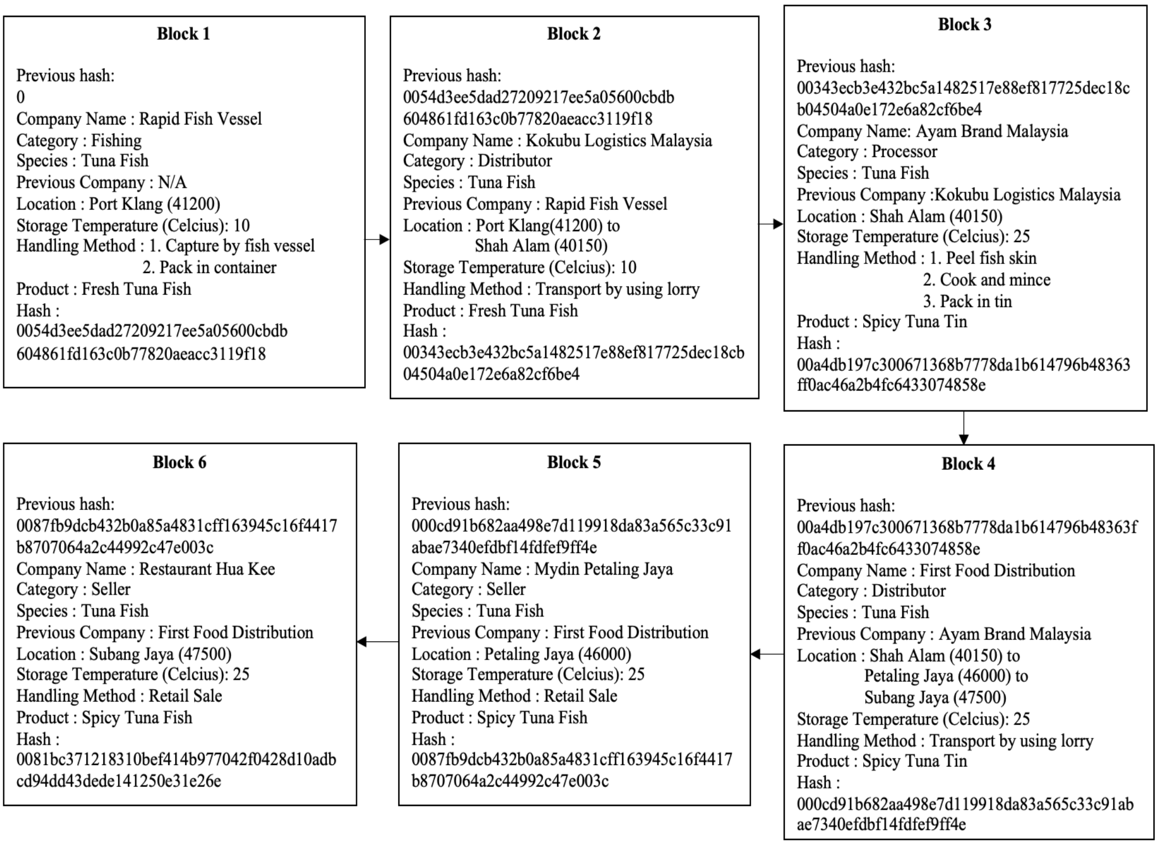

Figure 5: Validation blockchain transactions.

The hash of each block is their unique identity. The following block must have exact same previous hash number with the hash of previous block to ensure the immutability of chain. The main advantage is to fortify the blockchain and ensure the credibility and reliability of the supply chain. Consumers no need to question about the accuracy of data and transparency during data operation. No modification of data is allowed after the block is mined into chain. The peer-to-peer network allowed each individual in the chain links to each other's for data sharing without centralized system. Each individual abled to key in the transaction data in the traceability system after registered in the peer-to-peer network. The new individual, node will be connected to the existing node for data sharing among each other.

3.2 Contamination tracking system validation

The second case study is to generate superstructure chain and determine the contaminant tracing in multiple chain. The data of the shrimp supply chain was collected from Pathumnakul et al (2019). In Figure 6 showed the multiple supply chain which able to be distributed into six single chains. The multiple branches of supply chain involve many individuals which increase the possibility of contaminants happened and increase the difficulty of tracing the affected chain. The processing method used by each individual is clearly listed as processing in the easier part prone to contamination if lack of standard operation or basic food hygiene. By using the designed traceability tools, the affected chain will be easily trace out which showed in Figure 7. Based on Figure 7, the chain which affected by the defect individuals" GP Shrimp Food" were listed out, which were "Shrimp Farm S/B", "JT Logistics", "Kokubu Food Logistics", "Qiant Tampoi" and "Mydin Tampoi". The main benefit of is decrease the cost of recalling since only affected chain product will be recalled instead of recalling all the products from beginning until the end. Instead of recalling both product shrimp paste and frozen shrimp, only the affected products which was shrimp paste was recalled.

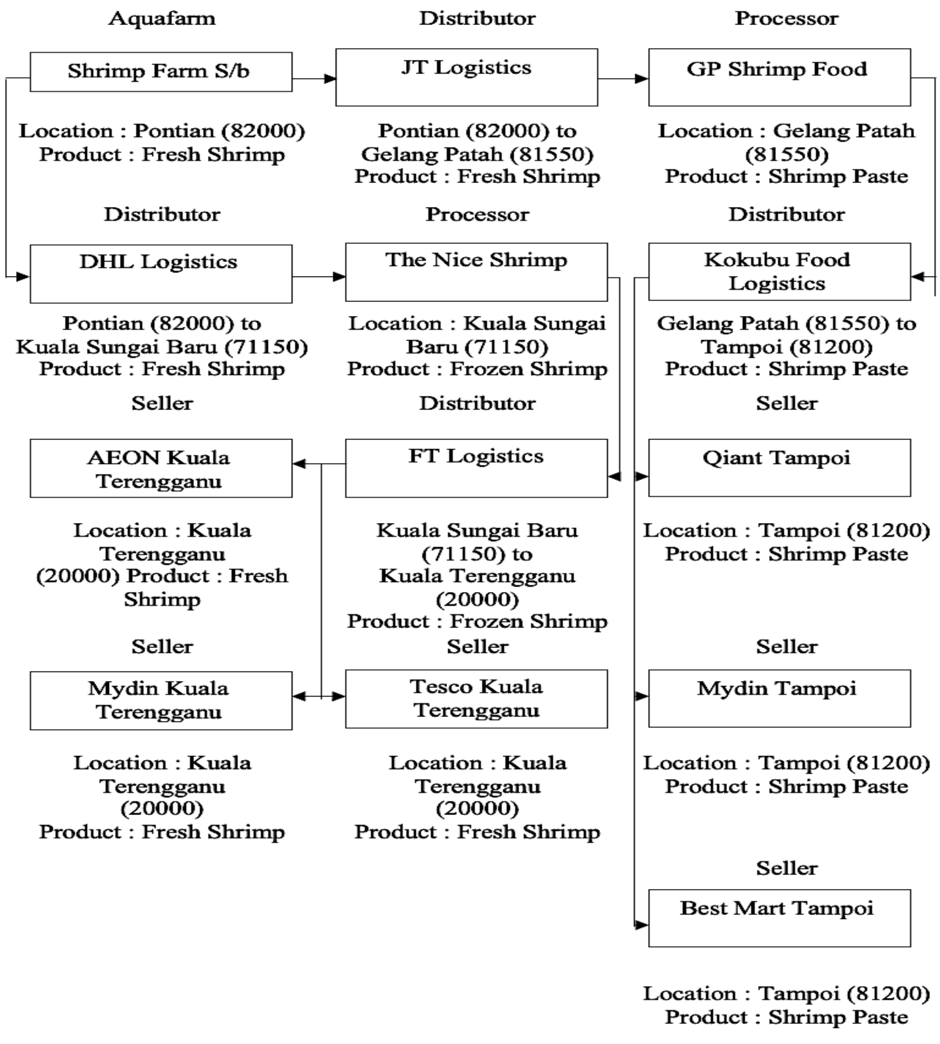

Figure 6: Superstructure of the shrimp supply chain.

```
lowxinyi@Lows-MacBook-Air python_blockchain_app-ibm_blockchain_post % python3 sea.py
The defect individual: GP Shrimp Food
The defect: GP Shrimp Food
The affected chain:
['Shrimp Farm S/B', 'N/A', 'JT Logistics'] [' GP Shrimp Food '] ['Kokubu Food Logistics', 'Qiant Tampoi', 'Mydin Tampoi', 'Best Mart Tampoi']
lowxinyi@Lows-MacBook-Air python_blockchain_app-ibm_blockchain_post %
```

Figure 7: Results of the affected chain from the seafood traceability system.

4. Conclusion

In this study, a seafood supply chain traceability system was developed. A seafood traceability system provides an interface for individuals in the seafood supply chain for inputting data. These data include product species, handling method, storage temperature, category of individual, location, and product in each stage. Consumers able understand the process of manufacturing products through the same interface but using different login methods. This seafood traceability system can cope with complex chains in a supply chain whereby the complex chain increases the chance of contamination and difficulty in tracking and tracing back the affected chain. This traceability tool plays a major role in tracking the affected chains of single and multiple chains. The contaminated product in the affected chain can be recalled or further investigated. Food safety issues can be resolved and reduced. The recalling cost will be decreased and minimize the waste of labour and raw materials. This system can be further improved by considering the food hazards and critical points along the seafood supply chain in the future study and validate with the actual seafood supply chain in the future study.

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