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Blockchain Technology in Aquaculture Supply Chains

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Abstract

Fish and fishery products are important sources of protein around the world, but the way it is caught or raised has been questioned in recent times as important as the product itself. Nowadays, consumers are more interested in knowing the source, whether they are caught or farmed and whether they are processed in a sustainable way. In this context, blockchain technology answers doubts raised by consumers. By implementing blockchain technology, the consumers will be able to obtain digital records that track the fish from its source to their plate. This article explains the working principle of blockchain and its integration in seafood industry. This article also describes the concepts employed in blockchain, types of blockchains, its implementation in seafood traceability and tools used in eventual deployment of blockchains. As the world keeps evolving digitally, blockchain technology has the potential to improve the way people trust seafood from ocean to consumption.

Keywords: Aquaculture, Blockchain technology, Consumer, Traceability

Introduction

At the global level, fish and fishery products have become one of the major protein sources, which burgeoning the demand for fish in recent times. The market demands were primarily met through the expansion of aquaculture production as the capture fishery reached its sustainable exploitation level. In contrast, modern-day consumers have started focusing on the source and methods employed during the production cycle of the fish, not only on the nutritional value of the fish. Hence, consumers need a source that gives information on the fishery product they receive on their plate. In this context, the fishery value chain comes into play, by which the consumers obtain detailed information about the source and processing methods used in fishery product. The fishery supply chain can be categorized into two major groups based on production methods and harvesting. One category pertains to farmed fish and the other pertains to wild-caught fish (Gephart *et al.*, 2017). This calls for the meticulous monitoring of activities from fish capture or aquaculture production all the way to consumption. For the past few decades, a lot of approaches have been implemented in fishing industries, such as accomplishing collaborations between public and private entities, private branding and certification programs intending to ensure sustainability, collective measures that have been implemented to oversee and control fish harvesting and its supply chain. As a result, blockchain technology can be ultimately used in order to establish traceability within the fisheries and aquaculture value chain. This article describes the blockchain technology, which ensures traceability throughout the entire fish and fishery value chain.

Concept of Blockchain Technology

Blockchain is a form of digital database distribution-based ledger system that maintains transactions associated with records of value, data and digital occurrences. This means citizens don't need a centralized entity to verify and access these transactions. When these records are appended into the blockchain, they become permanent and unchangeable and as a result, the transactions in the ledger cannot be modified. Here, the word "transaction" refers to various types of information that include records, contracts, or currency. By "consensus protocol" procedure, these transactions are validated by multiple blockchain nodes (individual internet-connected computers). These transactions are then merged to form a data block, which results in the creation of a "blockchain". This blockchain is accessed concurrently across thousands of distributed nodes, making blockchain a permanent and immutable record.

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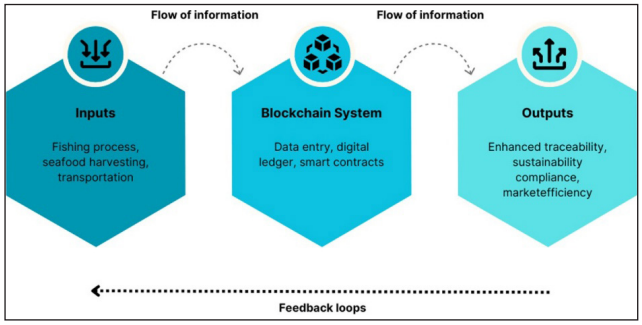

Figure 1: Framework of blockchain in fisheries (Pratiwi *et al*., 2024)

Types of Blockchains

In accordance with their intrinsic properties, blockchains can be differentiated into three types. The network participants in each category are offered with different levels of accessibility and control.

1. Public Blockchains

These blockchains are publicly available to all the users, miners and validators without any limitations on their involvement. Implementing censorship on these types of blockchains becomes difficult due to restricted central authority. All the transactions in this blockchain are completely decentralized so that the specifics of each transaction are permitted to be viewed by anybody. Public blockchains are also termed as permissionless blockchains. These blockchains include Bitcoin, Ethereum and Litecoin.

2. Private Blockchains

These blockchains play a contrasting role to public blockchains by placing limitations on validation, access and transaction execution. These blockchains can be centralized often, with network managers having substantial influence over membership and organizational setup. Only an authorized user can access the transactions that take place on this network. It is also called as a permissioned blockchain. Some of the examples of private blockchain are VeChain (seafood authentication & traceability), TE-FOOD (seafood traceability) and Tuna trace by WWF.

3. Blockchain Consortiums

In this type of blockchain, a consortium is formed where the aspects of public and private blockchains are combined. A collective of members rules the network in this blockchain. Workflow efficiency, resource sharing and accountability can be improved by this partnership, which encourages transparency throughout their business processes. Some of the blockchain consortiums are Global Dialogue on seafood traceability (GDST), IBM food trust and seafood chain consortium.

Participants and Elements of Blockchains

1. Food and Drug Administration (FDA): The primary responsibility of FDA is to ensure the compliance of blockchain by all legitimate stakeholders within the blockchain network. FDA also has the power to condemn individuals with penalties who violate the guidelines.

2. Fish Seed Company: The one who breeds and produces the seeds of fish comes under this category. Fish farmers purchase seeds from these companies. On the other side, seed companies run DNA tests and store the results on the IPFS storage system to confirm the fish species.

3. Fish Farmer: Fish farmers buy the seeds and rear them using a mixed aquaculture system that combines freshwater and saltwater environments. The environmental factors and fish growth patterns were continuously monitored by the fish farmers and for the upcoming audits; they had to upload photos and profiles of the culture system.

4. Wild-Caught Fisher: The wild-caught fisher collects the fish from natural environments such as lakes, ponds, reservoirs and oceans. They update the data on fish harvesting from the wild to the next participant of the blockchain, *i.e.*, fish processors.

5. Fish Processor: The main study participant of the blockchain is fish processor. They sort the various species of fish they receive according to their source and mode of production. Based on their requirement, fish processors may deskin, dress and fillet the fish. They also perform genetic testing and upload the information on IPFS for validation. After packaging, the packs will be sent to the distributors as processed fish packages.

6. Distributor and Retailer: Distributors receive the packages from the processors in large units and ship those units to authorized retailers, who buy the units and resell the processed fish to the consumers.

7. Consumer: The ultimate stakeholder concerning the life cycle of a fish product is the consumer. They consume the processed fish products sold in the shops at the end.

Seafood Traceability with Blockchain Technology

The main characteristic of blockchain is making the fish traceable from the point of origin to the final consumer. Some of the technical characteristics such as smart contracts, distributed data storage system, *etc*. can be used for seafood traceability.

1. Smart Contracts: A smart contract may be characterized as a self-executing digital agreement with predetermined rules and coded conditions (Lin and Liao, 2017). These smart contracts execute and verify the transactions, eliminating the need for a middleman to supervise the transactions. It can be used in several applications, including financial transactions and supply chain management.

2. Distributed Data Storage System: Distributed storage systems like Inter Planetary File System (IPFS) are used to overcome the storage limitations of blockchains. After the data are stored in the IPFS, the stakeholders can access and verify that data by using this blockchain's immutability feature.

3. Decentralized Applications (DApps): DApps serve as an interface for the participants of the supply chain to interact with smart contracts. By using these DApps, the stakeholders would be able to access the data of the product through RFID tags, QR code scanning and other tracking methods (Patro *et al*., 2022).

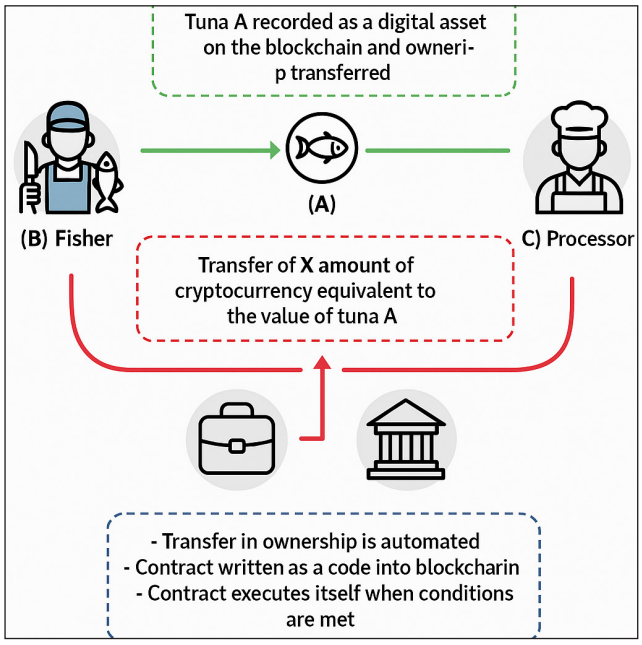

Figure 2: Illustrates how smart contracts are applied in seafood value chains. If the fisher (B) captures a Tuna (A) and registers the capture as a digital asset on blockchain, the processor (C) will reward the fisher (B) with an amount of cryptocurrency equal to the value of Tuna (A) and as soon as it is registered in blockchain as digital asset, the processor automatically claims "ownership" of the Tuna (A)

When specifying their contribution in seafood traceability, Smart contracts can enable and enforce stakeholder agreements among fishers, processors, distributors and retailers by documenting each transaction openly and without the help of intermediaries. Distributed storage systems such as the Inter Planetary File System (IPFS) can further be utilized in storing and associating necessary documentation like catch certificates, PCR testing results and videos of harvesting and handling of fish. By doing this large and important files are safely archived and readily accessed. DApps offer easy-to-use interfaces that enable supply chain stakeholders to interface with the blockchain through devices such as RFID tags and QR codes, providing instantaneous access to authenticated product information from the point of catch to the end customer. This combined system enables transparency, accountability and trust throughout the entire seafood supply chain.

Present Applications of Blockchain in Fisheries and Aquaculture

1. Traceability System: Seafood poses a high risk of traceability as the industry is extremely complex and highly dependent on old ways of working like paper-based records and spreadsheets. Blockchain offers a tamper-evident, open and permanent platform for ensuring the trust between parties with the recording of every piece of the supply chain. It helps in preventing illegal, unreported and unregulated fishing and sustainability regulations are followed.

2. Recycling of Fishing Nets and Fishing Gear: Recycling of fishing nets and gear using blockchains helps to promote transparency by allowing the end-to-end tracking of used nets and gear. Conversely, it aids in the recycling of the used fishing nets and gear into fresh goods, hence lowering marine pollution. Some programs like Ireland's Net 360 and Sea Shepherd's Ghost Network prevent sea pollution by utilizing blockchain to facilitate appropriate recycling and disposal. Automotive industries like BMW and Ford succeeded by utilizing recycled sea plastics in their auto components.

3. Tokenization of Aquaculture Assets: Fractional ownership and broader investment can be enabled by turning aquaculture assets like fish stocks into digital tokens, which in turn makes the aquaculture projects more accessible to a wider range of investors.

Future Prospects

The potential of the blockchain technology can be enhanced by the integration of Internet of Things (IoT), decentralized finance (DeFi) and automated technologies in fisheries and aquaculture sectors. IoT devices, such as fishing boxes equipped with sensors, help in tracking the environmental conditions and species verification in real time with chemical and DNA data, simultaneously reducing human error (Astill *et al.*, 2019). Microfinance opportunities can be provided to producers for implementing DeFi solutions that help the developing nations by cutting out intermediaries, lowering the interest rates and encouraging the usage of token-based incentives to boost participation. Automated technologies like Automatic Identification Systems for vessel tracking. The administrative burdens can be minimized by the integration of AI-powered fraud detection and computer vision for catch verification streamline operations, which also enhances the traceability and reliability in fisheries sector. Blockchain technology can be utilized to its fullest by integrating these methods.

Conclusion

Particularly in emerging countries, the fisheries sector is essential in confirming the food security of the planet and fostering economic development. Still, significant issues for the fisheries sector include pollution, illicit fishing and overfishing. These issues gave rise to the beginning of illegal, unreported and unregulated (IUU) fishing. This paper addressed the application of a disruptive digital technology, *i.e.*, Blockchain technology, which may solve these issues and could maybe transform the fishing sector. Despite its advantages, the integration of blockchain technology in fisheries encounters several barriers, such as limited resources and integration issues. But adoption of this technology will be critical in bringing the fisheries industry towards a transparent, efficient and sustainable industry. Hence, understanding the current applications and future regulatory scenarios in aquaculture will be crucial for maximizing blockchain effectively by overcoming its limitations.

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