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Blockchain Potential in Tilapia Supply Chain in Ghana

A. Rejeb[1]

[1] Széchenyi István University, Department of Logistics and Forwarding
Egyetem tér 1, 9026 Győr, Hungary
e-mail: abderrahmen.rejeb@gmail.com

Abstract: In a country like Ghana where Tilapia is the most preferred and cheapest source of animal protein, closer attention must be paid to the supply chain of such a product. This paper examines the major issues and problems in Tilapia supply chain and logistics in Ghana, and it suggests the intervention of the new and disruptive technology of blockchain. Blockchain technology can have the potential to revolutionize the supply chain of Tilapia in Ghana and bring many advantages to the flow of Tilapia from farmers till the end consumers. Besides, it highlights the role of blockchain in ensuring food safety and in rebuilding a trustful network of Tilapia distribution between producers and customers. A model of Tilapia supply chain based on blockchain technology will be exhibited and explained to provide relative solutions to supply chain management processes of Tilapia.

Keywords: Tilapia supply chain, Blockchain technology, Trust, Transparency, Decentralized system.

1. Introduction

Nowadays, supply chain management and logistics are considered as potent drivers of economic growth. Although firms now deal with an uncountable number of suppliers, outsourced service providers, logistic distributors, and customers, there is still ambiguity of how, when and where these products were originated, produced and used through the life cycle [1]. Similarly, the journey of products is still in every scenario unseen and beyond the supply chain partners' possession. In this context, Tilapia supply chain in Ghana represents the best frame of supply chain complexity, information asymmetry, and many other issues.

Given that fishes constitute 60 % of the protein intake in Ghana and have the potential to achieve food sufficiency, poverty alleviation and economic growth [2], the supply chain of Tilapia still knows many problems that stand against its competitiveness and profitability. In this respect, it is riddled with inefficiency since they rely heavily on paperwork, manual processes and huge numbers of people to perform a specific business transaction. In connection with inefficiency, the traditional organizational structure of aquaculture tends to drag down the supply chain through the silo mentality, wherein the inwardly focused organizational units pay insufficient attention to the external relationships and create a disjointed, disconnected and detrimental way of working [3]. Thus, there is prevention for any interaction between members of supply chain and barriers that clog the information flow between them.

Complexity is a key managerial issue that supply chain managers should address [4]. The today's immense challenges force companies to have a broad insight into products throughout the chain. It is imperative to revise the process of supply chain again and to integrate more than ever the involved partners. Hence, how companies could achieve sustainable and high performing supply chains remains the backbone question. This is neither manifested superficially by the expansion of the business nor by developing projects which are more concerned with the increased production of fish. The production of more Tilapia does not necessarily imply the profitability of farming businesses in Ghana. However, through the commitment to cope with the disruptive growth and new technologies, the profitability will increase in a sustainable manner for all value chain actors in the farmed Tilapia sector [2] [5].

Disruptive innovation is a powerful tool that taps new markets, leading to a new structure of supply chains, partners and new ways of collaboration across the network [6]. These new technologies change competition entirely by altering the performance metrics firms use to gain their competitive advantage. In this context, blockchain technology has been introduced as a breakthrough with high appreciation to its enormous potential in many fields [7].

Blockchain technology appeared firstly to support the new forms of digital currency Bitcoin in 2008. Nevertheless, it has many applications nowadays and it constitutes new foundation for a transaction in our increasingly digital society. In fact, blockchains have been deployed in reinventing currency, finance, economics, government affairs, legal services, healthcare and an unlimited number of other fields [8]. For simplicity, blockchain technology is the new pillar of distributed ledgers which trace chronologically the chain of "blocks" and each block contains a record of valid network activity since the last block was added to the chain [9]. The core principle of this new groundbreaking innovation is the decentralization of

transaction handling between industries and businesses. That is to say, there is a distributed database, replicate across many locations and operated jointly by a collective [10]. Also, researches and articles used to frame the exact meaning of blockchains are mainly periodicals since the concept is still new and at its infancy phase. The original work and application of blockchain technology has been introduced by the Japanese inventor and founder of Bitcoin Satoshi Nakamoto. Then, the same technology has been employed and affiliated to apply smart contacts and other business applications in the industry to optimize the company's operations and maximize therefore its bottom line.

This research paper will begin by introducing the literature review on the major issues in Tilapia supply chain management and logistics in Ghana. The next part will illustrate the flow diagram of the Tilapia supply chain and introduce the blockhain framework in Tilapia industry. Then, we will evaluate the contributions of blockchain adoption in Tilapia industry and how this technology will bring solutions to the problems inherited from the current supply chain model. A discussion part will be outlined base on the role of blockchain in improving customers' trust in the authenticity of supplied Tilapia and the infrastructure required to adopt this technology in Ghana. Finally, we will make a brief conclusion for the paper.

2. Literature Review

Fish and fisheries products represent one of the most traded commodities in the world food sector, accounted for 78% of seafood products traded at a global scale [11]. In this context, the Tilapia aquaculture industry experienced fast growth and it is spread throughout all continents. Tilapia is farmed in more than 80 countries and the production methods emanate from the artisanal to intensive operation [12].

Since the Food and Agriculture Organization reported rapid progress made by Sub-Saharan African countries, namely Nigeria, Uganda, Kenya, Zambia [13], the growth in aquaculture production in Ghana remains the most remarkable one. The production was estimated 26000 tons in 2012 [13]. Ghana is seen as the most capable Sub-Saharan African country to increase importantly its fish production. The reasons that put Ghana on the pedestal for this exponential growth are the development of a national aquaculture strategic framework [14], the effective policy of the national fisheries [11] , and the initiation of national aquaculture development plan that aims to increase the production from 10200 to 100000 tons between 2010 and 2016 [11]. Tilapia aquaculture production followed the current growth trend and recorded a growth of 28000 tons between 2006 to 2013 [11]. The production growth of other species has not reached the cadence of Tilapia aquaculture.

Although Ghana makes great strides in Tilapia industry, there are still persistent problems in the supply chain and logistics of such commodity. Fish farmers are unable to produce Tilapia at competitive costs on the international market [15].

Besides, the Tilapia supply chain in Ghana is characterized by its high complexity and it is fragmented into many activities, from the upstream to the downstream supply chain partners and the multitude of short chains [13].

Given that Tilapia supply chain in Ghana splits between the artisanal and the modern urban-biased (i.e., it is one among different types of the farmed Tilapia) and that there is an increased sense of better traceability in terms of products and profit flow through the modern urban-biased chain [13] because farmers are the owner of distribution or sales points, this could not deny that a gap of transparency may occur between the partners of supply chain. Besides, the aquaculture of Tilapia in Ghana is dominated by many smallholder fish farmers who have weak connections between them and their aquaculture input suppliers [5]. This weak linkage between the different actors in Tilapia value chain makes many of Tilapia farmers unable to be competitive and have strong value chain network.

Many traders and partners do not differentiate between the farmed and wild Tilapia and there is limited distinction in the marketing of wild and farmed Tilapia, and the two often share the same marketing chain [16]. Also, the buyers of Tilapia do not possess any means to follow up and evaluate the quality of Tilapia they buy from producers and farmers. The small-scale pond farmers find feeds at very high and sometimes unaffordable prices. Besides, the number of cage farmers who use consistently commercial feeds is limited due to capital constraints [5]. Alternatively, they resort to feeding source like cocoa pod husk, palm kernel cake to compound their own feed on-farm. Although they are proven to be viable, these ingredients are not produced under the strict bio-secure condition, and this subsequently affects the quality of Tilapia. Consequently, this may also give a room for quality issues, lack of trustfulness in products, and product safety risks.

The typical Tilapia supply chain in Ghana includes a vast majority of fish farmers who mostly sell their harvest to wholesalers or retailers and the retailers in return sell to the final consumers. Among the major institutions and interveners in the supply chain to support Tilapia trade operations are the fisheries commissions, Ghana Standards Authority, and Food and Drugs authority. The certification, traceability, and enforcement of sanitary conditions are the main services rendered by these institutions. Despite the presence of these regulatory bodies dedicated for fish farming control, consumers' concerns are increasing about the health implications of Tilapia due to pollution and the use of chemicals in the storage and conservation of Tilapia under unstable electricity supply conditions [17]. Therefore, Tilapia supply chain plays a major role in providing a rich source of

nutrition to Ghanaians. Proper supply chain management and building transparent value network are essential for production efficiency, processing, distribution and retailing of Tilapia that meet customer's expectations in terms of quality and sanitary conditions compliance.

3. Tilapia Supply Chain and Blockchain Technology

3.1. The Traditional Tilapia supply chain

The Tilapia supply chain follows the multi-stage supply chain system which consists of the following various actors: input suppliers, farmers, Tilapia processors, traders, retailers, institutional buyers, and final consumers. Figure 1 describes in detail the different partners of the supply chain and their roles. Input suppliers start the upstream flow in the chain. Their main role is to provide farmers with the raw materials. They consist mainly of cage and pond constructors, fingerlings suppliers, feed suppliers, and nets fishing. In addition, farmers are classified into two categories Pond Farmers and Cage grow-out Farmers. Their farmed Tilapia goes through the processors which are central to the value chain because they deal with all partners in the chain. The processors of Tilapia are predominately women [5] who provide the service of gutting and scaling the fish to traders, institutional buyers, and consumers at the points of sale. The interaction between the processors, traders and institutional buyers (e.g., restaurants, hotels) is direct since those actors do often outsource the service with bulk or large quantity of Tilapia to be processed at either distribution points or sales outlets. Traders consist of wholesalers, distributors, and retailers. Wholesalers are the only actors who are in direct connection with the farmers and they supply both distributors and retailers. Retailers can also be either provided by distributors in relatively small quantities or by wholesalers in more significant quantities. Final consumers buy Tilapia from retailers' sales point and at restaurants, hotels.

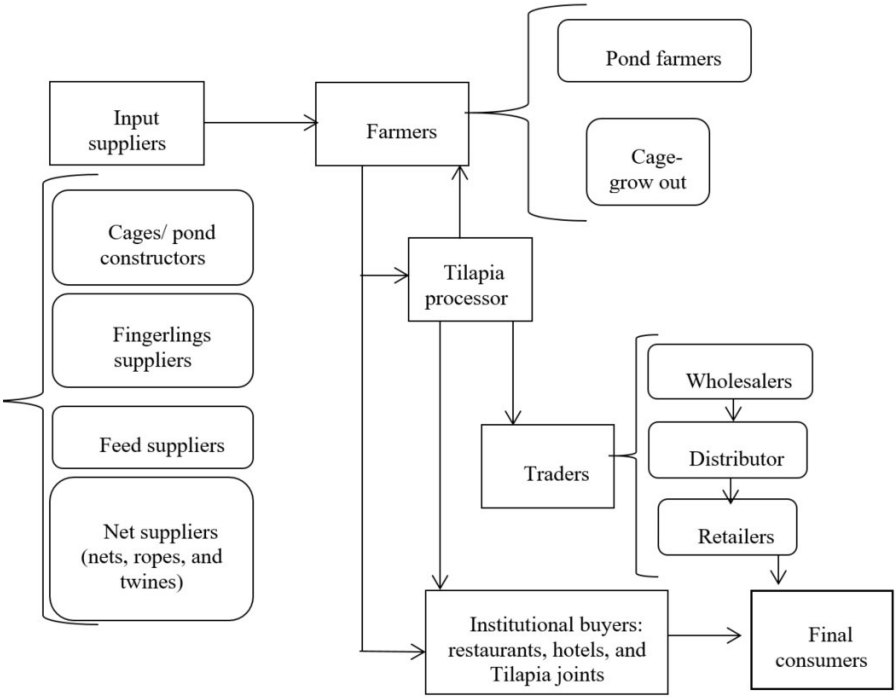

Figure 1. Tilapia Supply Chain in Ghana

3.2. Conceptual Framework of Blockchain-based Model

"*The blockchain is an exchange network for moving transactions, value, assets between peers, without the assistance of intermediaries*." [18]. It is also defined as the network of exchange and moving of value between the interested parties in the business. Besides, blockchain can be also described as the platform whereby peers or partners exchange values using transactions without the need for a central trusted arbitrator [7]. The business of blockchain encompasses the exchange of money, the flow of information and the effective allocation of resources that were enabled by money in the human and corporate level of the economy [19]. In actuality, some of the most promising non-finance applications are expected to involve those in the supply chain, power and food/ agriculture [20]. In this section, we will discuss the integration of blockchain technology in Tilapia supply chain.

So, all supply chain partners mentioned previously should register themselves in the peer-to-peer network and match their identities and digital profiles in back-end database which maintains an openly distributed ledger that can be inspected at any time and from any location [18]. After registration, each user (i.e., node) will be provided with a public and private cryptographic key. The public key serves to identify the user within the system and the private key can be used for authentication when interacting in the network. The different phases included in the value chain are: Procurements, Farming, Processing, Distributing and Retailing.

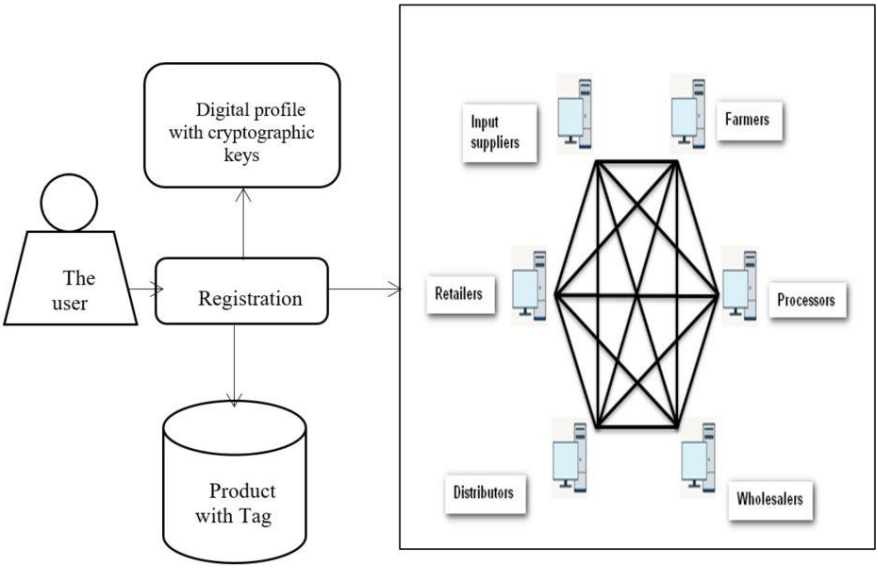

Figure 2. Conceptual framework of Tilapia blockchain (adapted from Tian 2016)

4. Evaluation of Blockchain in Tilapia Supply Chain

4.1. Procurement

At procurement stage, Farmers will get the raw materials which consist of fingerlings, hatcheries and feed supplies. The input suppliers may register under the blockchain network and a digital profile of fingerlings is updated in the distributed ledger by providing essential information about the fingerlings (e.g., the hatcheries' environment, the growth condition, information related to their feed). The implementation of blockchain in this phase will increase the quality of

fingerlings and the control over the climatic changes on hatchability of fish eggs. The challenges encountered by African farmers in general and Ghanaians in particular regarding product quality [17] could be effectively eliminated with the introduction of blockchain instead of opting for the self-production of fingerlings.

4.2. Farming

The harvested Tilapias are packaged in corrugated cardboard boxes and labeled with RFID Tag, and then each fish box will be entered into the blockchain with a digital profile. Many answers to questions regarding the system will be provided through the blockchain such as the characteristics of the harvested Tilapia, their sizes, their weights, the harvesting intervals of fish, and even the staffs responsible for their harvesting and packaging. Besides, the raising of Tilapia becomes so transparent under blockchain use since the downstream supply chain partners can figure out the quality of Tilapia feeds, the temperature, the water salinity, the oxygen levels, the volumes of water, and the stocking density of tilapia. After that, a business transaction is initiated between the farmers and the traders or the institutional buyers, where the products are exchanged after signing a digital contract (smart contract) which is resided within the blockchain in order to execute a required function when certain conditions are met (e.g. the release of funds, the transfer of information, and the purchase of Tilapia...). Consequently, the business transaction becomes automated and it crosses beyond the boundaries of the farming companies in a secure and decentralized manner. For instance, to counter the risks attributed to the shipment of Tilapia to customers, a smart contract can be the solution to ensure that the payment by the customers will be only released if the shipping company confirms the delivery of Tilapia in appropriate conditions.

4.3. Processing

The actual processing activities raise many questions relative to the adequacy of food safety knowledge [5], and the growing mandatory regulations are not enough to ensure food safety. In blockchain model, one food safety inspector can evaluate the processing facility and enter the information regarding the gutting and scaling of Tilapia, the cleanness of the processing environment, and the use of stainless tables and equipment. During the processing, tags of Tilapia unit loads may be destroyed, but their digital profiles will be updated throughout the blockchain system and new tags can be attached to the packages of processed fishes. Thus, this helps to ensure the compliance of processing operations to the necessary sanitary requirements.

4.4. Distribution

After receiving the Tilapia from processors, the information of Tilapia warehousing and storage will be continuously updated in the system. This can be achieved easily through the use of Internet of Things (IoT) equipment such as wireless sensors and monitoring devices which ensure the real-time storage information of the product (i.e., the quantity, the temperature, the humidity) [21]. Therefore, this helps managers to better track storage and make judgmental decisions relative to the release of storage in case of risks of spoilage and perishability.

The distribution process under blockchain framework entails to safety in the transportation of Tilapia. This is demonstrated by the use of vehicles equipped with a safety system which controls the temperature and the humidity in the different areas in the refrigerated containers. This enables possibilities to track real time environmental data of Tilapia and the system can be easily implemented and the integration of IoT equipment is affordable. For instance, GPS system helps to position refrigerated trucks from remote distribution centers and identifies the optimal routes to short delivery time in a way to preserve the freshness of Tilapia.

4.5. Retailing

After receiving Tilapia, all retailers maintain the full information of the flow of the product in the supply chain. The traceability of the products can be achieved through the details stored in its digital profile on the blockchain. Any person registered in the blockchain network could figure out the freshness of stored Tilapia and their shelf life in a real-time manner. Consequently, blockchain yields to shift away from the centralized tilapia supply chain to a new decentralized system which eradicates trust problems, such as frauds, tampering and falsifying product information. Furthermore, all supply chain partners are informed with the permanent history of the product and operate in a common platform which promotes more openness, transparency, reliability and security.

5. Blockchain- Based Supply Chain: Tilapia Authenticity and Infrastructure

5.1. Blockchain and Product Originality

Since the traceability system assumed in this paper is based on the use of RFID tags to store information in the different stages of the supply chain, the manual retrieval and storage of this information in the central database pose a problem. This is manifested by the possibility of reproducing or forging information at any

time [22]. Similarly, it is difficult to identify counterfeit products accompanied by misleading provenance histories. However, blockchain technology helps to ensure the authenticity and provenance of Tilapia through an effective trace-back capability. In fact, the customer can figure out the complete data and related information by entering the digital identifier (ID) in the blockchain system. When the ID is entered, the customer in the supply chain will be provided by all related information and data from the retailers to the farmers. Given that the details of sold Tilapia are also recorded in the blockchain, it is not possible to sell the same item twice. Consequently, the blockchain system prevents any fraudulent actions related to the intentional fish mislabeling and species substitutions. Besides, fish traceability is key to fighting fish fraud, enforcing the safety regulations and ensuring high standards of sustainable fisheries management [23]. In this respect, blockchain will provide a unique digital product memory for not only the finished processed Tilapia but also for the ingredients, the raw materials, and all the quality certifications and data used in the entire supply chain. Thus, it is evident that by assigning blockchain technology which is resistant to falsification, immutable, and traceable, the platform enhancement is ensured by a move toward genuine product originality assurance that meets customers' expectations.

In addition, to solve the problem of RFID tags' information interrogating and cloning while the products reach the end of supply chain and are displayed in retail stores, Toyoda et al. proposed a novel Product Ownership Management System (POMS) [24] which makes the efforts of counterfeiters to clone genuine tags redundant since they cannot prove the possession of products on this system. In fact, the concept of proving "the possession of products" and designing POMS helps to manage and track the possession of Tilapia from their input suppliers (i.e., when they are fingerlings) to the current owners (i.e., they are assumed to be retailers). With the application of this scheme, any potential counterfeits may be detected if a party cannot prove the possession of claimed products. Their proposed system is built upon the requirements of having; only the legitimate manufacturers' role to claim the initial ownership (origin) of products, each manufacturer can declare their own products, the events "Shipped" and "Received" can be separated, and a manufacturer must give some incentives to each party who follows the POMS protocol [24]. The overall objective of their proposed solution in supply chain applications of the blockchain technology is the proof of origin [25] which helps in turn to increase customers' trust in products' originality.

To sum up, the traceability of provenance under blockchain system helps to assure that no individual entity or actor can corrupt the chain of custody and hence the final consumers will have more trust in the supplied Tilapia.

5.2. Blockchain Infrastructure and Challenges in Ghana:

Several blockchain projects were underway in so many countries, and the speed of expansion of government-led blockchain projects is astonishing at the global scale [26]. Moreover, to face the problems related to land registry in Ghana and the corruption that creates obstacles for both citizens and foreign investors in all kinds of real estate and business dealings, Bitland was introduced in 2013 as an experimental platform using blockchain technology to bridge the gap between the government and the undocumented areas for land registry and title services [27]. Another startup called Benben was created for the same purpose. Therefore, Ghana has benefited from existing tech hubs and networks to adopt blockchain technology and thus have a fertile innovation ecosystem that could enhance its local development [28] and extend to other fields such as supply chains and logistics.

The concentration of food production in developing countries involves many challenges in the supply chains since there are high corruption levels and insufficient environmental, social and economic regulatory frameworks [29]. Thus, a decentralized platform based on the blockchain technology is an interesting option for these countries. For blockchain to be implemented in Tilapia supply chain in Ghana, the engagement across the whole supply chain is required. In other words, the input suppliers, farmers, processors, wholesalers, retailers, and other supply chain actors must be willing to adopt the technology. Besides, internet connectivity and digital literacy are required for the potential adoption of these technologies in the aquaculture sector since the most significant operational risks and challenges are mainly due to insufficient (and few) numbers of people who understand blockchain functioning [30]. Infrastructure partnerships including the government, international companies (e.g., IBM) and potential startups can work jointly to raise new solutions for current problems in Tilapia supply chain. Moreover, blockchains rely heavily on the extensive use of cryptographic tools which require the development of several kinds of infrastructure, or infostructure known as public key infrastructure [28]. This infrastructure consists of a set of roles, policies, and procedures required for securing the electronic transfer of information between the supply chain actors. Although the institutional capacities in developing countries are not enough for harnessing blockchain technology and facilitating its adoption on a sustained basis, Ghana institutions can embrace the use of blockchains by either importing know-how and expertise or using local expertise, if available, outside government [28].

Despite that fact that blockchain technology may contribute to the reduction of transaction time and costs by eliminating third-party intermediaries within the Tilapia supply chain and overhead costs for exchanging the products, the high initial implementation cost can be a deterrent for small farmers in the aquaculture

sector [30]. Additionally, the Ghanaian government may consider putting more efforts into blockchain adoption in Tilapia supply chain by a further promotion of the cultural acceptance and the shift brought by this technology in the sector of aquaculture. The government support by funding and setting the appropriate regulatory framework is necessary for the successful implementation of other extended blockchain projects.

6. Conclusion

This paper aims to present the potential benefits that blockchain technology could bring to supply chain management and logistics. As an application scenario, the case of a much-traded commodity in Ghana is chosen to demonstrate how blockchain can solve the current problems and pitfalls in the supply chain of Tilapia. This new disruptive technology is a ground-breaking innovation which emphasizes the importance of a decentralized system in improving visibility, traceability, and collaboration across the supply chain. Businesses, suppliers, retailers, and distributors get hold of events happening within the chain and monitor the quality and safety of Tilapia. In the near future, Tilapia supply chain actors may consider to invest in tracking technologies such as RFID, GPS, genetic marking and to store all the critical data gathered in this process on a blockchain to ensure transparency and traceability for aquaculture farmers, consumers and everyone in between. This research taps a new area in supply chain management since blockchain implementation in such field is still yet at its infancy stage and it provides solutions to the current customers' growing concerns about safety and quality products in food supply chain.

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