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Use of Block Chain in Tracking and Tracing Supply Chain of Fruit Products: A Readiness Survey I Makueni County, Kenya

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Abstract: ***With the growing demand for transparency, quality control, and traceability in agricultural products, blockchain technology offers a potential solution to the agriculture sector's problems with fraud, spoilage, and inefficiencies. A readiness survey was conducted to assess the adoption of blockchain by key participants in the fruit supply chain, including farmers, processors, wholesalers, and retailers. The survey looked into things like local supply chains' perceived potential and problems, technological infrastructure, and knowledge of blockchain's advantages. The findings point to differing degrees of preparedness, with some stakeholders expressing delight about blockchain's potential to increase market access, decrease post-harvest losses, and improve product traceability. However, issues including poor technology access, a lack of digital knowledge, lack of legal framework and the upfront expenditures of implementation were cited as major obstacles. In order to promote a blockchain-enabled, transparent, and effective fruit supply chain in Makueni County, the findings highlight the necessity of customized approaches to increase knowledge and technological capacity, increase awareness, and close infrastructure gaps. This -survey offers insightful information about the viability and uptake of blockchain technology in a rural agricultural setting, as is the case with the four sampled sub-counties.***

Keywords: block chain, transparency, tracking and traceability, fruit products

1. Introduction

Blockchain-based supply chain management has emerged as a game-changing method for boosting transparency, efficiency, and accountability across a range of industries (Gaurav et al., 2022). The agricultural sector stands to benefit greatly from blockchain's ability to produce an immutable, transparent record for product monitoring and tracing from farm to table, particularly in terms of enhancing food safety, quality control, and fraud prevention (Zhang et al., 2021). In fruit supply chains, where issues like fraud, rotting, and lack of traceability are common, blockchain can ensure that all parties have real-time, verifiable access to information about the product's origin, handling, and condition (Alaoui et al., 2021). A vital agricultural area in Kenya, Makueni County is well-known for producing crops like oranges, tangerines, papaws, bananas and mangoes, but it also faces challenges in ensuring the quality and traceability of its agricultural products (Sartor et al., 2022).

The purpose of this study wasto determine how prepared Makueni County fruit growers were to use blockchain technology for fruit product monitoring and tracing. This study assessed these players' technological infrastructure, awareness, and desire to adopt blockchain-based solutions through a readiness survey. The study's conclusions advances- knowledge of the potential for blockchain adoption in the fruit supply chain and offer useful information to industry stakeholders, technology developers, and policymakers. The survey's findings can guide future plans for using blockchain technology to improve Makueni County's fruit supply chain's efficiency and transparency

2. Related Work

Blockchain technology has generated a lot of attention in supply chain management, particularly in relation to tracking and tracing products, because of its potential to increase efficiency, traceability, and transparency. Blockchain's potential to improve food safety, reduce fraud, and expedite logistical procedures has been highlighted in a number of studies that have looked at its application in food and agricultural supply chains. In their comprehensive study of blockchain applications in food supply chains, for instance, Alaoui et al. (2021) highlighted how blockchain can ensure traceability, increase consumer confidence, and prevent foodborne illnesses by keeping accurate records (Kim et al., 2023; O'Dwyer et al., 2024). Tracking perishable goods, such as fruits, where quality control and quick supply chain movement are essential, is made possible by blockchain's capacity to give real-time, unchangeable records.

Blockchain can help with issues like food spoiling, false claims of origin, and incorrect labeling in the context of fruit supply chains. In their investigation of blockchain integration with IoT (Internet of Things) devices in the fruit supply chain, Gaurav et al. (2022) proposed that sensor data in conjunction with blockchain could offer a comprehensive picture of a product's journey from farm to consumer, including handling conditions, temperature, and humidity. In markets where fruits are particularly perishable and sensitive to handling

conditions, this can greatly minimize waste and increase product quality. Furthermore, Kim et al. (2023) showed how successful blockchain-based traceability systems are in the fresh produce industry, demonstrating that buyers are more inclined to believe in goods with verified origins, which raises demand and market value for agricultural products.

The advantages of blockchain technology in agriculture have also been highlighted by a number of case studies, especially in underdeveloped nations where trust and transparency are frequently absent. O'Dwyer et al. (2024) emphasized the potential of blockchain to improve supply chain efficiencies in developing nations in their study on blockchain adoption in agriculture. They also emphasized the significance of readiness assessments to determine the technological infrastructure and stakeholders' willingness to adopt such innovations. Their research highlights how local stakeholders, such as farmers, distributors, and retailers, must be ready for blockchain deployment because lack of infrastructure and knowledge could make integration difficult. For areas like Makueni County, where agriculture is a major economic driver and many stakeholders might not be familiar with emerging technologies, this is especially pertinent.

Another important issue in fruit supply chains is food safety, which blockchain might help with. According to Sartor et al. (2022), blockchain can improve food safety by guaranteeing precise documentation of every product's path and any interventions or treatments it has received. Consumer confidence in markets with increasingly strict food safety regulations depends on traceability, which allows customers and regulatory agencies to be sure of the product's quality and safety.

Additionally, smart contracts are becoming more widely acknowledged for their ability to automate transactions and guarantee compliance. Blockchain-enabled smart contracts in the supply chain can autonomously initiate payments or release goods based on predetermined criteria, minimizing delays, fraud, and human error (Zhang et al., 2021). This functionality is particularly helpful in fruit supply chains, where prompt delivery and payment are important for protecting the integrity of perishable items.

There are obstacles to blockchain adoption for tracking the fruit supply chain. According to Liu et al. (2023), the digital divide, interoperability problems, and data privacy are the main barriers to blockchain implementation in agriculture, especially in poor nations. In areas like Makueni County, where technological infrastructure might not be as developed, these problems must be resolved to guarantee successful implementation. Furthermore, it has been demonstrated that readiness surveys are useful for determining stakeholders' ability to successfully adopt blockchain technology. The significance of readiness evaluations in detecting gaps in organizational, technological, and human resource preparedness was underlined in a research by Singh et al. (2021) on blockchain adoption in supply chains. This is especially crucial in rural regions like Makueni, where effective blockchain integration would require education and awareness campaigns.

By guaranteeing transparency, enhancing productivity, and boosting customer confidence, the application of blockchain technology to fruit product tracking and tracing has the potential to revolutionize supply chains. However, resolving preparedness, infrastructure, and technology issues unique to areas like Makueni County is essential to its successful deployment. A readiness assessment helps identify these elements and offer important insights on how blockchain technology can be successfully incorporated into the local fruit supply chain to benefit all parties.

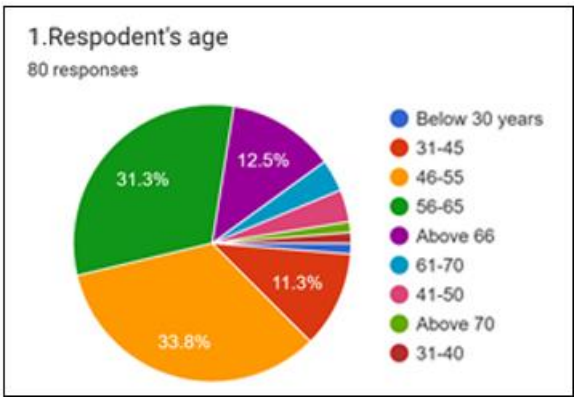
3. Methodology

Makueni County was the study's location. Taita Taveta, Machakos, Kajiado, and Kitui Counties are all adjacent to Makueni County. The county's prominence in producing a wide range of fruits for both domestic and international consumption influenced the choice of Makueni County. The goal of this study was to use the knowledge that farmers and other supply chain participants had gained to help accomplish the desired results. Six subcounties make up Makueni County.

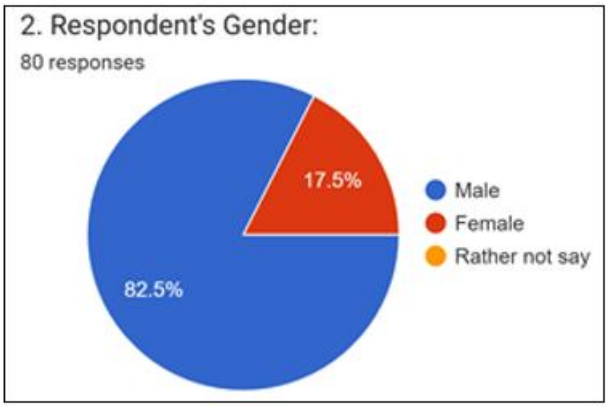
Four sub- counties; Makueni, Mbooni, Kaiti and kibwezi west were sampled. This was informed by the geographical positioning of the four sub-counties, which makes them suitable for growing fruits The study involved farmers from the four selected sub counties The survey targeted at least 20 respondents from each sub-county making total sample size of 80 farmers. Data collection tools were administered to the sampled population. A questionnaire was used to gather data on the existing production and supply chain mechanisms. The questionnaires was interviewer administered through google forms to increase accuracy and completeness of the data collected.

4. Research Results

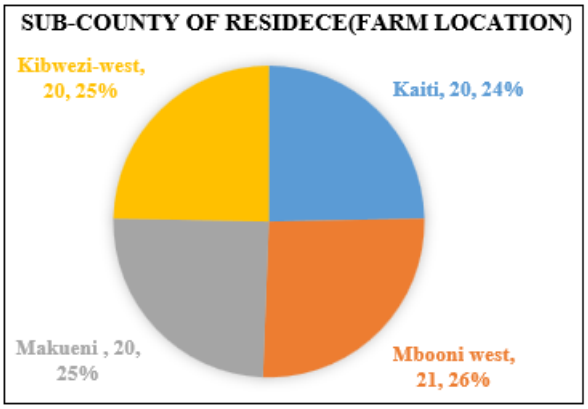
The following were the results from the data collected from the four sampled sub-counties in Makueni County captured per theme



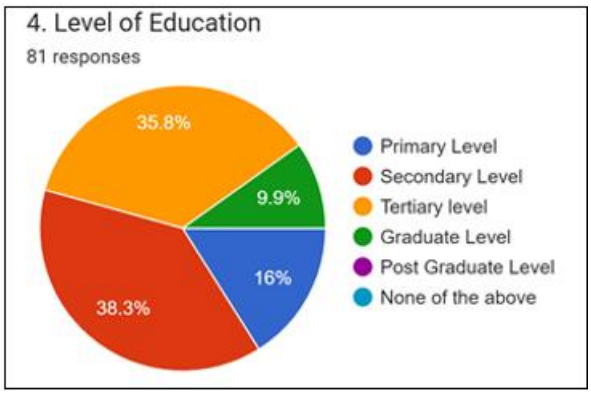
The largest number of respondents sampled was within the age bracket of 46-55 at 33.8%, followed by 56-65 age bracket at 31.3%. The third was above 66 at 12.5%., the lowest was 31-45 age group. This indicates that majority of those participating in fruit farming in the sampled population are above 45 years. This implies that the uptake of agriculture among those below 31 years is low.



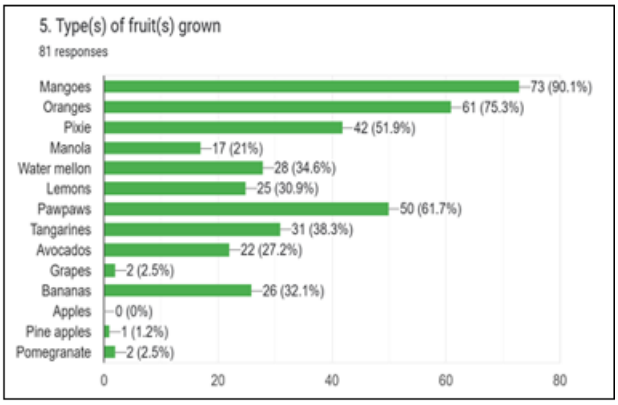
The findings show that men involvement in fruit farming is at 82.5% while female involvement is at 17.5%. This corroborators the fact that 99% of land ownership in Kenya is by men (Kenya land allocation 2021) although women contribute 80% of the work force in agriculture.



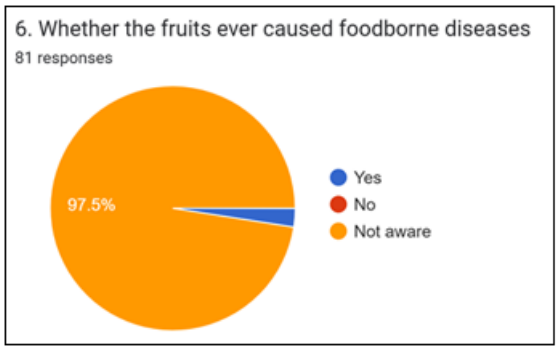
Four sub-counties were sampled. The respondents' distribution was Kibwezi-west 20 farmers accounting for 245%, Makueni 20 farmers accounting for 25%, Kaiti 20 farmers at 25% and Mbooni-west 21 farmers at 26 % of the total sample size. This shows that the response rate was good in all the sub counties.



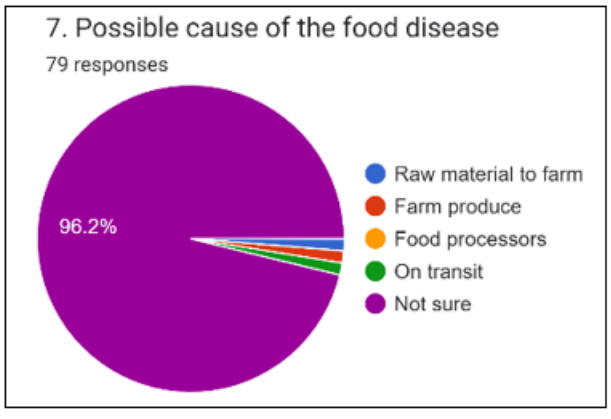
38.3% of the respondents had academic qualifications of secondary level, followed by Tertiary level at 35.8%. Further 16% had primary school level while only 9.9% were graduates. Majority of the farmers have academic qualifications of secondary school and above at a combined percentage of 74.1%. This implies that it is possible to introduce block chain concept in fruit farming due the relatively good literacy level among the fruit farmers.



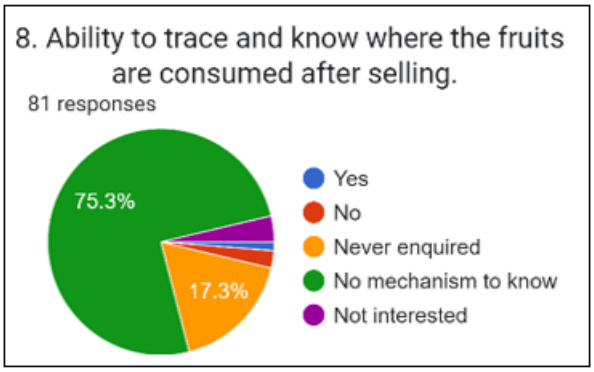
As shown on the bar graph, a variety of fruits are grown in the sampled sub-counties. All the sampled farmers grow more than one type of fruit. Of all the fruits grown, Mangoes is the most common, followed by oranges then papaws. Pixie and tangerines are the fourth and fifth respectively in order of popularity of growing. Pineapples are the least grown while apples are not grown in the sampled areas



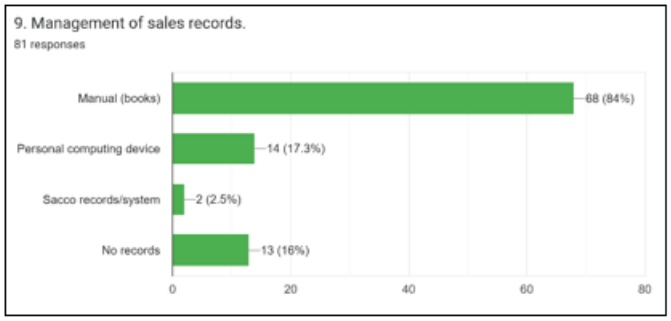
97.5% of the sampled respondents were not aware if their fruits have ever caused a food-borne disease. Response implies that there is need to embrace the block chain concept to track and trace the supply chain for fruits to determine the impact of the product on the consumers.



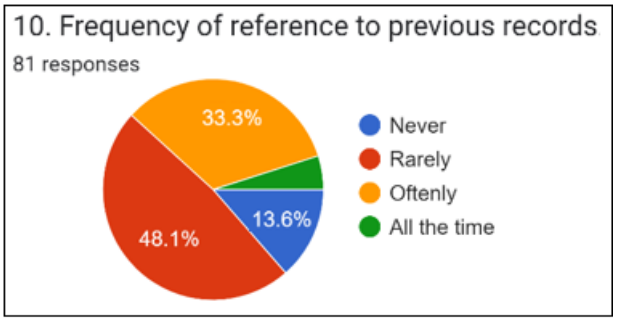
Of the 2.5 % who had an idea that their products had caused food born disease, 96.2% of them were not sure of the actual cause This implies that the farmers have no mechanism no monitor the fruit supply chain.



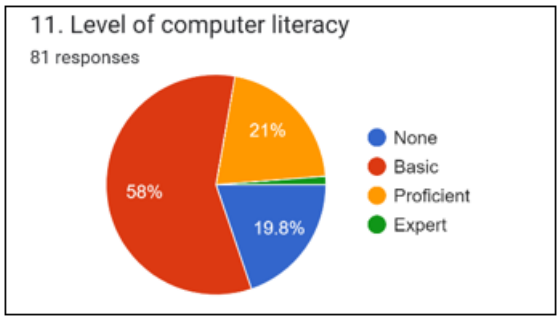
5.5% of the Respondents were not aware where their fruits were consumed after selling. 17.3% have never enquired about it while 75.3% were not aware where the fruits are consumed because they did not a mechanism to know. The results imply there is need to have a mechanism help the farmers to trace and know where their farm products (Fruits) are consumed, hence the need to embrace block-chain technology.



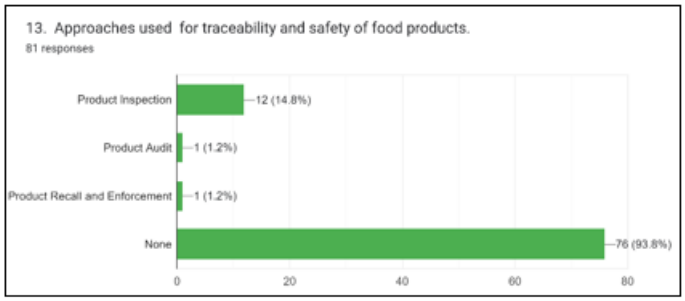
Majority of the Respondents use books to record their sales at 84%, while 17.3% keep records in personal computing device. 16% have no records while 2.5% depend on SACCO record system to keep their records. These results show that there is need to embrace and train farmers on e-record keeping practices.



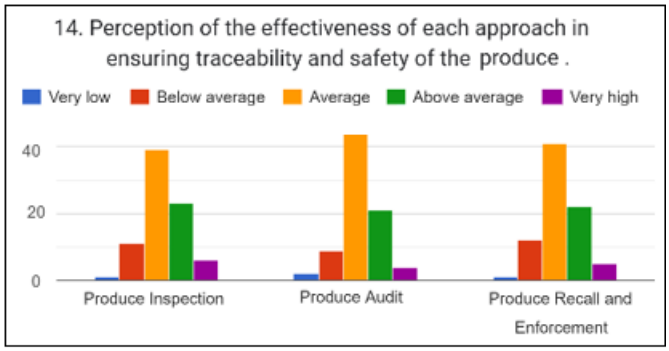
61.7% either never or rarely referred to the records while the rest (38.3%) did so oftenly or all the time. The results show that the farmers should be trained on record keeping and use to improve their efficiency.



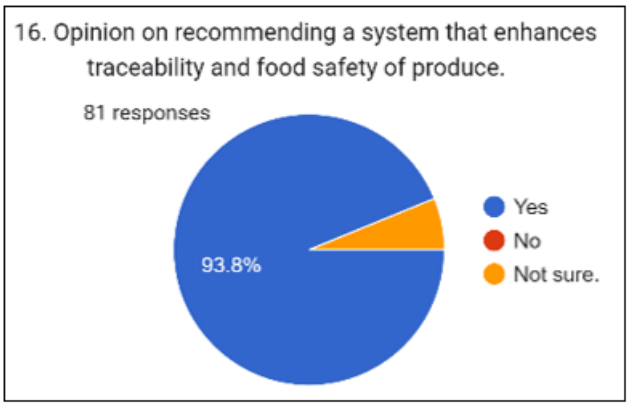
Majority of the respondents representing 58% had basic computer skills. 21% are proficient in computer skills while 19.8% have no computer skills. Only 1.2% were expert in computer skills. The relatively high percentage of IT literacy implies that it's possible to leverage on technology to do record keeping and track and trace fruit supply chain.



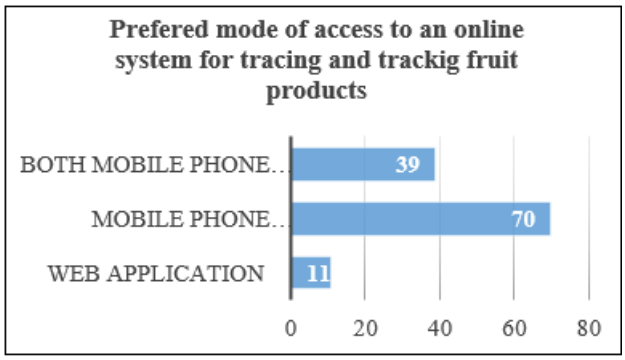
93.8% of the Respondents have no mechanism for tracing and monitoring safety for their fruits. 14.8% do fruit inspection before selling as a way of enhancing safety while the rest either use product audit or product recall and enforcement at 1.2 % each category. The finding suggest that most farmers are unable to get a feedback on the safety of their farm products hence not able to learn areas of improvement.



The respondents identified the Lack of technology, Lack of Know-how, Lack of mechanism, Lack of adequate resources, lack of capacity and literacy as the challenges faced in product traceability and product safety.



93.8% of respondent felt that there was need for a system that enhances traceability and food safety of fruits.



With respect to the means of accessing the system of enhancing traceability and safety, majority at 70 preferred mobile phone access, 11 preferred web application while 39 preferred both mobile application and web application. The response is most likely informed by the fact that mobile phone access is higher than web applications among the farmers in rural areas.

5. Discussion

This study provides an investigation of the feasibility and readiness of implementing blockchain technology to improve the fruit supply chain's transparency, efficacy, and sustainability in Makueni County, Kenya. The results demonstrate how blockchain technology has the potential to revolutionize fruit product monitoring, tracing, and verification from farm to consumer. In order to manage their fruit supply chain, respondents have indicated that they are willing to embrace new technologies.

However, it is of great concern that very few of them are maintaining records of their sales, worse still a portion of them have no records at all. In this case, more to block chain providing remedy of immutable, real-time tracking data, stakeholders would gain from increased traceability if every stage of the product journey was documented on a decentralized ledger. This may result in better product quality, more consumer trust, and access to premium markets.

The study also identifies a number of issues that must be resolved for blockchain adoption to be successful. Lack of technological expertise and digital literacy among farmers is one of the biggest obstacles found. Evidently, there is relatively high percentage of IT literacy among the respondents which implies that it's possible to leverage on technology to do record keeping and track and trace fruit supply chain.

Although blockchain's potential is generally seen favorably, the majority of stakeholders are not aware with its technical features, which may prevent such technologies from being widely adopted. Additionally, there are significant barriers to the successful deployment of blockchain systems due to infrastructure constraints, namely with relation to internet connectivity, smartphone adoption, and access to technical support services. Stakeholders may find it difficult to use blockchain for tracking and tracing fruit items in the absence of strong digital infrastructure.

Frameworks for regulations and policies are another important issue. Farmers and businesses are unsure of how to safely and legally use blockchain technology in agriculture since the Kenyan government has not yet put clear policy guidelines in place. Smallholder farmers have little reason to invest in blockchain-based solutions without government support, particularly as the advantages of blockchain technology are not immediately apparent. Furthermore, unless specific financial incentives or subsidies are implemented, the significant upfront expenses of deploying blockchain solutions—such as software development, training, and hardware—may further discourage adoption.

The readiness study also shows that stakeholders are largely upbeat about the long-term advantages of blockchain adoption, despite these obstacles. This is clearly evident where more than 90% recommended a system that enhances traceability and food safety of produce. More so a big majority of the respondents recommended use of mobile phones to implement the block chain solution. Such farmers can benefits from blockchain technology by gaining improved supply chain visibility, decreased fraud, and expanded market access. Additionally, for farmers looking to increase the value of their produce in both domestic and foreign markets, blockchain's potential to speed up payments, lower transaction costs, and simplify certification procedures is especially pertinent.

6. Recommendation

Building on these findings, a blockchain technology pilot project in at least one sub-county is required to enhance blockchain understanding and application in Makueni County's fruit supply chain. This will make it easier to assess the scalability and feasibility of blockchain applications in a real-world environment.

A pilot project can help better understand the operational, financial, and technological challenges of implementing blockchain technologies locally. The pilot programs would also enable the development of tailored blockchain solutions that address the particular needs of Makueni's fruit supply chain. Connecting blockchain technology to existing agricultural data platforms or mobile payment systems are a couple of examples of these options.

Second, a thorough cost-benefit analysis is required to ascertain whether blockchain adoption is financially feasible for smallholder farmers. Although blockchain promises long-term advantages like lowering fraud and raising market value, farmers who are already struggling financially may find the upfront expenditures too high.

In order to close the knowledge gap found in the survey, training and capacity-building initiatives are essential. To guarantee a thorough grasp of blockchain and its advantages, educational programs should be created for farmers as well as other supply chain participants like carriers, merchants, and county government. Blockchain-focused digital literacy initiatives could be incorporated into agricultural extension services to expand the pool of participants in Makueni County who are prepared for blockchain.

7. Future Work

Integration with other technologies, such as artificial intelligence (AI) for crop yield prediction analytics and the Internet of Things (IoT) for real-time fruit storage condition monitoring, might also significantly boost blockchain's effectiveness in the fruit supply chain. In order to improve demand projections, optimize supply chain operations, and further reduce post-harvest losses, future research should look at how these technologies might work in tandem with blockchain technology.

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