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# Areas of Block Chain Technology Application in the Fruit Supply Chain in Makueni County, Kenya

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**Abstract:** ***The application of blockchain technology in the fruit supply chain in Makueni County, Kenya, presents an opportunity to enhance traceability, food safety, and market access. This study reveals that 74.1% of farmers have at least a secondary-level education, indicating a favorable environment for adopting blockchain solutions. The dominance of fruit farming, with mangoes, oranges, and papaws being the most common, necessitates an efficient tracking system to monitor supply chain movements. Currently, 93.8% of farmers lack formal mechanisms for tracing their produce, and 75.3% are unaware of where their fruits are consumed. Blockchain technology offers a decentralized and immutable system for recording production data, enabling real-time monitoring of fruit origin, handling, and safety compliance. Additionally, inefficient record-keeping remains a challenge, as 84% of farmers still rely on physical books. The study highlights the need for digital training and mobile-based blockchain applications, with 70% of farmers preferring mobile phone access to traceability systems. However, challenges such as inadequate resources, lack of knowledge, and technological constraints must be addressed. By integrating blockchain with mobile applications, government, and agricultural stakeholders can improve supply chain efficiency, ensure compliance with food safety standards, and empower farmers with market intelligence for better economic outcomes.***

**Keywords:** blockchain, transparency, tracking and traceability, fruit products

## 1. Introduction

The application of blockchain technology in the supply chain of fruit products in Makueni County, Kenya, presents a transformative opportunity to enhance transparency, traceability, and efficiency in the agricultural sector. Makueni County is renowned for its vibrant fruit farming industry, particularly in mango, avocado, and citrus production, which significantly contributes to local livelihoods and economic development. However, challenges such as post-harvest losses, supply chain inefficiencies, market access limitations, and food safety concerns persist, limiting the full potential of the sector. Blockchain technology, with its decentralized and immutable ledger system, offers a viable solution to these challenges by ensuring accurate record-keeping, real-time tracking, and enhanced trust among stakeholders, including farmers, distributors, retailers, and consumers.

Key areas of focus in the application of blockchain technology in Makueni's fruit supply chain include farmer registration and digital identity, smart contracts for fair trade agreements, real-time tracking of produce, and enhanced quality assurance mechanisms. By providing smallholder farmers with a digital identity on a blockchain platform, the technology can facilitate direct market access, fair pricing, and financial inclusion. Smart contracts can automate transactions ensuring farmers receive timely payments while reducing reliance on intermediaries. Additionally, blockchain-enabled tracking can monitor fruit products from farms to markets, minimizing fraud, counterfeiting and supply chain disruptions. Quality control is another critical area, as blockchain technology can store and verify data on pesticide use, storage conditions, and compliance with food safety standards thereby boosting consumer confidence in Makueni's fruit exports.

Despite its potential benefits, blockchain technology application faces challenges such as inadequate digital infrastructure, limited technical knowledge among farmers, and high deployment costs. Addressing these barriers through stakeholder collaboration, government support, and capacity-building initiatives will be essential for successful blockchain integration. This paper explores the areas of focus, challenges, and opportunities in leveraging blockchain technology to revolutionize the fruit supply chain in Makueni County.

## 2. Related Work

The integration of blockchain technology into agricultural supply chains has garnered significant attention in recent years, with various initiatives demonstrating its potential to enhance transparency, traceability, and efficiency. In Kenya, several projects have been implemented to address challenges in the supply chain of fruit products, particularly avocados and indigenous vegetables (Spitalleri, 2023) .

Twiga Foods Ltd is a notable example of companies leveraging technology to streamline agricultural markets in Kenya (García-Bañuelos, 2022). Established in 2014, Twiga Foods connects farmers directly with vendors through a business-to-business e-commerce platform, effectively reducing the number of intermediaries. This approach has led to decreased food wastage and lower prices for consumers. The company has also explored the use of blockchain technology to improve traceability and accountability within

its supply chain, ensuring that produce is delivered efficiently and transparently to urban markets

In the avocado sector, One Million Avocados (OMA) has partnered with Dimitra, a blockchain-based agricultural technology company, to assist small-scale farmers in Kenya (Spitalleri, 2023). This collaboration aims to tackle challenges such as limited market access and stringent export regulations. By digitizing avocado trees as non-fungible tokens (NFTs) on the Polygon blockchain, farmers gain access to essential data, including GPS locations and farm development histories (Ojo, 2023). This transparency enhances compliance with environmental, social, and governance standards, thereby opening new markets for their produce

Similarly, Ifarm Konnect, a Kenya-based startup, enables micro-investors to fund smallholder farmers in exchange for a percentage of the proceeds (Zhang, 2023). The company leverages on blockchain technology to monitor farmlands and provide agronomic advice aimed at enhancing productivity. By offering a combination of software and a mobile application, Ifarm Konnect assists farmers with technical support to maximize their farm produce and quality (O'Dwyer, 2024) . This approach not only improves productivity but also facilitates better market access for smallholder farmers

In western Kenya, a project led by Virginia Tech's Center for International Research, Education, and Development has adapted a blockchain-based smartphone application known as AgUnity's Version 3 App (V.3 App) to support the supply chain of African indigenous vegetables (Kim D. L., 2023). This app tracks produce from the farmer to the end consumer, providing information on growing practices, transportation, and processing. By ensuring that all transactions are permanently and securely recorded on a blockchain ledger, the app enhances transparency and trust among all stakeholders in the supply chain (Sartor, 2022).

These initiatives illustrate the growing interest in applying blockchain technology to agricultural supply chains in Kenya. They focus on key areas such as improving traceability, enhancing market access, providing technical support, and ensuring compliance with international standards. While these projects are still evolving, they offer valuable insights into the potential benefits and challenges of applying blockchain solutions in the agricultural sector.

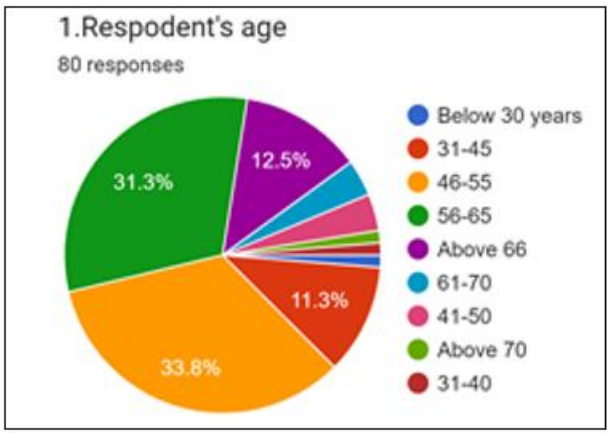
## 3. Methodology

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.

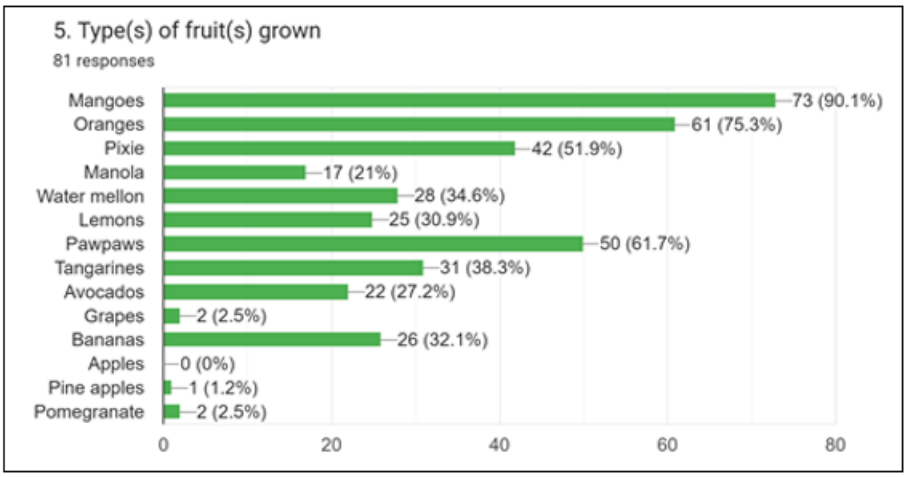
Four sub- counties; Makueni, Mbooni, Kaiti and kibwezi west were sampled. This was informed by the geographical positioning of the four sub-counties, which makes them suitable for growing fruits The study involved farmers from the four selected sub counties The survey targeted at least 20 respondents 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

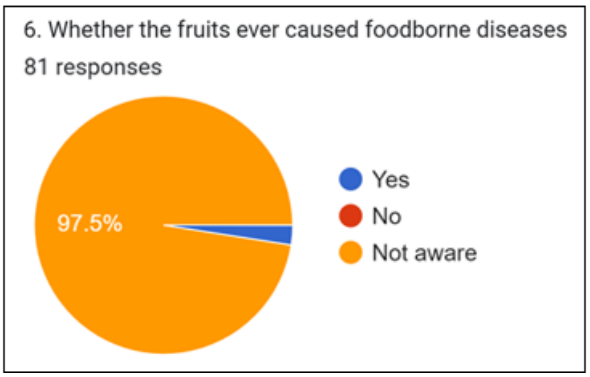
The study findings highlight key factors influencing the application of blockchain in the fruit supply chain in Makueni County. A significant proportion of farmers (74.1%) have at least a secondary school education, suggesting a favorable literacy level for adopting blockchain technology. Farmers grow multiple fruit types, with mangoes being the most common. However, 93.8% lack mechanisms for tracing fruit safety, and 75.3% are unaware of where their produce is consumed. Record-keeping is mainly manual, with 84% using physical books. Additionally, 70% prefer mobile phone access for traceability, indicating the potential for blockchain-based mobile solutions in improving transparency and efficiency. The study details are presented below:



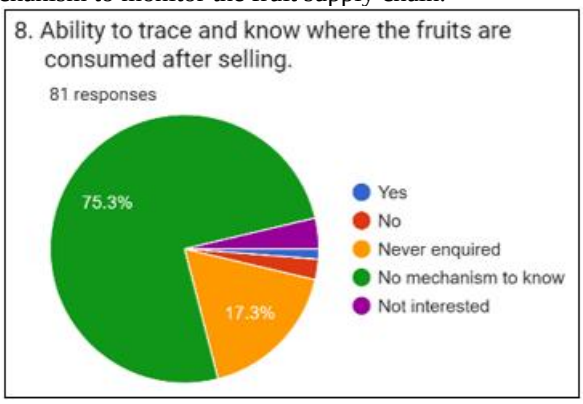

38.3% of the respondents had secondary level academic qualifications, followed by 35.8%. with Tertiary level Further 16% had primary school level while only 9.9% were graduates. Thus, majority of the farmers (74.1%) have academic qualifications of secondary school and above. This implies that it is possible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



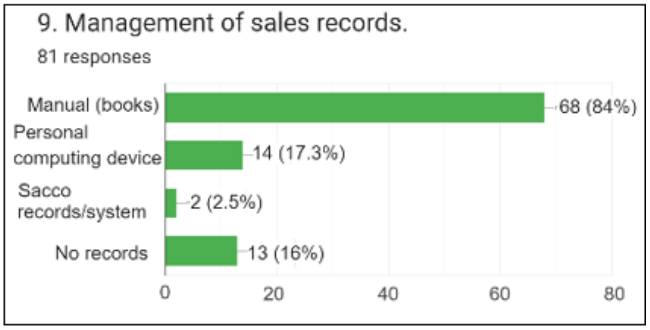

As shown on the bar graph, a variety of fruits are grown in the sampled sub-counties. All the sampled farmers grow more than one type of fruit. Of all the fruits grown, Mangoes are the most common, followed by oranges then papaws. Pixie and tangerines are the fourth and fifth respectively in order of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



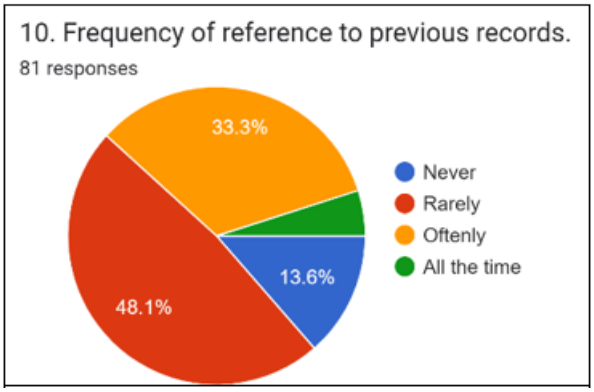

- 2.5 % of the respondents - had an idea that their products had caused food born disease, 96.2% of them were not sure of the actual cause This implies that the farmers have no mechanism to monitor the fruit supply chain.



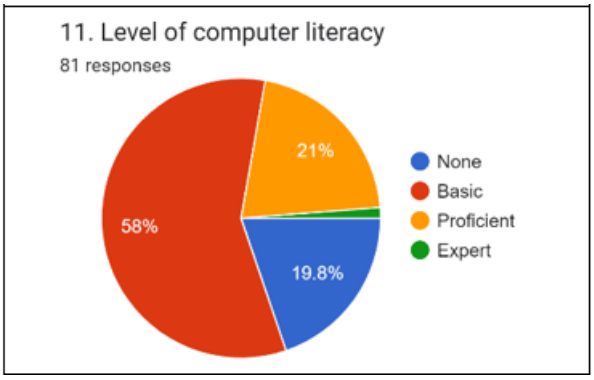

Only 5.5% of respondents knew where their fruits were consumed after selling. 17.3% have never enquired about it while 75.3% were not aware where the fruits are consumed because they did not have a mechanism to know. The results imply there is need to have a mechanism to help the farmers to trace and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



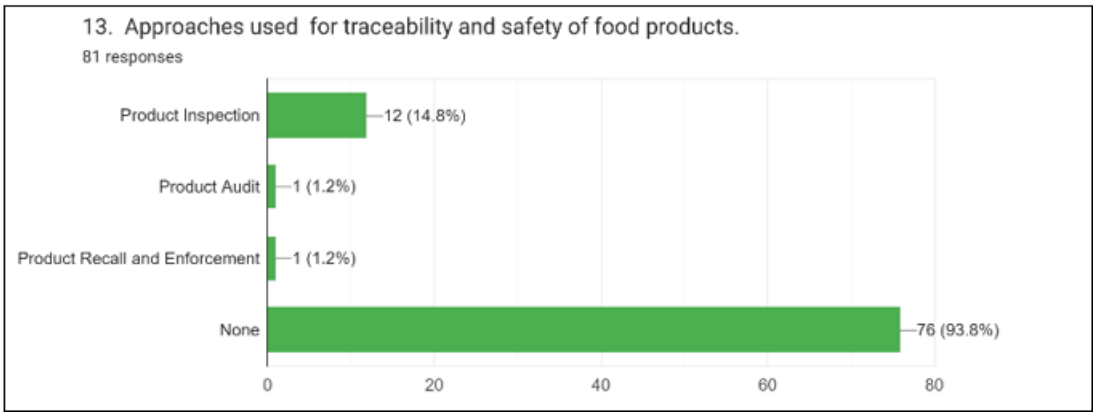

Majority (84%) of the Respondents use books to record their sales while 17.3% keep records in personal computing device. 16% have no records while 2.5% depend on SACCO record system to keep their records. These results show that there is need to embrace and train farmers on e-record keeping practices.



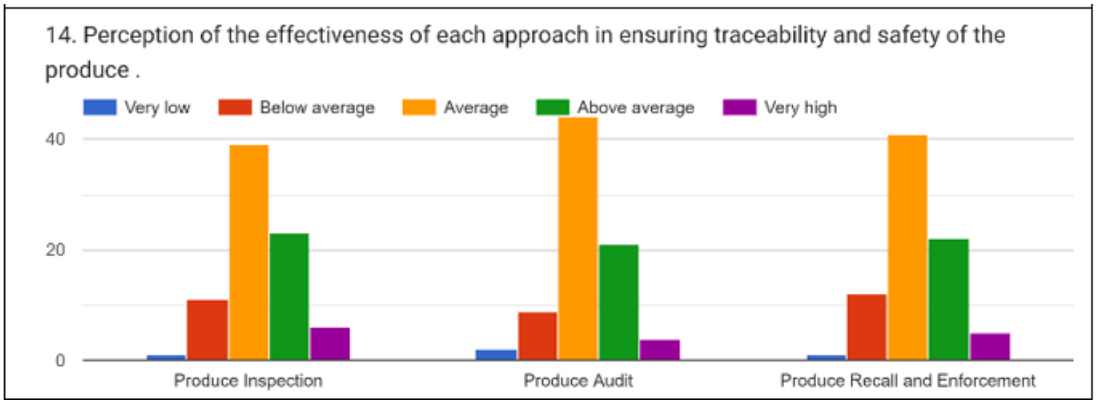

61.7% either never or rarely referred to the records while the rest (38.3%) did so oftenly or all the time. The results show that the farmers should be trained on record keeping and use to improve their efficiency.



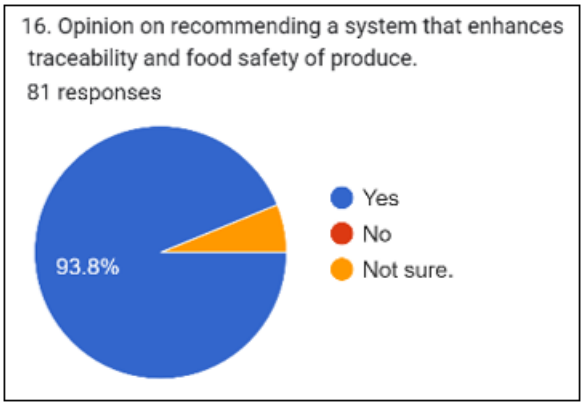

Majority of the respondents representing 58% had basic computer skills. 21% are proficient in computer skills while 19.8% have no computer skills. Only 1.2% were expert in computer skills. The relatively high percentage of IT literacy implies that it's possible to leverage on technology to do record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



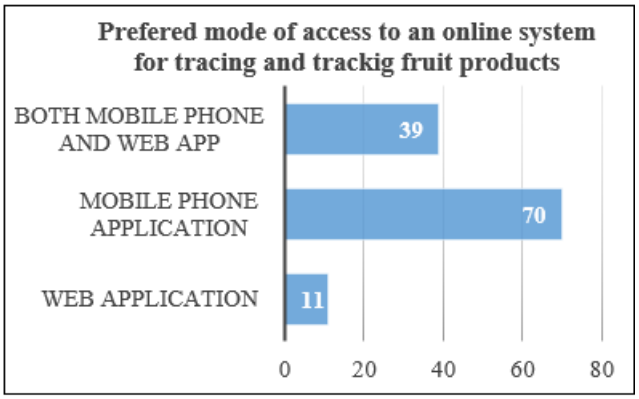

93.8% of the Respondents have no mechanism for tracing and monitoring safety for their fruits. 14.8% do fruit inspection before selling as a way of enhancing safety while the rest representing 1.2% either use product audit or product recall and enforcement. The finding suggest that most farmers are unable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




Above data not communicating with the analyzed information below. 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 preferred 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

The findings indicate that a significant proportion of fruit farmers in Makueni County have a relatively high level of literacy, with 74.1% having at least secondary school education. This suggests a favorable environment for the introduction of blockchain technology in the supply chain, as literacy is a crucial factor in the adoption of digital innovations. The presence of tertiary-level educated farmers (35.8%) further strengthens the potential for effective training and application of blockchain solutions. With adequate sensitization and training, the farmers can grasp the fundamentals of blockchain-based record-keeping, traceability, and transaction management, ensuring improved supply chain efficiency and transparency.

The study also highlights the diversity of fruit farming in Makueni County, with farmers cultivating multiple types of fruits. Mangoes are the most widely grown, followed by oranges and papaws, while apples are not cultivated in the sampled areas. This diversity necessitates an efficient tracking system to monitor the movement of various fruits along the supply chain. Blockchain technology can provide a decentralized and tamper-proof mechanism for recording farm production data enhancing visibility for both farmers and consumers. By integrating blockchain with digital labeling and scanning technologies, stakeholders can access real-time information on fruit origin, handling and quality assurance ultimately improving market confidence.

A crucial challenge in the supply chain is the lack of monitoring mechanisms for food safety. Although only 2.5% of farmers suspected their products may have caused foodborne illnesses, 96.2% of them were unsure of the actual cause. This indicates a significant knowledge gap and the absence of a structured traceability framework. Furthermore, 93.8% of farmers admitted that they had no formal system for tracking and monitoring fruit safety. The application of blockchain technology could provide a verifiable and immutable record of farming practices, pesticide use, storage conditions, and distribution channels, thereby enabling quicker identification of contamination sources and improving food safety management.

Similarly, the lack of awareness regarding the final consumption of their produce is a key concern. The study found that 75.3% of farmers did not know where their fruits were consumed because they lacked a tracking mechanism, while 17.3% had never inquired about it. Blockchain technology can bridge this gap by offering an end-to-end traceability system that allows farmers to monitor the movement of their produce through unique digital identifiers or QR codes. This would empower farmers with data on market trends, consumer preferences, and potential areas for expanding their sales, ultimately leading to better pricing and income generation.

Another critical challenge in Makueni's fruit supply chain is record-keeping. A majority (84%) of farmers still rely on physical record books, while only 17.3% use personal computing devices, and 16% do not keep any records. Additionally, 61.7% either never or rarely refer to their records, indicating inefficiencies in farm management. Blockchain technology can address this issue by providing a digital ledger where farmers can securely record sales, transaction histories, and production data in real time. Training on digital record-keeping and the benefits of blockchain-based systems will be essential to ensure its successful adoption.

Encouragingly, the study reveals that 58% of respondents have basic computer skills, and 21% are proficient in computer, meaning that a majority of farmers possess the foundational IT knowledge needed to engage with digital platforms. This presents an opportunity to introduce blockchain-based mobile and web applications for traceability and financial transactions. The fact that 70% of respondents preferred mobile phone access for a traceability system aligns with the widespread use of mobile technology in rural areas. Blockchain-based mobile applications can serve as user-friendly platforms for farmers to track their produce, access digital payments, and gain insights into market demands.

Despite the potential benefits, farmers identified key challenges hindering product traceability and food safety, including lack of technology, knowledge, mechanisms, resources, capacity, and literacy. Overcoming these challenges requires collaborative efforts from the government, agricultural organizations, and technology providers to create awareness, offer training and subsidize the costs of blockchain adoption. Policymakers must also invest in digital infrastructure to support seamless integration of blockchain in the fruit supply chain.

Overall, the findings strongly suggest that blockchain technology can revolutionize the fruit supply chain in Makueni County by enhancing traceability, improving food safety, increasing market access, and streamlining record-keeping. With a structured implementation plan and adequate training, farmers can leverage blockchain technology to modernize their operations, ensure compliance with safety standards, and secure better market opportunities.

## 6. Recommendation

To successfully implement blockchain technology in the fruit supply chain of Makueni County, several strategic actions should be taken. First, training and capacity-building programs should be introduced to educate farmers on blockchain-based record-keeping, traceability, and transaction management. Since 74.1% of farmers have at least secondary education and 58% possess basic computer skills, targeted training will enhance adoption and maximize the benefits of blockchain solutions.

Second, stakeholders should invest in digital infrastructure, particularly mobile-based blockchain applications, since 70% of farmers prefer mobile phone access for traceability systems. These applications should be designed to be user-friendly, enabling farmers to track their produce, access market information, and conduct financial transactions seamlessly.

Third, the government and agricultural organizations should support blockchain technology adoption by providing subsidies, incentives, and grants to farmer since a major challenge is the lack of technology and financial resources. Such interventions would facilitate accessibility and affordability of blockchain solutions.

Additionally, blockchain-based traceability mechanisms should be developed to enhance food safety and market transparency. A system integrating QR codes or digital identifiers will help farmers track their produce from farm to consumer, reducing contamination risks and improving compliance with safety standards.

Finally, continuous monitoring and policy support will be necessary to ensure effective application, sustainability and scalability of blockchain technology in the fruit supply chain.

## 7. Conclusion

Blockchain technology offers a promising avenue to transform the fruit supply chain in Makueni County by enhancing traceability, ensuring food safety, and improving market access. This study reveals a receptive farmer base with adequate literacy and a clear need for digital solutions, yet challenges like resource constraints and technical knowledge gaps remain. With targeted interventions, blockchain could empower farmers and elevate the region's agricultural sector.

## 8. Future Work

Future research should focus on developing and testing blockchain-based traceability systems tailored to the unique needs of Makueni County's fruit farmers. Pilot programs should be implemented to assess the feasibility and effectiveness of mobile-based blockchain applications in improving record-keeping, market access, and food safety. Additionally, studies should explore strategies for integrating blockchain technology with other emerging technologies, such as IoT and AI, to enhance supply chain transparency.

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