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From Hive to Consumer: A Decentralized Blockchain Solution for Real-Time Honey Authenticity Verification and Fraud Prevention*

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Abstract

The rise of counterfeit food products, particularly honey, threatens public health and erodes consumer trust, necessitating robust traceability solutions. While blockchain technology has been explored for supply chain transparency, existing systems often lack seamless integration with official regulatory databases, leaving a critical gap in fraud prevention. This study introduces Yaqen, a blockchain-based traceability platform designed to authenticate honey products in Saudi Arabia by generating tamper-proof barcodes for end-to-end supply chain tracking. Unlike conventional systems, Yaqen enhances accountability by directly validating supplier credentials via Wathq, an official government registry, ensuring only verified entities participate. The methodology combines blockchain's immutability with real-time verification, enabling consumers to scan products and access immutable provenance records. Findings demonstrate that Yaqen effectively mitigates fraud risks by providing a decentralized, transparent ledger while fostering compliance with national regulatory standards. The platform's success in honey authentication suggests scalability to other high-risk food sectors, offering a model for bridging regulatory oversight with consumer assurance. This study contributes a replicable framework for combating food fraud through technology-driven traceability.

Keywords: blockchain, supply chain traceability, counterfeit prevention, fraudulent goods, Saudi Arabia

Introduction

The proliferation of counterfeit products has become a critical global challenge, threatening economic stability, consumer safety, and brand integrity across multiple industries. These fraudulent goods, which range from luxury items to pharmaceuticals and food products, illegally replicate genuine trademarks and packaging to deceive consumers. The consequences are far-reaching, including substantial revenue losses for legitimate businesses, potential health hazards for consumers, and market destabilization due to unfair competition from counterfeiters who avoid research and development costs (OECD, 2021). Among food products, honey has emerged as a prime target for sophisticated adulteration due to its high market value and the difficulty in detecting fraudulent modifications. Common practices such as dilution with inexpensive sweeteners or false origin labeling not only compromise product quality but also erode consumer trust in authentic producers (Siddiqui et al., 2022). Traditional authentication methods

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like visual inspection or taste testing have proven inadequate against increasingly sophisticated fraud techniques, creating an urgent need for more advanced traceability solutions.

Modern supply chain technologies offer promising tools to combat this growing problem. Robust traceability systems incorporating blockchain technology and RFID tagging can provide comprehensive product tracking from production to retail, creating immutable records that deter fraud. When combined with authentication markers like QR codes or DNA-based verification, these systems establish multiple layers of protection against counterfeit products (Tian, 2022). Effective solutions also require collaboration among all supply chain participants, from producers to regulators, to create coordinated detection and enforcement mechanisms.

To address these challenges, we present *Yaqen*, an innovative blockchain-based application designed to restore trust in honey supply chains. The solution empowers consumers to verify product authenticity through simple barcode scanning, while enabling producers to securely document their products on an immutable ledger. *Yaqen's* integration with Saudi Arabia's official Wathq API adds an additional layer of security by validating the commercial registrations of all supply chain participants. While initially focused on honey due to its particular vulnerability to fraud, the platform's architecture is designed for potential expansion to other high-risk product categories such as pharmaceuticals and organic foods.

The development of *Yaqen* focuses on three primary objectives: creating supplier tools for product registration with blockchain-based identifiers, providing consumers with real-time verification of product origins, and establishing systemic barriers against counterfeiters through tamper-proof record-keeping. By combining advanced technology with supply chain governance principles, *Yaqen* aims to transform product authentication practices while establishing a replicable model for broader anti-counterfeiting applications across global markets.

Literature Review

The global challenge of counterfeit products has prompted significant interest in blockchain technology (BCT) as a means to enhance supply chain transparency and security. Traditional honey supply chains, which rely on centralized regulatory systems and government audits, are particularly vulnerable to fraud due to their opacity and inefficiency. Blockchain offers a paradigm shift toward decentralized surveillance networks, where all stakeholders—suppliers, vendors, markets, and consumers—collaborate to verify authenticity. This transformation not only mitigates counterfeiting but also strengthens consumer trust in product origin and quality.

A systematic mapping study by Tribis et al. (2018) examined BCT applications across agriculture, manufacturing, and product ownership, revealing a critical gap: while numerous blockchain solutions have been proposed, few undergo rigorous economic feasibility testing. This underscores the need for real-world implementations that validate both technical and financial viability. Research on food supply chains (Duan et al., 2020; Feng et al., 2020; Casino et al., 2019; Lashkari, B. and Musilek, P., 2021) further highlights BCT's potential to address vulnerabilities in agricultural networks, where traceability and handling are paramount. For instance, Balamurugan et al. (2021) demonstrated how IoT sensors integrated with blockchain can improve transparency and deter illegal product entry, while Day et al. (2021) developed FoodSQRBlock, an open-source framework using QR codes to make production data accessible to consumers. Ethereum-based certification systems (Dos Santos et al., 2019) and hybrid on-chain/off-chain architectures (Lin et al., 2019) have also emerged as solutions to scalability and data management challenges.

Real-world implementations, such as Walmart's blockchain pilot with IBM (*Aramex Mobile*), showcase the technology's practical benefits. By reducing mango traceability time from seven days to 2.2 seconds, the project proved blockchain's capacity for real-time auditing and stakeholder collaboration. Similarly, Caro et al. (2018) confirmed the efficacy of blockchain in ensuring transparency through deployments on Ethereum and Hyperledger Sawtooth. Despite these successes, adoption barriers persist. Wang et al. (2019) identified key drivers—including trust, supply chain complexity, and public safety—alongside challenges such as organizational resistance, interoperability issues, and regulatory hurdles.

While existing research extensively covers broad food supply chains, niche markets like honey remain underexplored. Honey's high value and susceptibility to fraudulent dilution make it an ideal candidate for blockchain-based traceability. Current solutions often focus on large-scale implementations or theoretical models, leaving gaps in

practical, user-friendly applications for specialized products. *Yaqen* addresses these gaps by leveraging Ethereum's decentralized ledger and Flutter's cross-platform capabilities to create an accessible, end-to-end traceability system. By incorporating QR-based verification and government-validated commercial data (via Wathq API), *Yaqen* not only combats counterfeiting but also contributes to the broader discourse on blockchain's role in supply chain innovation. This approach aligns with findings from Pournader et al. (2019) and Juma et al. (2019), emphasizing the interplay of technology, trust, and transparency in modern supply chains, while offering a scalable model for high-risk, high-value markets.

Most studies focused on large-scale industries, with limited exploration of specialized markets such as high-value agricultural products (e.g., honey). Additionally, few implementations address end-to-end tracking from supplier to consumer while ensuring fraud prevention.
To bridge this gap, our work introduces *Yaqen*, a blockchain-based traceability system tailored for honey supply chains in Saudi Arabia. Leveraging Flutter for cross-platform mobile development and Ethereum for decentralized ledger management, *Yaqen* ensures real-time product authentication, tamper-proof records, and seamless stakeholder collaboration.
By addressing scalability, usability, and regulatory alignment, this solution advances prior research while offering practical insights for BCT adoption in niche supply chains.

Methodology

The methodology employed in developing *Yaqen*, focused on its software development approach, user research, and system design to address honey product counterfeiting.

Yaqen was developed using the iterative waterfall model, which combines the structured phases of traditional waterfall with iterative refinement. This approach allowed for flexible adaptation to changing requirements during development, incremental improvements through repeated cycles of feedback and modification, and early error detection by revisiting each phase (requirements, design, implementation, testing) as needed.

To validate the problem and design requirements, an online questionnaire was distributed to 202 honey consumers and stakeholders in Saudi Arabia. Key findings shown in Table 1 included:

1. **91.1%** of respondents regularly used honey products.
2. **57.9%** encountered issues when purchasing honey, with **60.4%** reporting suspected fraud.
3. **95.5%** expressed demand for a free application to verify honey authenticity and end-to-end traceability, from source to store.

The survey revealed critical gaps in existing solutions, such as lack of transparency and incomplete product data, justifying *Yaqen*'s development.

Table 1: Overview of the Survey

Questions	Answer	Result
Do you use honey products?	Yes	91.1 %
	No	8.9 %
What is the rate of your purchase of honey products?	0% - 20%	32.2%
	30% - 50%	45%
	60% - 100%	22.8%
Do you face problems when buying honey?	Yes	57.9 %
	No	42.1 %

If your answer to the previous question was yes, what problems do you face when buying honey?	There is no service to ensure the authenticity of the product before buying it	25.2%
	Lack of source information	5%
	No accurate product tracking	2.9%
	all the above	61.2%
	otherwise	5.7%
Have you been fleeced when buying a honey product before?	Yes	60.4%
	No	39.6%
Do you want a free application to ensure the authenticity of the honey product?	Yes	95.5%
	No	4.5%
Do you want to know the information about the source of the honey product and trace it from the primary source to the point of sale before buying it from the store?	Yes	95.5%
	No	4.5%
Are you interested in the app that was described (*Yaqen*) up top?	Interested	86.6%
	Not interested	13.4%
Do you know of any application that is similar to *Yaqen*?	Yes	2%
	No	98%

The design and implementation of *Yaqen* were informed by comprehensive survey data, which revealed critical user needs in combating honey fraud. To address these pain points, the system incorporates three core technological components. First, blockchain integration ensures an immutable record of every step in the supply chain journey, from supplier to vendor to market, while unique QR/barcodes provide tamper-proof product identification. Second, integration with the Wathq API enables real-time validation of commercial registrations through Saudi Arabia's Ministry of Commerce, guaranteeing participant legitimacy. Third, user-centric features were prioritized, including simple barcode scanning for consumers and comprehensive product registration tools for suppliers.

Yaqen distinguishes itself from conventional tracking systems through several key advantages. The platform offers unprecedented transparency by making the complete product journey visible to end consumers, while its government-verified data ensures credibility unmatched by commercial solutions. Perhaps most importantly, *Yaqen's* free-to-use model maximizes accessibility and adoption potential among all stakeholders. This careful balance of technical innovation and practical usability enabled the system to effectively address the systemic challenges of honey fraud while meeting both technical specifications and user requirements.

The project's key strengths lie in its methodological rigor and real-world applicability. By combining empirical user data from surveys with a structured iterative waterfall development approach, the team created a solution firmly grounded in actual user needs. The technical design - particularly the blockchain architecture and API integrations - was carefully aligned with practical requirements for fraud prevention and supply chain traceability. Most significantly, *Yaqen's* unique value proposition addresses critical gaps in existing solutions, offering a compelling alternative that prioritizes transparency, credibility, and accessibility in equal measure. This multifaceted approach positions *Yaqen* as both a technological innovation and a practical tool for combating food fraud in the honey industry.

Implementation

The development of *Yaqen* followed a structured parallel implementation approach to ensure efficient progress and system cohesion. Our team was strategically divided into two specialized units working concurrently: a mobile application team focused on Flutter-based UI development and application logic, and a blockchain team dedicated to smart contract implementation and Ethereum integration. This parallel workflow enabled simultaneous advancement of both components while maintaining continuous coordination to guarantee seamless system interoperability.

The system architecture was designed as a comprehensive four-tier framework supporting all critical stakeholders in the honey supply chain. Suppliers benefit from specialized modules enabling product registration with unique barcodes, parcel creation, logistics management, and real-time shipment tracking. Vendors utilize tools for parcel verification, delivery status updates, and chain-of-custody documentation. Markets gain inventory management capabilities through parcel scanning, product status updates, and stock monitoring. For consumers, we developed an intentionally simplified single-button interface allowing instant product authentication and complete supply chain visualization through barcode scanning.

Our development process embraced agile methodologies through iterative cycles that progressively refined the system. The initial phase focused on core functionality implementation, followed by rigorous design validation against use cases. Subsequent iterations involved architecture refinement through UML updates, code optimization for performance enhancement, and UI/UX improvements based on usability testing. This cyclical approach ensured continuous alignment with both technical specifications and user requirements.

User interface design was guided by principles of accessibility and intuitive interaction. Role-specific dashboards were created with customized workflows while maintaining a consistent design language across all modules. The consumer interface exemplifies our minimalist philosophy, featuring a single-scan functionality requiring no training. Key interface components include a barcode scanning overlay, visual supply chain representation, real-time status indicators, and contextually-aware action confirmations. Progressive disclosure techniques were employed to present complex features only when needed.

The technical implementation integrates multiple cutting-edge technologies across three layers. The frontend leverages Flutter framework for cross-platform compatibility, with custom camera integration for barcode scanning and responsive UI components. The backend combines Ethereum blockchain for immutable records, smart contracts for automated business logic, RESTful APIs for data exchange, and secure authentication services. Critical integrations include the Wathq API for commercial registration verification, blockchain oracles for real-world data feeds, and secure off-chain storage solutions.

Development Tools and Technologies

Yaqen's development utilized a carefully curated technology stack selected for robustness, efficiency, and scalability. For integrated development environments, Android Studio was employed as the primary IDE for its comprehensive Flutter development tools and advanced UI design capabilities, complemented by Visual Studio Code for blockchain-related tasks due to its excellent support for Dart and Solidity programming.

The core development platforms centered on Flutter framework for cross-platform mobile development, enabling creation of responsive interfaces with native device feature access. Firebase served as our backend-as-a-service platform, providing essential authentication services, real-time database functionality, and performance monitoring capabilities.

The blockchain infrastructure was built on Ethereum, chosen for its decentralized smart contract execution and immutable transaction records. The smart contracts we developed handle critical functions including product registration, ownership transfers, and supply chain event tracking. For integration services, the Wathq API proved invaluable for verifying commercial registrations through Saudi Arabia's Ministry of Commerce, while additional libraries enhanced barcode scanning, cryptographic security, and system interoperability.

This comprehensive technology stack was specifically architected to meet *Yaqen's* core requirements of security, transparency, and accessibility while ensuring development efficiency and future scalability. The synergistic combination of these tools has enabled creation of a robust anti-counterfeiting solution with unparalleled supply chain verification capabilities in the honey industry.

Testing

The *Yaqen* application underwent a rigorous, multi-phase testing process to validate its functionality, reliability, and usability before deployment. This comprehensive evaluation ensured the system met both technical specifications and user expectations while maintaining the highest standards of performance and security.

Testing was conducted through four systematic phases, each targeting different aspects of the application. The initial unit testing phase focused exclusively on the mobile application components prior to blockchain integration, with thorough verification of core features including user authentication, product management systems, parcel tracking functionality, and barcode scanning accuracy. This isolation testing established a solid foundation for subsequent integration.

The integration testing phase marked a critical milestone as the mobile application was combined with the blockchain network. This stage rigorously evaluated data synchronization between frontend and blockchain components, smart contract interactions, and the reliability of key functions like product verification and transaction logging. Special attention was given to supply chain update mechanisms to ensure seamless information flow across the distributed ledger system.

For complete system validation, an end-to-end testing was conducted that simulated real-world operational scenarios. These comprehensive tests covered the full spectrum of use cases, including supplier-to-vendor parcel transfers, market inventory management workflows, and customer-facing product verification processes. The system testing phase confirmed all components functioned cohesively as an integrated solution.

The final user acceptance testing (UAT) phase brought the application before actual end-users for practical evaluation. This crucial stage collected valuable feedback on usability and interface design from representatives of all stakeholder groups - suppliers, vendors, markets, and consumers. Identified issues were systematically addressed to optimize both performance and user experience before deployment.

The testing framework concentrated on three critical dimensions of quality assurance. Functional effectiveness testing verified all designed features operated correctly, including role-based permissions and product tracking systems. Task efficiency evaluations measured the speed and simplicity of completing essential workflows like product registration and barcode scanning. Interface clarity assessments ensured intuitive navigation and clear instructions across all user roles and scenarios.

This meticulous, multi-layered testing approach enabled continuous refinement of *Yaqen*, resulting in a solution that combines robust technical performance with exceptional user experience. The process not only validated the application's core functionality but also confirmed its ability to meet the complex demands of supply chain verification in real-world conditions, ultimately delivering a secure and reliable platform for combating honey adulteration.

Conclusion

Yaqen represents a significant advancement in combating counterfeit products through its innovative blockchain-based supply chain solution. By creating a transparent and traceable ecosystem, the application empowers all stakeholders—suppliers, vendors, markets, and consumers—to verify product authenticity at every stage of the supply chain. Suppliers benefit from streamlined product and parcel management, while vendors can efficiently update delivery statuses. Markets gain automated inventory tracking capabilities, and consumers enjoy unprecedented visibility into product origins through simple verification processes. This comprehensive approach not only enhances accountability across the supply network but also rebuilds consumer trust in product authenticity. While currently focused on Saudi Arabia's honey market, *Yaqen's* architecture demonstrates strong potential for scalability and adaptation to other regions and product categories.

Limitations and Future Directions

Despite its innovative approach, *Yaqen* currently faces certain limitations that present opportunities for future development. The application's geographic restriction to Saudi Arabia and specialization in honey products represent intentional initial constraints that allow for focused refinement. Additionally, the lack of formal integration with the Ministry of Commerce suggests potential for deeper governmental collaboration.

Looking ahead, several strategic enhancements are planned to expand *Yaqen's* impact: The system will evolve to support diverse product categories beyond honey, addressing a broader range of counterfeit challenges. Geographic expansion will extend the solution's benefits to international markets, while potential government integration could strengthen regulatory compliance. A proposed reward system aims to incentivize user participation in authenticity verification, fostering greater community engagement. Furthermore, cross-platform development will increase accessibility through web-based interfaces, complementing the existing mobile application. These planned improvements position *Yaqen* to become an increasingly versatile tool in the global fight against counterfeit goods, promoting more secure and transparent supply chain ecosystems worldwide.

Through continuous development and expansion, *Yaqen* has the potential to set new standards for product authentication, transforming how businesses and consumers approach supply chain transparency in an increasingly complex global marketplace.

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