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Sustainable Food Waste Management and Tracking System Using Blockchain

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Abstract**—***Efficient supply chain management is a laborious task in any company, but in food industry, there is extra complexity and risk of compromising supply chain in food waste management, which may directly affect consumer safety and the shelf life of goods. One possible solution is to use blockchain technology to improve the integrity, security, and transparency of food supply chain. This study intends to present a blockchain-based transparent traceability food supply system that would follow the passage of boxed leftovers from restaurants through nongovernmental organizations and lastly to the underprivileged. Furthermore, the system employs a QR code and an NFC tag to acquire access to secure data pertaining to food packaging. This can help to reduce fraud, theft, and counterfeiting, as well as improve the efficiency of leftover food supply chain.*

Keywords**—***Blockchain, transparency, traceability system, QR code, NFC*

I. INTRODUCTION

While billions of metric tonnes of food are produced each year, ~30%–50% of it is wasted along the total food supply chain from production to consumption. Food insecurity and food waste are manifestations of inequality in our modern food management systems [1]. Moreover, in comparison to world population, the amount of food wasted each year will expand exponentially. We are developing a web-based application that will monitor food waste from various restaurants in certain places and provide a platform for the needy or nongovernmental organisations to obtain information on how and where to collect it. In addition, with the aid of this mechanism, leftover food may be distributed to the public.

Food wastage is as widespread in restaurants as one could possibly imagine [2]. It appears to be the stupidest difficulty in our daily lives, yet it is a big problem regardless of how it appears. We have even seen some organizations committed to decreasing waste, but on a tiny scale and solely on the ground rather than online. The disadvantage of operating only on the ground is that it can only reach a limited number of individuals. With the use of Internet, food waste may be readily tracked and actions can be taken wherever required. The entire food supply chain must be thoroughly rethought and reorganized to build a traceability system [3]. Internet and social media are the most effective means of disseminating information. Notwithstanding restrictions such as some people not having Internet connection, we ardently hope that this effort will make a difference on some level. Making a difference is what is most important. As previously stated, food waste happens at all stages of food supply chain. Participants in food supply chain must monitor and restrict food sharing since there is substantial evidence that huge amounts are wasted during preparation and consumption phases [4].

This process might be aided by information technology, which would allow for more efficient coordination amongst participants in food chain. Blockchain technology might also be advantageous. It might help every level of food supply chain and allow hospitality businesses to improve their performance. It might also allow them to execute plans based on three pillars of sustainable development.

The remainder of the manuscript is organized as follows. Section 2 focuses on related work. Section 3 discusses technologies used for the system. Section 4 thoroughly explains our developed system for food traceability system. Section 5 showcases the parts of implementation and working. Section 6 concentrates on results and discussion of the developed system. Section 7 concludes the study with future scope.

II. RELATED WORK

A great deal of literature is available for food-related supply chain management (SCM) using blockchain technology, near field communication (NFC), and quick response (QR) codes. A few of them have been explicated below.

Noomhorm and Ahmad [5] discovered that nations such as Korea and Japan—although having agriculture-based economies—rely heavily on imported agricultural inputs. In Asia, the earlier supply chain has matured into a modern technology-based system, taking customer satisfaction as first priority. RFID traceability solutions have been employed efficiently in several nations.

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Dey *et al.* [6] developed a blockchain-based web framework to digitize data on food production and make it simple to access, trace, and verify. The use of QR codes enabled this. To show the framework's viability and scalability, it was suggested to integrate the project on a big scale utilising cloud technologies. To learn more about the framework's shortcomings, a study of the integration was performed.

Chandra, Liaqat, and Sharma [7] identified blockchain technology as a transformative factor that elevates the significance of halal legislation. In answer to the issues of the Halal Food business, blockchain provides a unique environment in which decentralized applications (Dapps) make product data available to the public, limit the possibility of artificial tampering, and promote increased audit and compliance. In addition, in terms of application, design, and technology components, Halal goods supply chain is based on a federalized blockchain. This distributed ledger technology with its unique features of a peer-to-peer network, consensus and data input method, and data privacy enablement will boost confidence amongst diverse participants across supply chain, thereby permitting consumers to make more informed and confident decisions.

Bhatia and Albarrak [8] introduced a revolutionary blockchain-based solution called XIA-based faster RCNN that aids in the digitalization of information on agricultural output and integrates QR codes for data tracking and validation between producers and customers. To replicate a real-world food manufacturing setting, Google cloud platform was used. The suggested method's performance was evaluated in terms of accuracy, performance time, and scalability. When compared to other current approaches, results demonstrated that the suggested technique had quickest reaction and processing times. The method's accuracy was 99.53%.

Pigini and Conti [9] developed a complicated traceability system based on NFC identification and used pig meat supply chain as a test case. RFID technology was frequently utilized. NFC enables information to be transferred to an end user. This enhanced brand loyalty while also delivering additional services. By recording customer's preferences and commercially viable location, the app may be utilized for marketing reasons.

Iftekhar *et al.* [10] in the food industry made use of blockchain technology to monitor and validate an end product's quality at a cheap cost. This contributed to the clear information being provided about food from farm to fork. Also, this information assisted food safety authorities in preventing potential food safety risks. It encouraged healthy competition among firms to consistently raise the calibre of their products. With no discernible difference in standard business practises or staff training, it provides decentralised, dependable, and transparent data stored on blockchain alongside a traditional database system utilised by existing business processes in the background.

Dey *et al.* [11] proposed a multi-layered architecture including blockchain technology and machine learning applications. The project evaluation revealed 9.46% reduction in food waste output. Since potato peel causes trash, data from potatoes was used for evaluation.

Omar *et al.* [12] emphasized the need of asset exchange amongst key suppliers. They acknowledged the need for exchanging data to run an efficient and successful supply chain organization. To increase trust, effectiveness, and accountability in complicated supply chains, the suggested system integrated smart contracts and distributed cloud platforms.

III. Technologies Used

A. Blockchain

A blockchain is a decentralized digital ledger that records transactions in a secure and transparent manner, using cryptography to ensure the integrity and immutability of the data. It is maintained by a network of computers rather than a central authority, making it resistant to tampering and censorship. Blockchains are commonly associated with cryptocurrencies such as Bitcoin, but their potential applications extend far beyond financial transactions.

B. Ethereum

Ethereum is a decentralized, open-source blockchain platform that enables the creation of smart contracts and decentralized applications (dApps). It has its own cryptocurrency called Ether (ETH), which is used to facilitate transactions and incentivize participants in the network. Ethereum is programmable, meaning that developers can build decentralized applications on top of its blockchain using Solidity, a programming language specifically designed for the platform. Conducting a transaction on a network necessitates payment, which is referred to as gas [13].

C. Interplanetary File System (IPFS)

It enables the creation of a new permanent web and supplements the use of existing protocols such as HTTP [14]. It is a distributed protocol and network designed to create a more efficient and decentralized method of storing and sharing files. It uses a content-addressed system rather than location-based addressing, meaning that files are identified by their unique hash rather than their location on a specific server or computer. This makes it easier to share and access files, as well as increasing their resilience against censorship or data loss.

D. MetaMask

Metamask is a browser extension and mobile app that serves as a cryptocurrency wallet and bridge between Ethereum-based decentralized applications (dApps) and web browsers. It allows users to securely store, manage, and transfer cryptocurrencies, as well as interact with dApps that are built on the Ethereum blockchain. The first stage in connecting Ganache and the built system would be to connect MetaMask with Ganache [14].

E. Ganache

Ganache is a personal blockchain for Ethereum development and testing purposes. It provides a local blockchain environment that can be used for developing and testing smart contracts, dApps, and other Ethereum-based applications [14]. Ganache simulates an Ethereum network, allowing developers to interact with it using web3.js or other Ethereum development tools.

F. Truffle

Truffle is a development framework for Ethereum-based applications. It provides a suite of tools and libraries that simplify the process of building and deploying smart contracts, dApps, and other Ethereum-based projects. Truffle includes a smart contract development environment, a testing framework, and a build pipeline for compiling and deploying smart contracts.

G. Flutter

It is a UI framework used to design mobile applications that was developed by Google in 2017. In recent years, flutter has gained popularity because to its cross-platform capacity, which means it can build apps for different platforms such as Android, iOS, and web. Flutter features several external plugins for speedy mobile application development and is a single codebase framework that can be changed to run on many platforms. DART is the language used in flutter framework. Flutter also enables hot reload, which allows you to instantly run the mobile app in an emulator or on an actual device while testing the apps.

H. Solidity (Smart Contracts)

Solidity is an object-oriented programming language similar to C and C++. Syntax is comparable to JavaScript, which is used to create smart contracts that change transactions on the blockchain [15]. The language is primarily used to generate solidity contracts on public blockchain as well as smart contracts on other blockchains. Solidity is utilized here to build and store the product invoice data in the form of smart contracts that will be implemented in the blockchain. Figure 5 delineates solidity smart contract snippet.

I. NFC Tags

It is a medium less technology that boosts the intelligence of electronic devices across a short distance. NFC is the apex of connectivity [16]. One may quickly and easily transmit information between devices with NFC whether for paying bills, swapping business cards, downloading discounts, or sharing essential documents. NFC tags refer to small devices that use this technology. They are small and convenient to carry as well as they are embedded in smartphones. One of the limitations of using NFC is that not all devices support NFC, which means that it may not be possible to use NFC for communication with some devices.

J. QR Codes

A QR code is a type of product code that encodes data as a series of pixels in a tile matrix and may be read instantly by smart devices equipped with cameras [17]. QR codes are frequently used in advertising and branding to track data on objects in a supply network. QR codes may be difficult to scan if they are damaged, distorted, or printed at a small size. This can lead to errors in reading encoded information.

K. Angular

Angular is an open-source front-end framework developed by Google for creating dynamic, modern Internet applications. The ability of angular to reduce unnecessary code results in lighter and faster programmes. The appealing characteristics of angular including those of templates, multiple binding, prefabrication, REST API processing, DLL, and AJAX handling aid in the development of responsive and interactive single-page applications. Designers may utilize HTML as a scripting language and even modify HTML syntax to clearly explain the software's components. Figure 6 shows the snippet of implementation written using angular framework.

IV. Proposed System

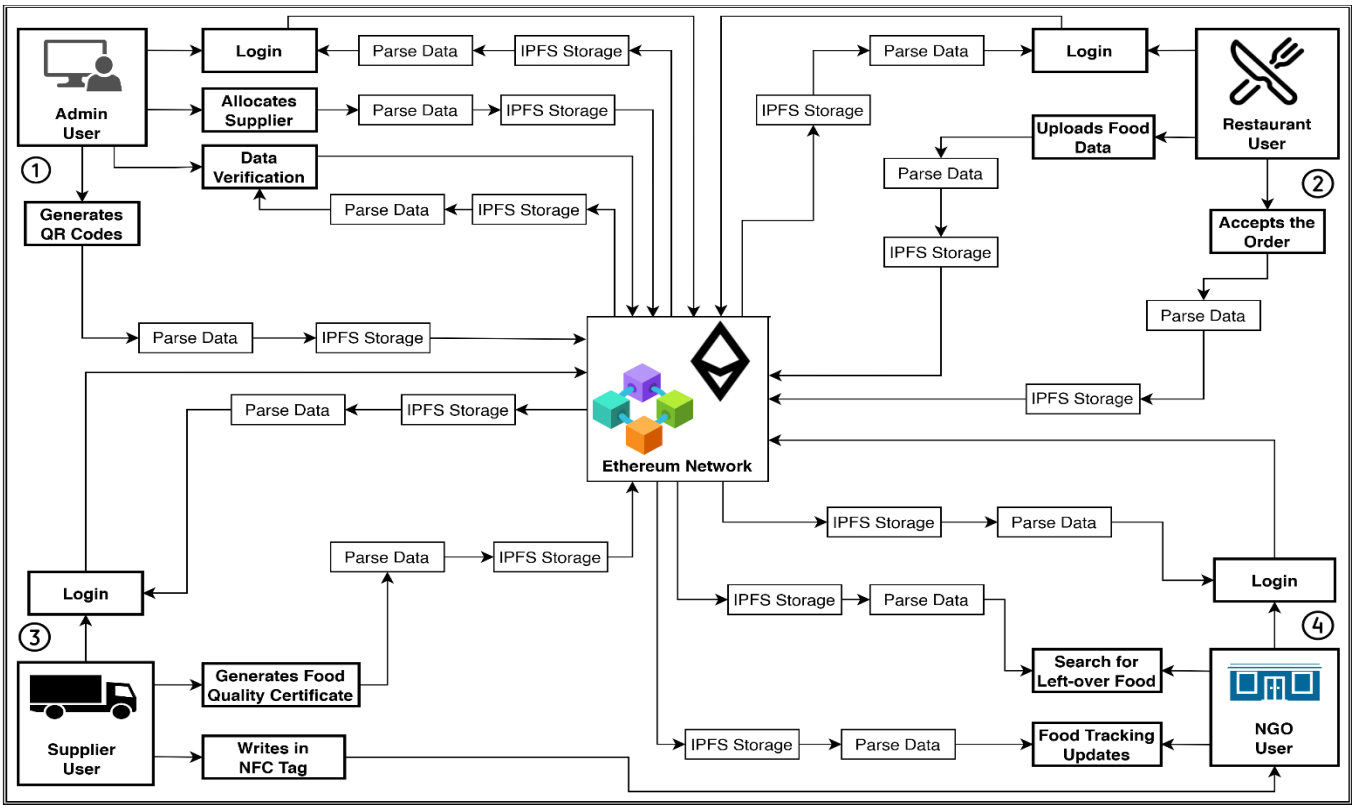

Fig. 1. Block diagram of the proposed system for food supply chain

Figure 1 represents the proposed system of the application consisting of four users:

- ***Admin User:*** The administrator has complete access to the system's capabilities. This user is also in-charge of the food traceability system. It has the ability to add new users to the system. An administrator may produce QR codes, validate data

for the granted food certificate, and assign suppliers to distribute food packages to NGOs.

Admin dashboard consists of

1. *Allocate supplier*
2. *Authenticate new restaurants*
3. *Generate a QR code*
4. *Verify certificates*
5. *View and track batches*

- ***Restaurant User:*** A restaurant user's function is to upload details about meals to be given away on the website. Weight of food, temperature of food, type of food, and other information are uploaded. In addition, when an NGO approves the meal request, the restaurant is required to put the excess food into little packages for shipment. Eventually, these packages are given over to the supplier to be processed further. Figure 8 portrays the restaurant dashboard.

  Restaurant dashboard consists of

  1. *NGO requests*
  2. *Upload food details*
  3. *Generate a batch*

- ***Supplier User:*** The supplier is in-charge of delivering food from a restaurant to the charity. The supplier ensures that the food quality is excellent. Upon confirmation, a food quality certificate is created and delivered to the admin user for authentication. Eventually, the food is provided to the non-profit organization. Figure 7 illustrates the supplier dashboard.

  Supplier dashboard consists of

  1. *Restaurants to service*
  2. *Generate food quality certificate*
  3. *Send food quality certificate*

- ***NGO User:*** The last stage of food traceability system is the safe delivery of food parcels to the charity. The charity will first receive the package and inspect it for tampering. The device will then scan QR codes and NFC tags for authentication and food information. After the information is valid and verified, the organization will proceed to distributing this food parcels to deprived/needy people.

  NGO dashboard consists of

  1. *Search for food*
  2. *Timeline of the food package*

The proposed system also consists of a mobile application, which are illustrated as follows:

1. Mobile Application

The mobile application is the way through which objects in the proposed system are validated and authenticated. The functionality of a mobile application involves three distinct components, each of which employs a distinct technology. Figure 9 shows the UI of mobile application. They are illustrated below.

A. QR Code Scanner

It refers to the capability of a camera to scan and read QR codes or rather information stored inside random patterns of QR code. After reading a QR code, a food quality certificate containing details related to packaging will be displayed.

B. NFC Tag Reader

This functionality is useful in combination with the NFC feature available on smart phones and physical NFC tags. This feature lets a user read and write into an NFC tag. However, only the reading part is implemented in the application to keep the information from being altered. After scanning the NFC tag, users will get an OTP.

C. View Certificate

This section of the mobile application will feature a text entry field wherein the OTP has to be entered. The OTP that is to be used is the one that is generated in the previous section of the application. With the help of this, NGOs will be able to view food quality certificate, which contains information related to the packaged food. This certificate will be authenticated and uploaded by the Admin.

2. Flow of Implementation

Figure 2 outlines the activity flow of the food supply chain and Figure 3 shows the graphical view of the system.

1. After the NGO receives food parcels, they must scan the QR code on the package using QR code scanner included in the mobile app to check food-related data.

2. The NGO will now open the shipments after scanning the QR code and inspecting food packages. NFC tag will be located at the bottom of packages. The NGO will scan and read the tag using the phone's NFC tag reader.

3. The NFC Tag will have a One-Time Password (OTP) that the NGO must input in order to read and download the Food Quality Certificate.

4. The NGO may view and download food certificate that has been authenticated by the Admin, after entering the OTP in the view certificate section.

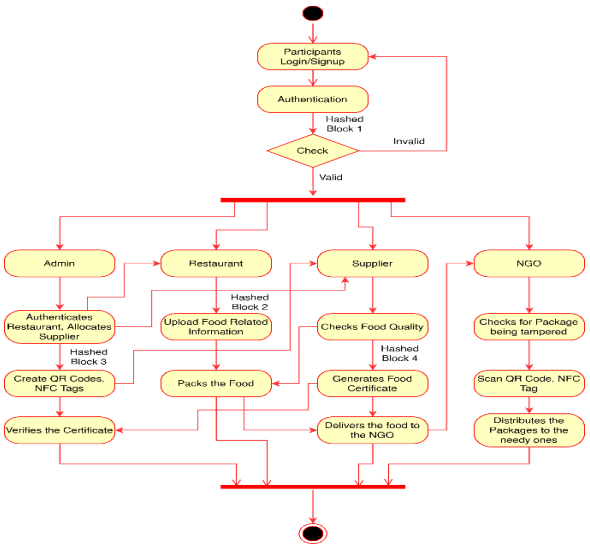

Fig. 2. Activity flow diagram of food supply chain management

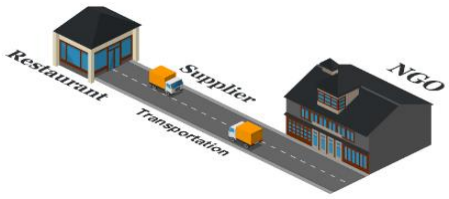

Fig. 3. Graphical representation of food supply chain management

V. IMPLEMENTATION

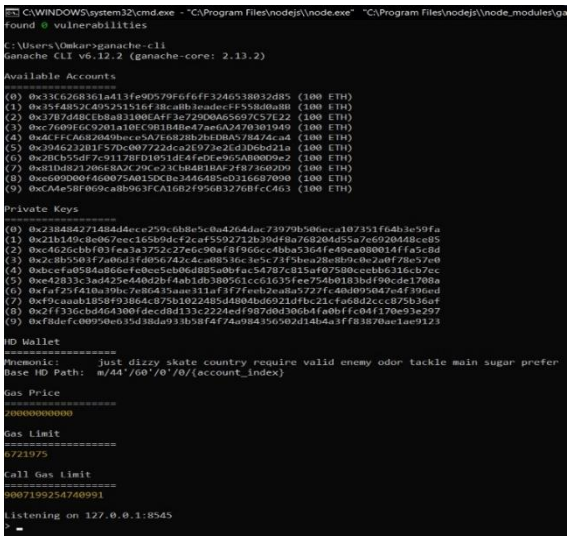

Fig. 4. Running Ganache CLI

Figure 4 depicts the running of *ganache-cli*. It supports standard RPC calls like events and may be executed deterministically to make development easier.

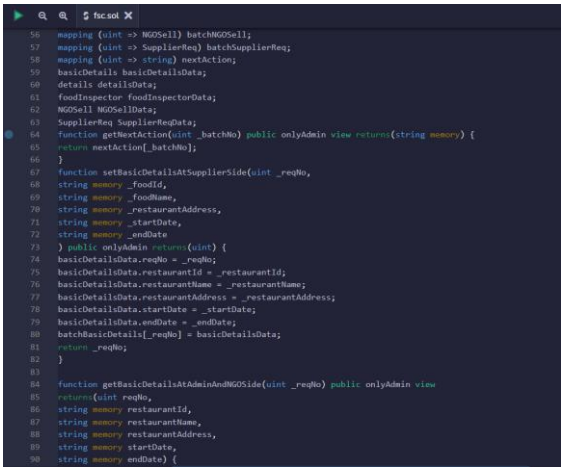

Fig. 5. Snippet of Solidity Smart Contract

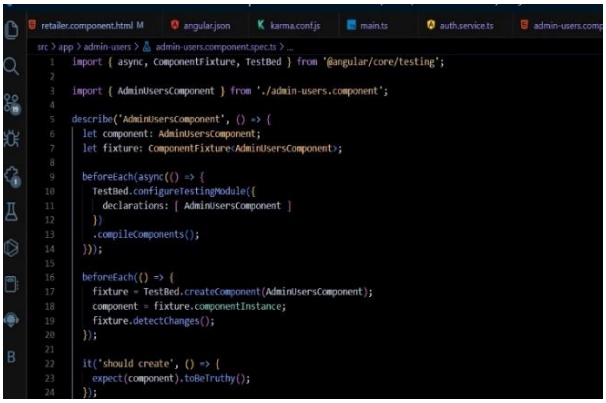

Fig. 6. Snippet of AngularJS implementation

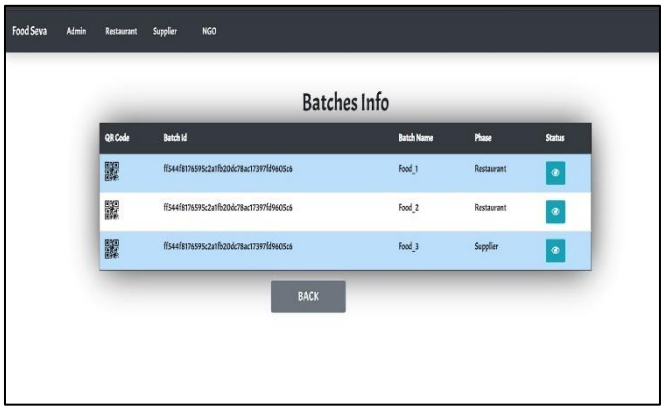

Fig. 7. Supplier Dashboard

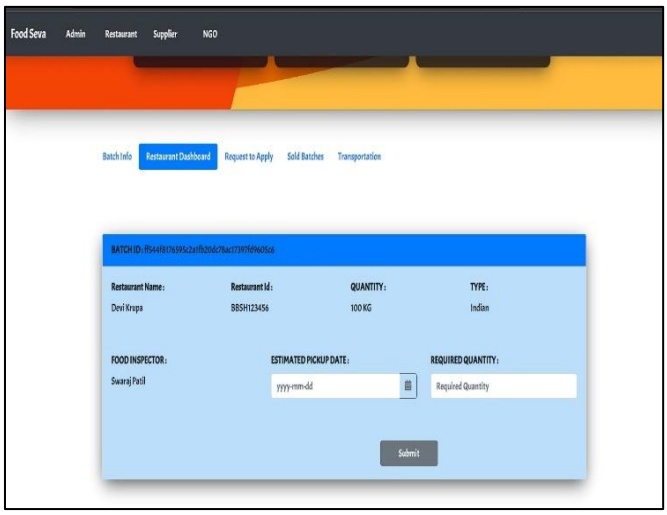

Fig. 8. Restaurant Dashboard

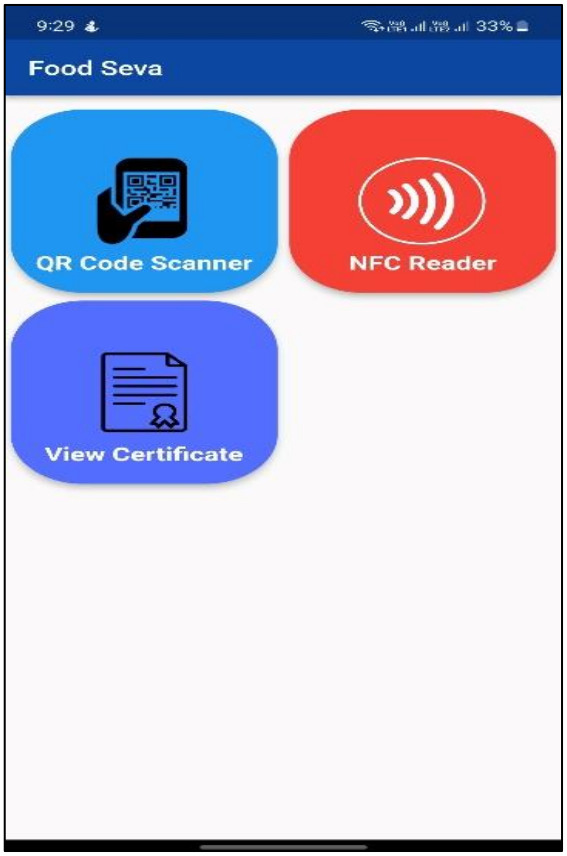

Fig. 9. Android app main menu

VI. Results and Discussion

Blockchain incorporation, QR code, and NFC technology in food supply chain management has been shown to improve transparency, traceability, and accountability. These technologies allow for secure and decentralized tracking of food packages from a restaurant to an NGO, making it easier for NGOs to verify the authenticity of food packages and monitor safety and quality of food supply. Blockchain technology provides a secure and decentralized platform for tracking food packages as they move through the supply chain. Each participant in the supply chain, including admin, restaurant, supplier, and NGO, can record transactions on the blockchain, creating an immutable and transparent record of the food package's journey. This allows for greater transparency and traceability, which can improve consumer confidence in food supply. QR codes and NFC technology provide a way for NGOs to access this information easily. By scanning a QR code or tapping an NFC-enabled device, consumers can access information about the food package's origin, preparation methods, and supplying history. Small-scale restaurants and NGOs may not have the resources to invest in the necessary technology, and some NGOs may not have access to devices that can scan QR codes or read NFC tags. However, as technology becomes more widespread and affordable, these barriers may be overcome. Overall, the integration of blockchain, QR code, and NFC technology has the potential to improve food safety, sustainability, and transparency in food supply chain.

VII. Conclusion and Future Scope

In conclusion, the integration of blockchain, QR code, and NFC technology in food supply chain management has the embryonic to revolutionize the way NGOs track and verify the quality and safety of food packages. These technologies offer great transparency and traceability, which can improve NGOs confidence in food supply and promote sustainability and safety. While there are challenges to the adoption of these technologies, including cost and accessibility, potential benefits make them a promising area of research and development. Looking ahead, there are several areas where the integration of blockchain, QR code, and NFC technology could have an astonishing impact on consumables supply chain management. One of the potential applications is in the tracking of food waste, which could be reduced through better management and redistribution of surplus food. As these technologies become more widely adopted, it is likely that new applications will emerge, and the benefits of transparency, traceability, and accountability will continue to be realized. However, it will be important to address the challenges of cost, accessibility, and privacy to ensure that these technologies are available and beneficial to all participants in food supply chain. With continued research and development, the integration of blockchain, QR code, and NFC technology in supply chain management has the embryonic to promote a safer, more sustainable, and more trustworthy food supply chain.

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