Cereals Supply-Chain Traceability Using Blockchain and IoT Technology

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***Abstract*—The TraCEREAL project explores the integration of Blockchain and Internet of Things (IoT) technologies to enhance traceability, transparency, and efficiency in Cyprus' cereal supply chain. By identifying the farm-to-fork key actors, their needs and priorities, the project develops a prototype system across the critical points of production and distribution by combining intelligent algorithms and real-time data for improved decision-making.**

Keywords - blockchain; cereal; Internet of Things; traceability.

I. INTRODUCTION

The world faces a multitude of challenges related to food security, health, nutrition, and sustainability [1]. These issues stem from a combination of factors, such as the growing global population, the escalating impacts of the climatic crisis, water scarcity, and limited local food production (often caused by ongoing conflicts around the globe), which result in a fragile cereal supply chain that is highly reliant on imports [2]. The cereal supply chain is vital for food security, but also for ensuring food quality, as pests and toxins can contaminate cereals.

Blockchain technology is emerging as a promising solution to the many challenges facing food supply chains, as it promotes transparency and efficiency by creating secure, immutable records of transactions, thereby enhancing traceability [3]. In addition to traceability, there is also the need for accurate and real-time information on the factors that affect both qualitative and quantitative yield traits. When applied in agriculture, the IoT, a network of interconnected devices that collect, analyze, and enhance data in real-time, enables precision agriculture, automation, and data-driven decision making [4] [5].

The TraCEREAL project [6], is dedicated to investigating how blockchain technology, in conjunction with advanced IoT capabilities, can contribute to the establishment of resilient supply-chain operations within Cyprus. The project's objective is to develop and demonstrate a functional prototype system consisting of an intelligent algorithmic framework, seamlessly integrated with IoT technology. To this end, cultivation practices for recording sensory data were implemented as part of the demonstration activities, including a set of pilot experimental fields established across Cyprus. Telemetric stations equipped with IoT sensors were installed in mid-January at each plot to comprehensively track and report crucial environmental and soil conditions. The sensors can collect real-time data on various critical soil parameters, such as moisture levels, temperature, salinity, PH, and nitrogen/phosphorus/potassium content.

For the development of the TraCEREAL system, the first step was to map the key actors across the cereal supply chain: (a) breeders, can document and track the genetic characteristics of new crop varieties, ensuring their adaptation to environmental conditions and market needs, (b) seed producers, receive insights on seed quality, germination rates, and resistance to environmental factors, facilitating better production planning, (c) farmers, can utilize IoT sensor data and platform recommendations to optimize agricultural inputs, irrigation, fertilization and yield, ensuring sustainable and high-quality production, (d) flour mills, gain access to detailed grain quality analyses, enabling them to maintain consistency and improve processing efficiency, and (e) end consumers, i.e., bakeries and consumers benefit from full traceability, with access to information on the origin, nutritional properties, and processing history of food products (e.g., flour, pasta). The main objective of this paper was to identify and document the priorities and needs of the key actors across the cereal supply chain.

The structure of this paper is organized as follows: Section 1 introduces the background and objective of the study. Section 2 describes the materials and methods used in the study. In Section 3, we present the results of our empirical investigation. Finally, Section 4 concludes the paper with a summary and main findings.

II. METHODOLOGY

Three different structured questionnaires (grouped as either producer, milling industry, and end-users) were co-created to determine which traits should be included in the blockchain, recognizing that each stakeholder has unique priorities and needs. The first questionnaire was addressed to

seed producers and cereal farmers, the second questionnaire was directed towards flour mills, and the third questionnaire was interested in the views of end consumers (e.g., local bakeries and consumers).

Personal interviews were conducted, between November 2024 and January 2025, with seed producers, cereal farmers, mills' executives, and bakers. Consumers answered an online-version of the questionnaire. Representatives of two mills provided input to the relevant questionnaire. Two out of the four of the seed producers and thirty-three cereal farmers answered the second questionnaire. Eleven bakery owners and 101 consumers answered the third questionnaire.

III. RESULTS

A. Seed producers and cereal farmers

Among the most desirable wheat traits that seed producers and cereal farmers wish to be informed about through the blockchain system are drought resistance, disease resistance, as well as the adaptation to diverse edaphoclimatic conditions. Surprisingly, the breeding method, i.e., conventional breeding or the use of New Genomic Techniques, is not a primary concern (Figure 1). In addition, seed producers (cereal farmers) are particularly interested in accessing data on yield, soil temperature, soil moisture, and fertilization needs. Conversely, important traits, such as starch composition and dough traits are of limited interest to seed producers and cereal farmers.

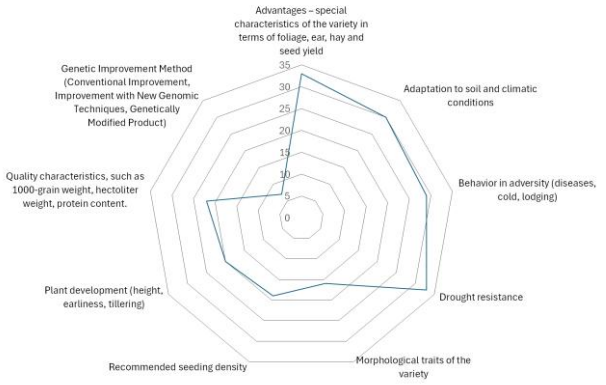

Figure 1. Seed producers (cereal farmers) data traceability requirements.

B. Milling industry

The milling industry has a distinct set of priorities regarding the data of interest within the blockchain system. The most important traits that emerged are the type of cultivation (conventional or organic), protein and starch content, as well as dough elasticity, since these features affect both the price and quality of the produced flour.

C. Bakeries and consumers

For the end-consumers, the most important aspects of traceability information are the country of origin for the raw material, the origin of the final product (e.g., flour, pasta), and the type of the cultivation (Figure 2).

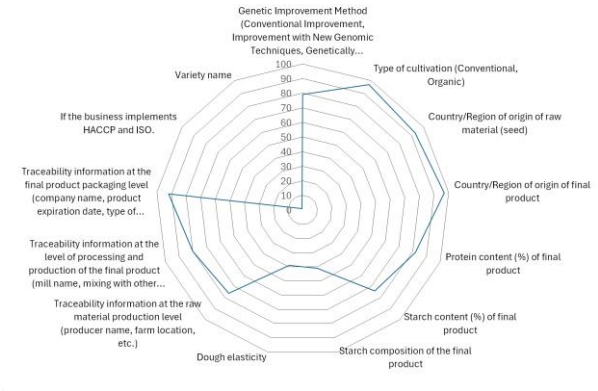

Figure 2. End consumers traceability data requirements.

Interestingly, consumers do not prioritize the implementation of Hazard Analysis and Critical Control Points (HACCP) and International Organization for Standardization (ISO) certificates, nor the specific crop varieties used.

IV. CONCLUSION

TraCEREAL is an ongoing project focused on leveraging blockchain and IoT to ensure secure, immutable data storage, fostering trust among all stakeholders across the cereal value chain. The initial phase involved mapping and documenting the priorities and requirements of the main stakeholders throughout the cereal supply chain. Survey results revealed that each key actor has distinct priorities and needs. The feedback from these stakeholders will contribute to building the TraCEREAL blockchain framework and database. This system aims to assist policymakers and industry players in creating more resilient cereal supply chains, specifically adapted to the unique needs of Cyprus.

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