In the agro-food supply chain, several technical challenges arise, which can be discussed in detail for a literature survey paper:

# 1. Data Quality and Traceability

- Data Fragmentation: Data across the supply chain is often fragmented, leading to a lack of unified visibility. Different stakeholders use diverse systems, creating issues in tracking and traceability.
- Data Integrity: Ensuring that the information is not altered during transmission is a major challenge, affecting food traceability.
- **Sensor Accuracy**: IoT devices used in agriculture for tracking environmental factors might suffer from accuracy issues, leading to poor-quality data collection.

### 2. Integration of IoT and Blockchain

- **Interoperability**: IoT devices need to seamlessly communicate with blockchain networks for traceability. Lack of standardized protocols across devices hinders integration.
- Scalability of Blockchain: Blockchain's inherent limitations in transaction speed and storage requirements can pose a problem when integrating high-frequency IoT data from agro-food supply chains.
- Data Latency: Real-time data processing from sensors and devices is necessary for proactive decisions, which can be challenging with blockchain's transaction validation times.

#### 3. Cold Chain Management

- **Temperature Monitoring**: Technical limitations in continuous temperature monitoring during transit can lead to spoilage of perishable goods.
- **Energy Consumption**: IoT-based sensors require power, and maintaining the energy supply during transport is a technical constraint, especially in remote areas.

### 4. Information Asymmetry and Trust

- **Privacy-Preserving Data Sharing**: Data sharing among supply chain participants raises concerns about privacy. Methods like differential privacy and homomorphic encryption can be complex to implement.
- **Data Authentication**: Verifying the authenticity of data entries, especially for non-digital inputs like farm yields, is challenging in the absence of a robust verification mechanism.

# **5. Supply Chain Coordination**

• **Decentralized Information Sharing**: Agro-food supply chains have multiple stakeholders, including farmers, transporters, retailers, etc. Enabling secure, decentralized information sharing while avoiding central points of failure is challenging.

• **Smart Contracts**: Developing and managing smart contracts for supply chain automation is technically demanding, especially considering the dynamic nature of agricultural conditions (e.g., weather changes affecting crop yield).

### 6. Scalability and System Performance

- **Throughput Constraints**: As the number of stakeholders and data transactions increase, the system's ability to handle high transaction volumes without significant delays is limited.
- **High Data Volume**: The agro-food supply chain generates massive amounts of data, from farm sensors to transportation. Processing and storing this data in real-time is a technical challenge.

## 7. Interoperability between Systems

- **Legacy Systems**: Many stakeholders still use traditional, paper-based systems or older software, which makes integration with modern digital solutions difficult.
- API Standardization: Creating standardized APIs for communication between different supply
  chain systems can be technically complicated, especially when dealing with diverse and siloed
  data.

#### 8. Quality Control and Food Safety

- **Contaminant Detection**: Implementing automated systems for real-time detection of contaminants or adulterants in food products is challenging, often requiring advanced sensing and AI algorithms.
- **Spoilage Prediction**: Developing predictive models to assess food spoilage requires accurate, real-time data, which may not always be available.

#### 9. Security and Cyber Risks

- **Cyber Attacks on IoT Devices**: IoT devices in agriculture are prone to vulnerabilities such as Distributed Denial of Service (DDoS) attacks, which can disrupt the supply chain.
- **Blockchain Security**: Blockchain networks can be susceptible to attacks like 51% attacks, posing risks to the integrity of the supply chain data.

#### 10. Sustainability Concerns

- **Energy Consumption of Blockchain**: Consensus algorithms like Proof-of-Work consume significant amounts of energy, which is not suitable for a sustainable agro-food supply chain.
- **IoT Device Lifecycle**: Ensuring sustainability in the lifecycle of IoT devices, from production to disposal, is a technical issue that needs to be addressed.

### 11. Standards and Regulatory Compliance

• **Compliance with Diverse Standards**: Different countries or regions have varied regulatory requirements. Ensuring that the technology complies with all standards is complex.

• **Data Governance**: Establishing data governance frameworks that ensure compliance while allowing transparency is a major challenge in the agro-food supply chain.

# 12. Limited Connectivity in Rural Areas

- **Network Infrastructure**: Poor connectivity in rural areas where food production takes place can hinder the real-time collection of data and integration with digital supply chain systems.
- Edge Computing Limitations: While edge computing is used to process data locally, its integration with cloud systems for aggregated analysis can be technically difficult due to inconsistent network conditions.

Addressing these challenges requires a combination of technological advancements, infrastructure improvements, and stakeholder collaboration to enhance the efficiency and transparency of agro-food supply chains.