IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 3, October 2025
Impact Factor: 7.67

Opportunities of Employing Advanced Technologies (Artificial Intelligence, Internet of Things, Cloud Computing) for Serving Food Engineering Technology

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Abstract: *Recent advancements in technologies like Artificial Intelligence (AI), the Internet of Things (IoT), and Cloud Computing (CC) have captured the attention of the research community, particularly in their applications across various domains. Food engineering technologies play a crucial role in our daily lives by ensuring that food is healthy and safe for consumption, thereby protecting public health. The integration of AI, IoT, and CC with food engineering technology fosters the development of advanced systems that enhance the speed and accuracy of monitoring food freshness and quality. This integration helps mitigate serious health risks and protects the reputation of food companies. This study examines the potential of leveraging advanced technologies (AI, Deep Learning, IoT, and CC) to benefit food engineering. It outlines the general architecture of each technology and integrates them into a cohesive framework. This adaptable framework can serve multiple purposes within food engineering, including monitoring food quality, assessing freshness, implementing smart packaging, and detecting bacterial contamination. Moreover, the research highlights the existence of numerous online data repositories that can be utilized to develop sophisticated systems based on the integrated framework. By employing this framework, data for training intelligent systems can be accessed and managed through cloud computing, allowing for local or remote training based on required security and privacy standards. Finally, IoT infrastructure is utilized to gather sensory data, enabling real-time predictions.*

Keywords: Intelligent System, Framework, IoT Sensor Data, Storage, Gas-Based Signature

I. INTRODUCTION

Recently, advanced technologies such as Artificial Intelligence (AI), Internet of Things (IoT), and Cloud Computing (CC) have been attracted research community to serve other domains. Food engineering technologies is a vital in our daily life as it aims at ensuring that the provided food is healthy to avoid harm of people. Integration of AI, IoT, and CC with food engineering technology leads to develop advanced and intelligent systems that result in speed of responses in regards to monitoring food freshness as well as providing accurate indicators to test the quality of food. This in turn leads to avoid serious problems related to health of people and reputation of food companies.

A. Statement of Problem

Exploring opportunities of integration among the AI, IoT, CC and food engineering technologies is considered crucial concern since each technology has its own infrastructure, methodology of usage, and objectives [1, 2]. In this context, the problem can be described by providing a general framework that integrate all technologies mentioned previously to provide an effective base to develop intelligent and advanced systems that contribute to serve food engineering technology. To the best of our knowledge, this is the first work that provided details related to presenting a comprehensive framework that combines AI, IoT, CC and food engineering technology. Based on statement of problem, some research questions are derived as described below.

B. Research Questions

The research questions that are linked to the problem stated above are as follows:

1- What is the goal of AI, how to adapt it in the framework to build intelligent system, and what is the role of AI in the integrated framework?

2- What is the goal of IoT, how to adapt it in the framework to build intelligent system, and what is the role of IoT in the integrated framework?

3- What is the goal of CC, how to adapt it in the framework to build intelligent system, and what is the role of CC in the integrated framework?

4- How the integration of AI, IoT, and CC will be performed along with integration to food engineering technology?

II. OVERVIEW OF ARTIFICIAL INTELLIGENCE, INTERNET OF THINGS, CLOUD COMPUTING, AND FOOD ENGINEERING TECHNOLOGIES

This section provides an overview about the principles of each technology as well as related terms, primary objective and general architecture of each technology, as described below.

A. Artificial Intelligent Technology

Definition. Artificial intelligence is the technology that mimics the human brain work, so that the AI-based systems contribute to make accurate decisions. In other words, AI is the ability of computer systems to perform tasks that typically require human intelligence, such as learning, problem-solving, and decision-making [3]. It involves technologies that allow machines to see, understand language, analyze data, and act intelligently to achieve specific goals.

Primary Objective. The primary goal of AI is to provide predictions related to problems as accurate as possible, so that such predictions can be employed in reality to facilitate our daily activities. For example, in medical sector, AI contribute to accurately predict if a given lung X-ray or CT-scan images indicate to existing of COVID-19 or not [4, 5].

Basic Terms. First term used in AI is knowledge base. It is related to obtain data used to build intelligent systems. Such data sets can be online available for free usage in researches, or can be collected manually. Second term is pre-processing. It is related to process the knowledge base so that it will be of high quality to enable effective building of AI systems. Third term is training. It is related to train the AI system based on a specific portion of knowledge base. Forth term is testing. It is related to test the trained AI system to evaluate the accuracy. Final term is accuracy. It is related to calculate the accuracy of the prediction based on what is called confusion matrix [6].

General Architecture. The general architecture of building AI-based systems is illustrated in Figure 1, where knowledge base (denoted in orange rectangle), preprocessing stage (denoted in green rectangle), and neural networks as intelligent model (denoted in blue rectangle) are used. In addition, the standard steps used to create intelligent systems is illustrated in Figure 2.

DOI: 10.48175/IJARSCT-29371

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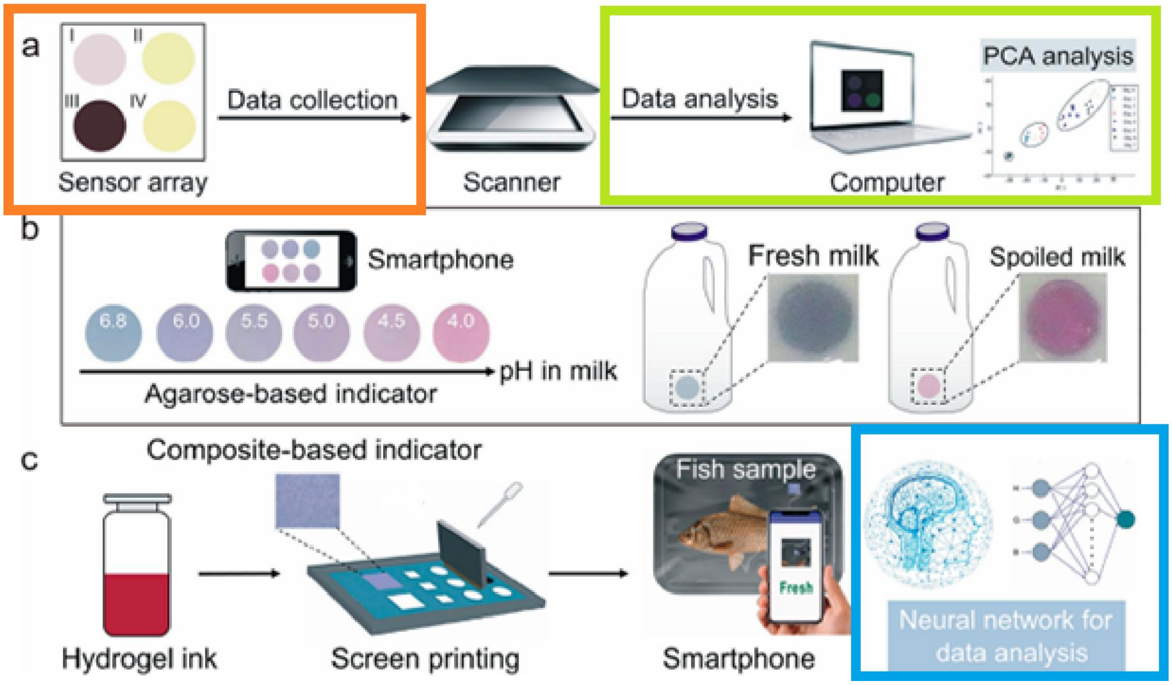

Figure 1. General architecture of AI-based systems [7].

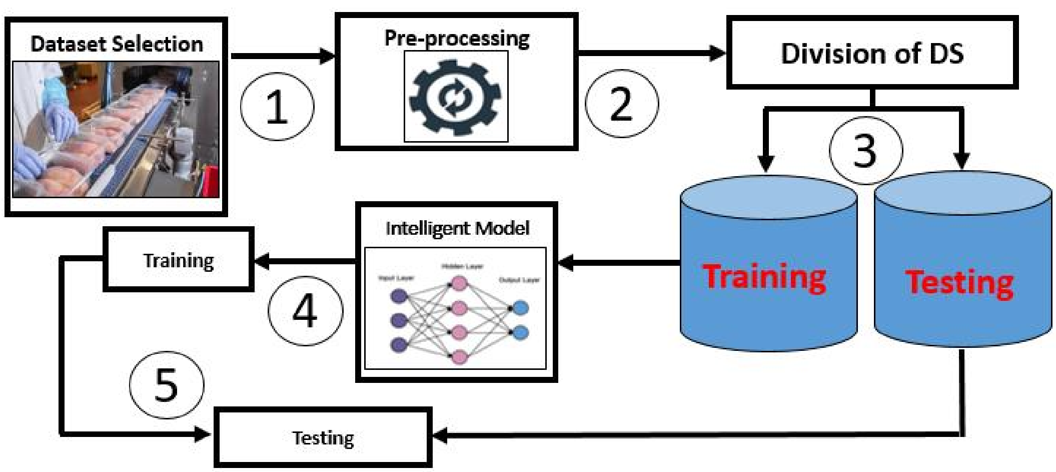

Figure 2. Standard steps used to create intelligent systems.

The most important step is selection of dataset, where it can be available online or created manually by researchers. In the context of food engineering technology, there are many available online datasets related to food products and related infection of bacteria that negatively affect the freshness. They are listed as arranged in Table 1.

TABLE 1: ONLINE REPOSITORIES WITH AVAILABLE DATASET RELATED TO FOOD ENGINEERING.

Repository Name	NO	Dataset Name	Dataset Size	Dataset Link
Universe	1	Chicken Salmonella	2391 Images	Chicken Salmonella Model > Overview
	2	Milk E.coli Detection	49 Images	EcoliDetection > Browse
	3	chicken-disease-	9337 Images	chicken-disease-detection

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		detection		Model > Overview
Kaggle	4	Pathogen Detection |Salmonella	250 Images	Pathogen Detection | Salmonella Enterica
	5	Meat Quality Assessment Dataset	1500 Images	Meat Quality Assessment Dataset
INRAE	6	Data INRAE	576 type of bacteria	Replication Data for "Large-scale multivariate dataset on the characterization of microbiota diversity, microbial growth dynamics, metabolic spoilage volatilome and sensorial profiles of two industrially produced meat products subjected to changes in lactate concentration and packaging atmosphere" - Data INRAE
UCI	7	Many food datasets	1000 Images	Datasets - UCI Machine Learning Repository

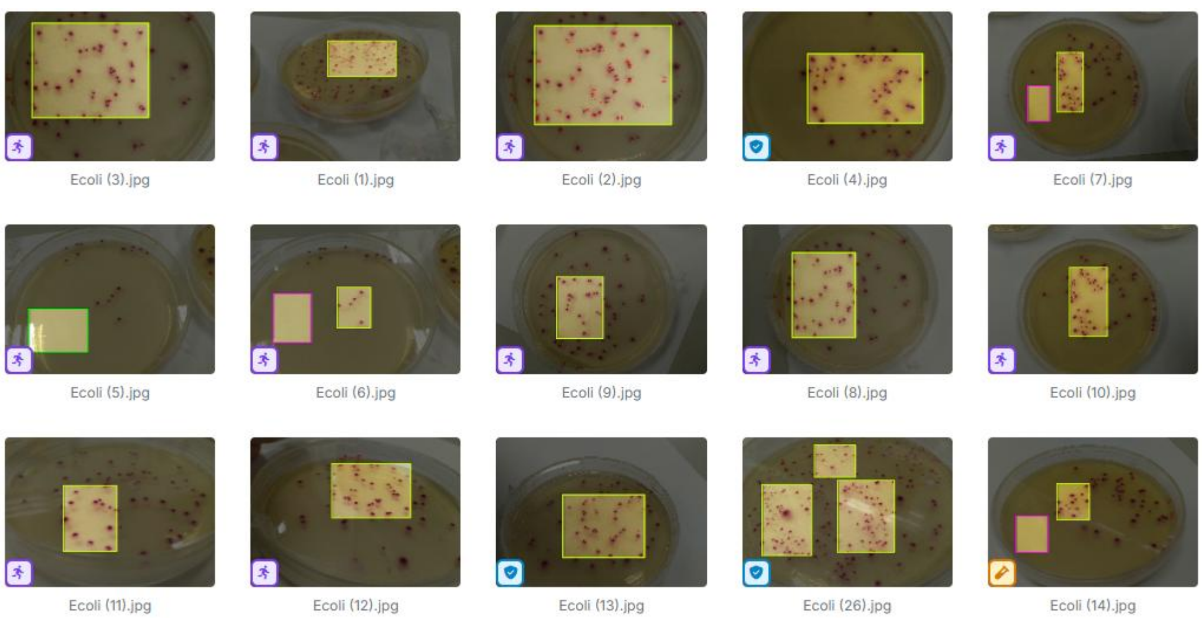

Figure 3. Samples of E.coli contamination taken form the Ecoli Detection dataset.

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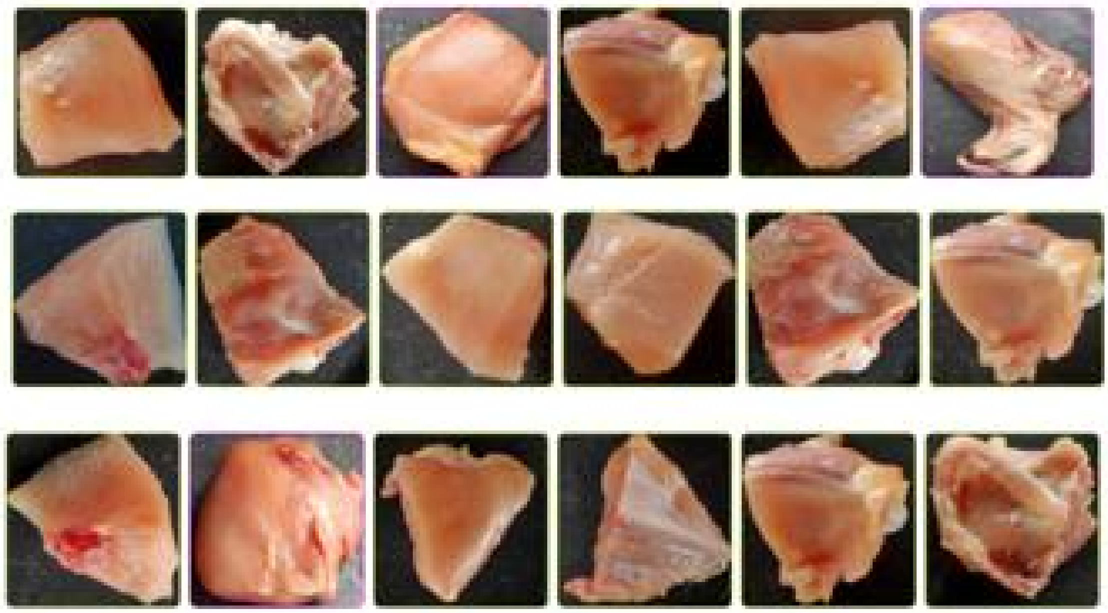

Figure 4. Samples of Salmonella contamination taken form the Chicken Salmonalla dataset.

B. Internet of Things Technology

Definition. Internet of Things (IoT) is a network of physical objects embedded with sensors, software, and connectivity to collect and exchange data over the internet. These "smart" devices, ranging from household appliances to industrial machinery, can communicate with each other, enabling remote monitoring, control, and automation. The primary goal of IoT is to use this connected network to improve efficiency, convenience, and decision-making [8].

Primary Objective. The primary goal of IoT is to provide infrastructure to build intelligent systems that take data from the sensors linked with devices, such as smart phones and others.

Basic Terms.The basic elements of IoT are sensors/devices, connectivity, data processing, and a user interface. Sensors are used to gather\collect data. Connectivity is the way of communication among sensors or devices. Data processing is the method used to prepare data to be of high quality. User interface is the graphical interface that enable users to enter data and get the results. Figure 5 illustrates the basic elements of IoT in the context of smart packaging of food.

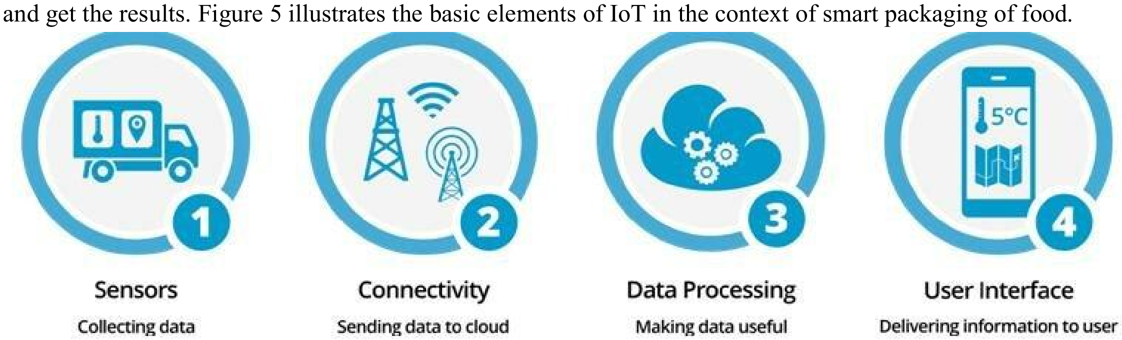

Figure 5.Elements of IoT.

General Architecture. The general architecture of IoT can be derived from Figure 5 above. It is obvious that the sensors embedded within smart devices are connected via wireless network, which forms the second layer of IoT. Within intelligent systems, data are processed by special techniques that are suitable for type of data. The last layer is related to designing a friendly and appealing interface to show results and infer conclusions that help to make accurate decisions.

C. Cloud Computing Technology

- Definition. It is a paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources with self-service provisioning and administration on-demand. In practical, cloud computing can be exploited to store data and retrieve it on time as well as harnessing its methods\capabilities to perform advanced processing using its powered resources.
- Primary Objective. The primary goal of cloud computing is to use it as portal repository of our big data, where we can access it anytime and anywhere using Laptops, PCs, or smart phones [9, 10].
- Basic Terms. The basic elements of cloud are: first, storage workplace where data are stored; second, servers that are responsible for processing the data; third, methods that are used to perform the desired task on the stored data; and finally, applications that are offered for usage based on payments.

General Architecture. The general architecture of cloud computing consists of servers, virtual desktop, software platform, application, and storage space of data. Figure 6 illustrates the architecture of clod computing.

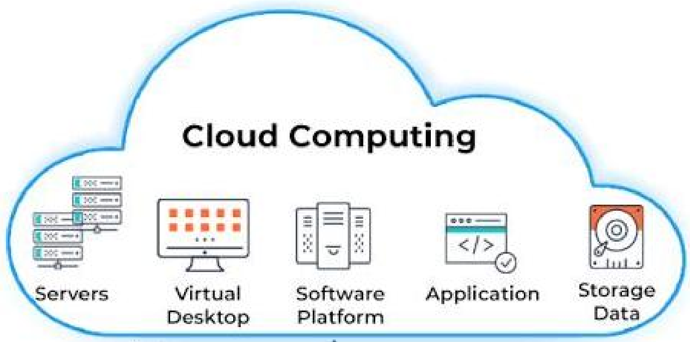

Figure 6. Architecture of cloud computing.

D. Food Engineering Technology

Definition. It is a scientific field that interprets and applies principles of engineering, science, and mathematics to food manufacturing and operations, including the processing, production, handling, storage, conservation, control, packaging and distribution of food products [11].

Relationship with Advanced Technologies. The relationship between food engineering technology and advanced technologies such as Artificial Intelligence (AI) and Deep Learning (DL) is increasingly significant. Here are some key aspects of this relationship:

1. Quality Control and Assurance

• AI and DL can analyze data from various stages of food processing to ensure quality. Machine learning algorithms can detect anomalies in product quality, helping to maintain standards.

2. Process Optimization

• AI can optimize food processing parameters, such as temperature and pressure, to enhance efficiency and reduce waste. Models can predict the best conditions for specific food products.

3. Supply Chain Management

• AI technologies improve logistics and inventory management in food engineering. Predictive analytics can forecast demand, leading to better supply chain decisions.

4. Product Development

• DL algorithms can analyze consumer preferences and trends, assisting food engineers in developing new products that meet market demands.

5. Food Safety

• AI can enhance food safety by monitoring and analyzing data from production to distribution, identifying potential hazards and ensuring compliance with safety standards.

6. Sustainability

• Advanced technologies can help in developing sustainable practices in food engineering, such as reducing energy consumption during processing and minimizing waste through predictive modeling.

7. Consumer Interaction

• AI-driven tools can enhance consumer engagement, providing personalized recommendations and improving overall customer experience.

III. INTEGRATED FRAMEWORK OF ARTIFICIAL INTELLIGENCE, INTERNET OF THINGS, CLOUD COMPUTING, AND FOOD ENGINEERING TECHNOLOGIES

This section provides the proposed framework used to integrate AI, IoT, CC, and food engineering technologies in one view for the purpose of serving food engineering. Figure 7 illustrates the proposed framework.

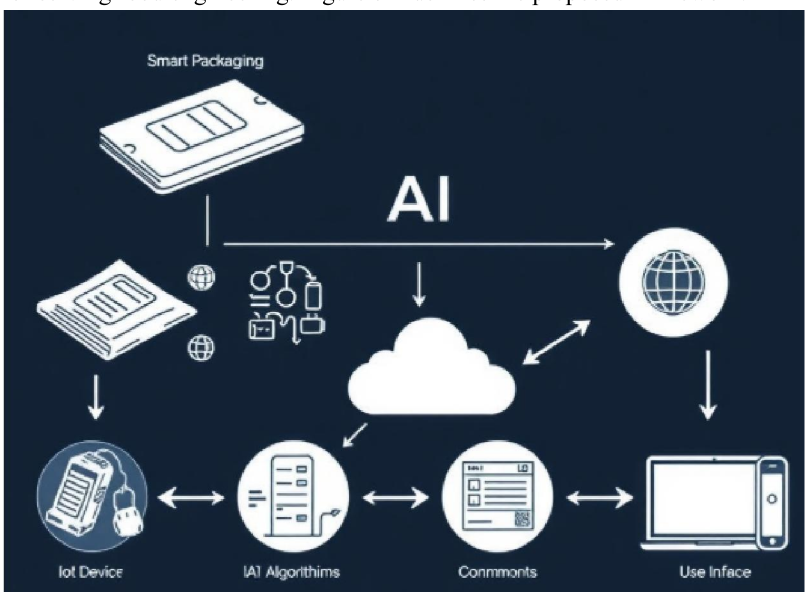

Figure 7. Proposed integrated framework.

In the context of smart packaging of food, the role of each component provided by the integrated framework is as follows:

1. Smart Packaging:

• Packaging embedded with sensors that monitor environmental conditions such as temperature, humidity, and gas levels. This technology helps in assessing the freshness and quality of food products.

2. IoT Devices:

• Various sensors and devices that collect real-time data from the smart packaging. These devices communicate with each other and send data to the cloud for processing.

3. AI Algorithms:

• Advanced algorithms that analyze the collected data to assess food quality, predict spoilage, and make recommendations for optimal storage conditions. AI helps in making informed decisions based on historical and real-time data.

4. Cloud Computing:

• A centralized platform that stores the data collected from IoT devices. It enables scalable analysis and easy access to data from anywhere, facilitating better management and oversight of food quality.

5. User Interface:

• A mobile or web application that allows consumers or producers to access and interpret the quality data. This interface provides insights and alerts regarding food freshness and safety, empowering users to make informed choices.

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These elements work together to create an efficient system for monitoring and ensuring food quality throughout the supply chain.

IV. FLEXIBILITY OF THE PROPOSED INTEGRATED FRAMEWORK

The proposed framework can be adapted to serve various purposes in food engineering technology. To develop a comprehensive system for manufacturing, supply chain, and delivering products as well as enabling users to rate the quality of the products, Figure 8 adapts our proposed framework for this purpose.

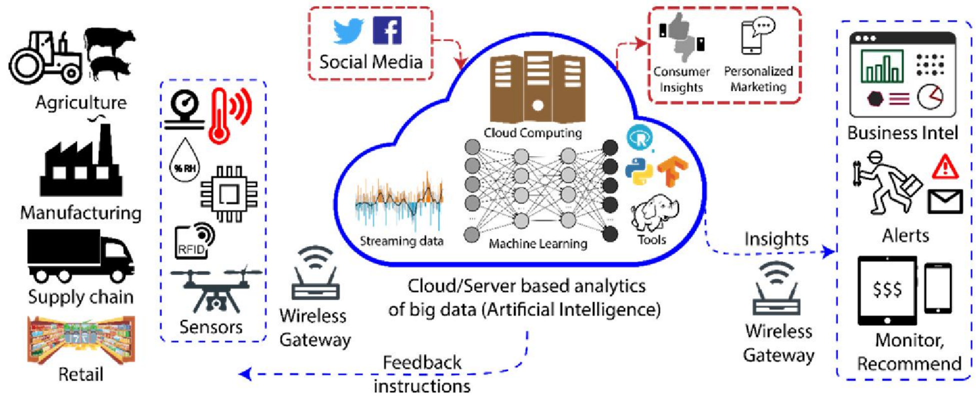

Figure 8. Adaption of our proposed integrated framework for control quality of food\products based on comments\rating of customers [12].

In addition, the proposed integrated framework can be adapted to develop advanced system to detect contamination of bacteria in various kinds of meat based on signatures of gases, as shown in Figure 9.

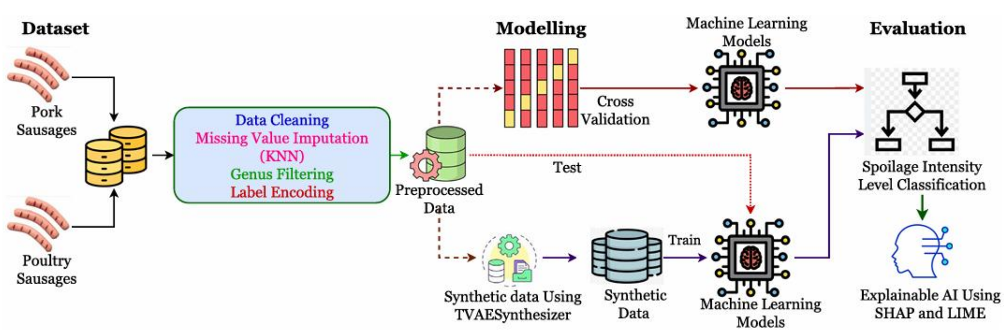

Figure 8. Adaption of our proposed integrated framework for developing gas-based signature for detection of bacterial contamination [13].

It is worth mentioning that privacy of data is a major concerns in such framework as well as security. In this context, the proposed framework can be maintained to integrate with advanced systems such as those proposed in the [14-18]

V. CONCLUSION

This work explores the opportunities of harnessing advanced technologies (AI, DL, IoT, CC) to serve food engineering technology. The work presents the general architecture of each technology, and then integrated them in a one integrated framework. The framework can be adapted for many purposes in food engineering technology, such as monitoring quality of food, evaluation freshness of food, smart packaging of food, and detection of contamination by bacteria. In addition, the work proves that there are many online repositories of data that can be exploited to create advanced systems based on the integrated framework. Using the proposed framework, the data that is used to train intelligent systems will be available and portal using cloud computing technology, and intelligent systems can be trained on the portal data locally of remotely based on the security and privacy level that is required. Finally, IoT infrastructure are employed to collect sensory data to provide predictions on real time.

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