Significance of RFID (Radio Frequency Identification) in the Food Industry

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Abstract

Radio Frequency Identification (RFID) stands as a viable alternative to conventional Universal Product Code (UPC) barcodes. Unlike barcodes, RFID allows for non-line-of-sight object identification from a distance. RFID tags have the capability to store extra information, including product details and manufacturer information, and can also transmit environmental data like temperature and relative humidity. The fundamental components of RFID include the tag, reader with an antenna, and associated software. The technology operates based on either magnetic induction or capturing electromagnetic waves. Its extensive applications are particularly evident in the food industry.

Introduction

The surge in food product demand has spurred substantial changes in food production and distribution processes, driven by advancements in food product technology. Rapid identification technologies, particularly those relying on wireless communication such as radiofrequency waves, have greatly enhanced the handling of raw materials and finished goods in the food industry. The origins of RFID (Radio Frequency Identification) trace back to World War II, where it was initially employed for Friend or Foe (IFF) identification of military aircraft (Kumari *et al.*, 2015). Unlike other identification systems like barcodes, RFID offers more convenience in product identification, allowing for non-line-of-sight object recognition from a distance (Bibi *et al.*, 2017). These RFID tags can be placed within objects, containers, or even injected into animals, providing a versatile solution (Finkenzeller, 2003).

Compared to barcodes, RFID offers a longer reading range of over 100 meters, and RFID readers can differentiate between multiple tags in the same area without human intervention. RFID technology operates in various frequency ranges, including low frequency, high frequency, amateur radio band, ultra-high frequency, and microwave frequency (Brown, 2007). Despite its advantages, it's worth noting that RFID technology is more expensive than traditional barcode technology (Want, 2006). The ongoing technological advancements in networking devices, sensors, and communication technologies are crucial for the sustainability of the Agri-food sector. RFID, as a pervasive technology, is increasingly being utilized in various facets of the food industry, including logistics, supply chain management, cold chain monitoring, and retail (Ruiz-Garcia & Lunadei, 2011).

Figure 1: RFID in food industry

Main Components of RFID

Following three are the main components of RFID:

Tag

An RFID tag, also referred to as a transponder, is a compact device designed for attachment to an object to facilitate its identification and tracking. It serves as the storage unit for information, containing an integrated circuit (IC) chip and an antenna enclosed within suitable packaging. The tag's dimensions are typically determined by the size of its antenna, as the microchip itself is generally quite small (Brown, 2007). RFID tags come in various shapes, sizes, and protective housings, with the smallest commercially available tags measuring 0.4×0.4 mm2 and being thinner than a sheet of paper (Roberts, 2006).

Reader or Interrogator

The RFID reader is instrumental in retrieving the information stored in a tag. It comprises a decoder for interpreting tag information and an antenna. The reader is a device that both powers and communicates with the tag. Its components include a high-frequency (HF) interface, consisting of a transmitter and a receiver, an antenna, and a control unit. The HF interface generates power to activate the tag, sends and receives data from the tag. The antenna, a conductive element, facilitates communication between the tag and the RFID reader. Both the reader and the tag in an RFID system possess antennas for data transmission and reception. The size of the antenna is crucial as it determines the operational range of the reader. The control unit, based on a microprocessor, manages communication with the tag, coding, and decoding signals. Reader performance is typically gauged by its range and the speed at which it can identify, read, or write to a tag (Finkenzeller, 2003; Brown, 2007).

Software

This component is employed for managing the data received and overseeing the operations of the reader and tag. The software is crucial for tasks such as communication with RFID readers, filtering and cleaning RFID data, and adapting the data for high-level applications, including automatic data transformation and aggregation.

RFID tags classification

I. Passive Tag: Passive tags lack an external power source and become operational when they enter the proximity of an RFID reader.

II. Active Tag: Equipped with a built-in battery, active tags maintain constant functionality, enabling communication with the reader at any given moment. These tags offer an extended read range and support read/write capabilities, albeit at a higher cost and with increased bulkiness due to the embedded battery.

III. Semi-passive Tag: Semi-passive tags incorporate a power source (battery) utilized solely to activate the chip's circuitry. Unlike active tags, they rely on the electromagnetic field generated by the reader for communication. The battery remains dormant until triggered by a signal from the reader. This approach conserves battery power, extending the tag's lifespan.

Principle

An RFID system consists of two primary components: a tag and a reader. The reader initiates communication by generating and transmitting an interrogation signal to the tag. A passive tag relies on the reader for power, utilizing either magnetic induction (near-field coupling) or electromagnetic wave capture (far-field coupling). The near-field coupling, based on Faraday's principle of magnetic induction, involves the reader generating an alternating magnetic field through its antenna coil by passing a large alternating current. If a passive tag, featuring a smaller antenna coil, is placed within this magnetic field, it induces an alternating voltage across the tag's coil. This voltage is rectified, coupled to a capacitor, and accumulates charge to power the chip of the passive tag. In the case of far-field coupling, resembling the principles of a radio set, far-field RFID systems operate by capturing electromagnetic waves from the dipole antenna attached to the reader. The smaller dipole antenna in the tag receives this electromagnetic energy as an alternating potential difference. The potential difference is rectified, coupled to a capacitor, and accumulates charge to power the chip of the passive tag.

Both methods effectively transfer sufficient power to sustain the operation of a passive tag. RFID systems operating in the frequency range between 100 kHz and 30 MHz utilize magnetic induction, while those based on microwave frequencies (2.45 and 5.8 GHz) operate using electromagnetic wave capture (Finkenzeller, 2003).

Application in food industry

Supply chain management

Effectively managing the supply chain of perishable food items presents a crucial and challenging task due to the inherent variability in products, stringent traceability requirements, limited shelf life, and the necessity to maintain optimal environmental conditions from production to enduser. RFID technology emerges as a promising solution to enhance supply chain efficiency by addressing issues such as inventory losses, management costs, dynamic logistics planning, reduced labor costs, and improved product flow efficiency (Tajima, 2007). The information provided by RFID is both accurate and rapidly collected, contributing to enhanced inventory visibility in the retail sector. RFID facilitates automated material inspection and handling, reducing instances of out-of-stock occurrences. Managing the spoilage of perishable products is critical, and RFID aids in effective stock rotation by ensuring products are sold in the correct order based on their expiry dates. RFID technology plays a pivotal role in boosting operational efficiencies by minimizing labor costs associated with inventory counts, enhancing theft prevention measures, and ensuring authenticity control. Additionally, RFID helps eliminate inventory record inaccuracies in the supply chain. Major companies such as Wal-Mart, GAP, P&G, JC Penney, and Old Navy have adopted RFID tags for supply chain management. The ability of RFID to track and trace individual items in real-time provides valuable information that can be shared among supply chain partners.

Temperature monitoring

RFID technology finds applications across various agrifood sectors, including horticulture, meat, pork, fisheries, dairy, bakery, and beverages. Freshtime™ Infratab Inc.'s semiactive RFID tags, based in Oxnard, California, U.S.A., are specifically designed to monitor the shelf life of attached food products. These tags incorporate temperature-sensing capabilities, integrating temperature data over time to assess and communicate the remaining shelf life of a product to a reader. Equipped with a battery, these tags also feature an optional visual display that indicates the item's status through color-coded indicators—green for freshness and red for potential safety concerns. The operational range of these tags' spans from -25 to 70°Celsius.

Livestock management

The demand for animal identification and traceability is steadily rising. In numerous countries, farmers have traditionally maintained animal records using various identification methods, including paint marks, tattoos, ear notches, and ear tags. However, ear tags are susceptible to loss (5–60% of the time), and paint marks or tattoos may suffer damage or fade over time. To stay globally competitive and ensure traceability, many countries are turning to RFID technology for livestock data recording and management. RFID systems offer superior livestock management as they are faster, cleaner, and more efficient than conventional methods. Implementing RFID in livestock operations streamlines automation, reducing labor costs and increasing profits. RFID tags are easily applied to animals, ensuring successful readings. Compared to traditional systems, RFID systems are estimated to introduce only one error per 1000 animals, while traditional methods may incur six errors for every 100 animals. In livestock markets, detailed data and information about animals can serve as product certificates, especially in situations where disease outbreaks occur.

The uniqueness of RFID tags ensures reliable and efficient tracking of animals from birth through various life stages, including transportation to different locations and up to the point of slaughter. RFID tags provide traceability information for chickens and enhance farm management in disease control, breeding management, and stock management. In pig farming, RFID technologies have proven beneficial by automating the feeding process and regulating individual pig feed intake. In addition to unique identification, RFID systems can store detailed information about animals, including growth status, medical treatment records, transportation history, and feedback data. This detailed information can be shared among farmers, processors, stockmen, or veterinarians through computer and database management systems. RFID is also employed for tamper detection of animal products along the supply chain, such as detecting unauthorized openings of poultry shipments during transportation. Generally, RFID tags used for animal identification include boluses, ear tags, and injectable glass tags.

Conclusion

Like any emerging technology, RFID technology presents both challenges and opportunities. Implementing this technology faces obstacles such as its unreliability in retail settings, limitations in read range and accuracy, nonuniform standards, cost considerations, and concerns related to recycling. Consumer apprehensions regarding privacy and security further impede the widespread acceptance of this technology. Notwithstanding these challenges, RFID holds great promise for various applications, including supply chain management, temperature monitoring, and ensuring food safety in the food industry. The adoption of RFID technology can enhance efficiency and productivity by improving inventory management, reducing instances of out-of-stock supplies, and minimizing food product spoilage. The establishment of uniform standards and the cost-effectiveness of implementing RFID technology could drive its widespread adoption in the food industry.

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