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AUGMENTED REALITY(AR)-VISUALIZING FUTURE DAIRY PROSPECTS

Sweety*1, Harinivenugopal*2, Arun Kumar H*3, Venekatesh M*4

*1M.Tech Scholar, Department Of Dairy Technology Dairy Science College, KVAFSU, Hebbal, Bengaluru, Karnataka, India.

*2Associate Professor, Department Of Dairy Technology Dairy Science College, KVAFSU, Hebbal, Bengaluru, Karnataka, India.

*3Dean, Dairy Science College, KVAFSU, Hebbal, Bengaluru, Karnataka, India.

*4Professor And Head, Department Of Dairy Technology Dairy Science College, KVAFSU, Hebbal, Bengaluru, Karnataka, India.

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ABSTRACT

This review article explores the transformative impact of Augmented Reality (AR) on the dairy and food industry, an idea that has gained popularity recently alongside many other technological advancements. AR enhances food safety, quality assurance, and sustainability by providing real-time data visualization and improving efficiency in production processes. It plays a crucial role in sensory science, marketing, consumer engagement, food traceability, and dietary assessment. The article highlights AR's potential to revolutionize manufacturing, training, and consumer transparency, fostering informed decisions and stronger connections with food. Despite current challenges, AR's integration into Industry 4.0 technologies promises significant advancements in efficiency, quality, and consumer satisfaction, paving the way for innovative and sustainable practices in the dairy and food sector.

Keywords: Augmented reality, Virtual Reality, Industry 4.0, Food Safety, Dairy Industry.

I. INTRODUCTION

In today's fast-paced world, digitalization is transforming almost every aspect of our lives. Over centuries, the evolution of our food supply chain, from 'farm to fork,' has developed into a complex global system [1]. This system encompasses farming, storage, processing, distribution, retailing, monitoring, and consumption, delivering a diverse range of safe, nutritious, and affordable food products. This led to the rise of new digital industrial technology or prevalently known as Industry 4.0, which was first spoken at the 2011 Hannover Trade Fair in Germany. The emergence of Industry 4.0 can be best envisaged using augmented reality as one of its pillars in development. Augmented Reality (AR) applications have become prevalent within smart industry manufacturing and wider popular culture sectors over the last decade.

Within dairy and food-based research, digital visualization technologies are contributing to the amelioration of food safety, quality assurance, and sustainable manufacturing practices by increasing efficiency and reducing costs. In this domain, AR finds an essential application in marketing. The reason AR is developing a particular role, surpassing other related optical technologies such as Virtual Reality (VR) due to its practical benefits and integration capabilities.

Augmented reality (AR) is a term used to identify a set of technologies that allows the view of real-world environment to be “augmented” by computer-generated elements or objects [2]. More specifically, AR describes a mediated reality, where the visual perception of the physical real-world environment is enhanced using computing devices.

Today's lifestyle and growing awareness of consumer about food quality have altered their choice of preferences and purchasing behaviour. A consumer expects a wide variety of progressively customized products in a shorter time frame. Consequently, it is important for dairy and food industries to remain competitive and robust by being adaptable, flexible, responding quickly, producing efficiently, and delivering the required quality. Meeting such needs can be feasible with technological advancement, where augmented reality plays a vital role.

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II. HISTORICAL DEVELOPMENT OF AR

There are many inventions brought forth by technological advancements. The idea of augmented reality is one of the ideas that has gained popularity recently. Cinematographer Morton Heilig had the concept for Augmented Reality (AR) in the 1950s. He sought to create a multisensory cinematic experience that would fully immerse viewers in on-screen action. The Sensorama, a mechanical device that merged 3D sights, sounds, sensations, and even scents to create a realistic world, was created in 1962 as a result of this idea. Even though digital computing was still in its infancy, Heilig's creative notion established the groundwork for further advancements in augmented reality [3].

Ivan Sutherland, a computer scientist, achieved a major breakthrough in 1968 when he created the "Sword of Damocles," the first head-mounted display (HMD) system. The fundamentals of augmented reality technology were first introduced by this crude gadget, which could superimpose basic computer visuals on the outside world. In 1990, Boeing researcher Tom Caudell first used the phrase "augmented reality" to refer to a computer display that assisted in the building of aircraft. This signified the formal distinction between augmented reality (AR) from virtual reality (VR) as a distinct field [4].

AR technology developed further in the 1990s and 2000s, propelled by developments in mobile and computer technology. Louis Rosenberg's 1992 invention of the Virtual Fixtures system, which enabled users interact with virtual objects in the real world, was one noteworthy development. Around this time, the commercial potential of augmented reality started to be investigated more thoroughly, and early uses in sectors including gaming, navigation, and education appeared [5].

In the 2010s, augmented reality (AR) technology gained popularity owing to key launches including Pokémon GO in 2016 and Google Glass in 2013. Despite its difficulties and eventual delaying, Google Glass introduced augmented reality (AR) to people across the globe and demonstrated its potential for everyday use. Pokémon GO showed how AR might combine virtual and real-world components in an incredibly captivating way, grabbing people's attention [6]. These days, augmented reality (AR) is still developing quickly, merging with artificial intelligence and more advanced hardware to provide more useful and immersive applications in a variety of industries, such as engineering, retail, and healthcare.

III. POTENTIAL AR APPLICATIONS IN DAIRY AND FOOD INDUSTRY

The food-tech industry is poised for exponential growth in the upcoming years, and the integration of augmented reality (AR) technology is already showing a significant impact. This innovative convergence is revolutionizing various aspects of the dairy and food sector, from enhancing consumer experiences to streamlining manufacturing processes. AR technology is being utilized to provide interactive and immersive experiences to consumers. Also, AR can help dairy farmers to optimize and improve their operations by remotely monitoring and tracking the condition of feed and equipment more accurately defining and mapping out milking parlours and associated areas. Moreover, it can also be used to create digital feed and milking records, which can be very useful for tracking feed and milk quality [7].

1. AR in Production Process

The deployment of Augmented Reality (AR) technology is transforming the processing of milk and other dairy products. AR can improve numerous stages of milk processing, from farm to finished product, by superimposing crucial information and interactive guidance directly into the real-world environment. Collecting and transportation, processes are typically time-consuming and frequently result in discrepancies, which can be considerably improved by incorporating AR technology. AR can enable real-time tracking and quality monitoring of raw milk, ensuring optimal conditions are satisfied. AR allows dairy producers to use remote sensing technology to constantly assess the state and condition of their equipment, ensuring maximum efficiency and avoiding costly breakdowns [8]. In processing facilities, AR aids in pasteurization and homogenization by presenting real-time data and step-by-step guidance to operators, minimizing errors and improving efficiency. Furthermore, AR enables the production of digital models of facilities such as the curd house or silo, leading to a comprehensive and interactive picture of the entire processing environment. These digital models facilitate real-time monitoring and management, enabling farmers to detect and handle pertains immediately. Additionally, AR may enhance training programs by allowing new employees to visualize complex machinery and processes interactively right before their eyes, leading to faster and more effective learning.

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The DTPoland AR Smart Wiring 4.0 system enhances the assembly of control cabinets and production line monitoring. This system includes EPLAN Smart Wiring software for the CAD design of control cabinets, a wire label reader, and visualization software integrated with Microsoft HoloLens Augmented Reality glasses. It is specifically designed to facilitate the wiring assembly between components within the control cabinet [9].

2. Sensory Science

Over the past decade, sensory science has made remarkable progress and is rapidly emerging as a crucial tool for forecasting the success of food products in the market. Recent technological advancements in virtual reality (VR) and augmented reality (AR) have opened up new possibilities for creating immersive and interactive systems. These systems can serve as powerful tools for capturing and understanding the complexities of human sensory perception. For many years, sensory data relied on averaging consumer responses collected under controlled conditions in sensory laboratories [10]. This data was primarily used by the industry to compare the acceptability and competitiveness of food products in the market (Tuorila & Monteleone, 2009). But with the ongoing strain on the food business to produce high-quality goods faster, the requirement for sensory information is growing more complex in the current, fiercely competitive, global food economy. Hence as the digital world advances swiftly, augmented reality (AR) technologies are poised to reshape the methods for gathering and analyzing sensory and consumer information. A first study of using AR in sensory in dairy industry was conducted by Dong *et al.,* 2021 where he aimed to study the effects of AR environments on the sensory responses of consumers towards different yogurts. Investigation was aimed to conducted under two views i.e. AR coconut view (ARC) and AR dairy view (ARD). ARC, ARD, and sensory booths (SB) were used to measure the hedonic ratings, just-about-right (JAR), check-all-that-apply (CATA) attribute terms, emotional responses, purchase intent, and customer purchasing behaviors of three varieties of yogurts: dairy, mixed, and dairy-free coconut. When contrasted with AR, the outcomes were a somewhat similar to those of the physical sensory booth. The study itself has a number of shortcomings, including an extremely small sample size, a failure to include a diverse range of age groups, and overly simplistic sensory characteristics [12].

3. Safety and Training

Augmented reality (AR) can significantly enhance safety and training in the dairy and food industry by providing interactive and immersive experiences. AR systems, such as Safety AR, developed by the University of Tuscia [13], can offer real-time safety information and training to workers, helping them identify risks and prevent accidents. Additionally, AR technologies can simulate various scenarios, including regular and extreme situations, to train employees effectively in safe work practices [14]. By visualizing error consequences in AR, learners can directly experience the outcomes of incorrect actions, improving occupational safety and health competencies [8]. Implementing AR in the dairy and food industry can lead to a reduction in accidents, increased productivity, and enhanced training outcomes, ultimately creating a safer work environment for employees. Porras *et al.*, 2019 using 3D and CAD software created a AR environment of industrial pasteurization plant which allows interaction with the industrial process. An individual was represented by an avatar, which improved the visualizing process even further. This technology made it possible to provide real-time details about a pasteurization plant that is not physically visible or accessible [15].

4. Marketing and consumer engagement

Personal nutrition decisions have a direct impact on health. Augmented Reality (AR) enables people to engage with virtual items, see products in real-world settings, and obtain extra data or experiences outside of conventional marketing channels [16]. Dairy and food industries can use AR to build a 360-degree view of products, allowing consumers to explore and discover products in a 3D environment AR greatly enhances brand experiences by improving brand recall and recognition, enriching storytelling and narratives, and fostering brand authenticity. It plays a crucial role in shaping how consumers perceive and emotionally connect with brands. Additionally, AR affects purchase decisions by facilitating product evaluation, reducing uncertainty, and boosting purchase intentions and behaviors [17]. Studies have shown that delivering nutritional information through AR can lead to healthier food choices, as participants base their decisions on nutritional data rather than package appearance [18]. In support to the above Naritomi and Yanai proposed “CalorieCaptorGlass”, a calorie estimation system based on actual size using image recognition and AR / MR glasses [19]. The use of augmented reality (AR) in food logistics is essential for preserving product freshness. A

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few strategies include constant temperature and humidity monitoring, product optical inspection (textural and color differences), particular sorting techniques, and the right in and out of products in cold storage and warehouses.

5. Food traceability

One crucial component of the quality management system is traceability. Food traceability refers to the ability to track and follow a food product, feed, or food-producing animal throughout all stages of production, processing, and distribution, ensuring transparency and security for consumers and producers. Traceability systems communicate information and validate the legitimacy of items using a variety of techniques, including optical, electrical, and biological identification [20].

While other introduced and specified systems acknowledge two notions, traceability is the sole concept defined in the monitoring process by European legislation.

- **Tracking**: this is the process of keeping track of goods as they move through the manufacturing, sales, and distribution chains, recording all pertinent data along the way.
- **Traceability**: the process of summarizing and linking all the data gathered during product tracking in order to recreate the product's history and current state at every link in the chain it has travelled through [14].

Food traceability is important because it helps to ensure food safety and quality and prevents fraud in the food chain. In the end, this ultimately results in customers receiving higher-quality and healthier goods, and it also certifies the raw materials utilized [21]. Furthermore, international government mandates for traceability seek to standardize location data from farm to fork, affecting people's autonomy over information about their food intake and travels [22].

Augmented Reality (AR) presents a plethora of advantages as well, including increased food safety and efficiency, better employee training, improved logistics efficiencies, improved new product development, increased sales, and utilization as a marketing tool [23]. Augmented reality (AR) technology can help stakeholders and consumers to get important information engagingly and interactively, such as food qualities, origin nation, and production processes. AR technology, particularly through mobile applications, enables consumers and stakeholders to interact with food packaging, accessing detailed information through digital overlays. Customers can obtain real-time information about the items they purchase by incorporating augmented reality (AR) into food packaging systems, which fosters confidence in the supply chain. Applications of AR in food traceability include comprehensive product provenance and content [24] and identification of Halal food [22].

6. Dietary and Food Nutrition Assessment

Assessing food and dietary nutrition is essential for monitoring health, preventing illness, and assuring overall well-being. These evaluations serve as a catalyst for the food sector to innovate and provide goods that satisfy health-conscious consumers' needs while maintaining food safety and quality. Technology plays a vital role in dietary and food nutrition assessment where augmented reality (AR) holds significant potential for enhancing these assessments [25]. This technology has shown promise in enhancing dietary and food nutrition assessment by improving food portion estimation skills among dietetic students [26]. Studies have demonstrated that AR tools can lead to higher accuracy in food portion estimation, with the AR group showing the highest relative error scores and overall improvement in estimation compared to traditional methods. The augmented reality tool was intended to function on the participants' smartphones as an app. Due to the limited resources available at the time, the technology allowed participants to examine virtual representations of food overlayed into real-world locations. Moreover, chanlin and chan investigated on a mobile AR system that allowed students to scan food images, receive information about nutrient content, and record as well as accumulate daily nutrient intake [27].

IV. CONCLUSION

This review article focuses on the integration of augmented reality (AR) in the dairy and food industry with a transformative shift towards more interactive, efficient, and consumer-centric practices. AR can simplify operations in manufacturing Through the provision of real-time data visualization, enhanced equipment maintenance, and worker training. Moreover, AR helps quality control by guaranteeing better standards and

cutting down on waste by overlaying crucial data and identifying errors. As this review explains, there are still certain obstacles preventing its wider adoption despite its many benefits.

For consumers, AR offers unprecedented transparency and engagement. AR gives consumers the power to make informed decisions and creates a stronger bond with the food they consume by providing comprehensive nutritional information, ingredient source, and even interactive cooking instructions. AR's immersive qualities also benefit public health initiatives and educational campaigns by improving accessibility and memorability of nutritional information. As the dairy and food industry continues to innovate, the adoption of AR technology is likely to expand, driven by its ability to enhance efficiency, quality, and consumer satisfaction.

Hence, Industry 4.0 technologies—such as digitalization, data analytics, robotization, and automation—will be essential as food manufacturing operations get increasingly complicated. However, digital connectivity of food goods and manufacturing processes is also necessary to optimize the resources. Given this, it is obvious that augmented reality technology will be essential to establishing this link for all the parties involved in the food supply chain. AR technology will keep developing at an exponential rate, leading to smaller, more affordable, and more durable AR devices. It will ensure the rapid creation of innovative AR solutions with opening a new chapter for food-related AR research.

V. FUTURE PROSPECTS

By combining sophisticated volume rendering and visualization capabilities of AR with imaging techniques (such as x-ray micro-computer tomography) to generate the 3D structure of food products, it is possible to "step inside" complex food products and obtain a novel assessment of their internal structure that is not thought to be possible with current technologies. Researchers can examine and assess the interior structures of food with this immersive and interesting technology, which advances new food research approaches. AR could overlay the generated image on the actual object. Students studying food science also gain from this direct representation, which helps them learn necessary information more quickly and helps food scientists better understand the intricate chemistry and biochemistry of food systems.

Therefore, the future of augmented reality (AR) in the dairy and food industry is promising, with several potential applications that could revolutionize various aspects of production, quality control, marketing, and consumer engagement. The integration of AR in the dairy and food industry holds significant potential for enhancing efficiency, quality, and consumer satisfaction. Its continued development and adoption could lead to more innovative and sustainable practices in the industry.

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