TRADE & INDUSTRIAL POLICY STRATEGIES

INDUSTRY STUDY

TECHNOLOGICAL CHANGE IN THE FOOD PROCESSING INDUSTRY

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TIPS industry studies aim to provide a comprehensive overview of key trends in leading industries in South Africa. For each industry covered, working papers will be published on basic economic trends, including value added, employment, investment and market structure; trade by major product and country; impact on the environment as well as threats and opportunities arising from the climate crisis; and the implications of emerging technologies. The studies aim to provide background for policymakers and researchers, and to strengthen our understanding of current challenges and opportunities in each industry as a basis for a more strategic response.

This study outlines the technological changes in the food processing industry, paying specific attention to emerging technologies. This report provides an overview of these emerging technologies, examining both their potential impacts and the drivers of technological change.

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1. INTRODUCTION

This study outlines the technological changes in the food processing industry, paying specific attention to emerging technologies. This report provides an overview of these emerging technologies, examining both their potential impacts and the drivers of technological change. It explores proven and unproven innovations, including digital twins, AI-powered crop management, robotics, and augmented reality, offering insights into how they are shaping the future of food processing. In addition, the report assesses the technological trends that are currently influencing the sector in South Africa and the likely disruptions that these innovations may bring in the coming years.

The food processing sector stands at a critical juncture as it faces the dual pressures of increasing global demand and the need to address environmental, social and governance (ESG) challenges. Rapid technological advancements – ranging from vertical farming and artificial intelligence (AI) to automation and the Internet of Things (IoT) – offer transformative opportunities for the industry. These emerging innovations present both proven and unproven solutions that could reshape the sector by improving productivity, enhancing sustainability, and addressing climate change concerns.

However, the adoption of these technologies introduces a complex set of challenges. While they promise to optimise efficiency and reduce environmental footprints, they also require significant shifts in workforce skills, production processes, and infrastructure. The key issue for the industry is balancing the potential benefits of technological advancements with the socioeconomic impacts, such as job displacement and the widening skills gap.

2. EMERGING TECHNOLOGIES IN THE FOOD PROCESSING INDUSTRY

Emerging technologies in the food processing sector, such as vertical farming, digital twins, automation, IoT, AI, 3D printing, and robotics, are outlined in Table 1 along with their potential industry impacts. These innovations present opportunities for the sector to address ESG challenges and meet the rising global demand for food. Moreover, these advancements can promote sustainable transformation and mitigate the industry's environmental footprint.

For businesses, these technologies offer significant potential to boost efficiency and productivity through automation, enhance food safety via IoT integration, and minimise waste with smart packaging solutions. However, the adoption of these innovations will likely impact employment, as they necessitate a shift in skills and education levels to adapt to the evolving technological landscape (Anderson and Sandin, 2022).

Table 1. Emerging technologies in the food processing industry

TECHNOLOGIES	DESCRIPTION	IMPACT
Vertical Farming	Method of growing crops in a vertical stacked layers and uses controlled-environment agriculture technology to regulate environmental factors such as light and temperature.	Can create resource efficiency, increased crop-yield and reduce transportation emissions.
Artificial Intelligence (AI)	AI reproduces human intelligence through machines. AI technologies range from machine learning, deep learning and natural language processing that perform tasks such as identifying patterns.	Can enhance automation, enhance quality control, improve efficiency, reduce food waste and improve supply chain optimisation.

3D Printing	Food printing involves the use of additive manufacturing techniques to create food items. Food-grade syringes are used to deposit edible materials to build complex shapes and structures and this is then translated into a physical form by a 3D printer	Tailored food items to dietary needs, reduce food waste, enhance food nutrition and reduce the need for resource-intensive food production.
Internet of Things (IoT)	Involves the use of interconnected devices and sensors to collect and analyse data in food production. These devices monitor various aspects of the production process such as temperature and equipment performance.	Enhance food safety, enhance operational efficiency, real-time monitoring and predictive maintenance and reduce waste
Digital Twins	These are virtual replicas of physical systems, processes and products and can use real-time data received from sensors to mirror the actual physical counterpart. In food processing they can mirror entire production lines.	Enhance process optimisation, improve quality control, reduce waste and improve traceability.
Automation	Automation in the food industry involves the use of advanced machinery, robotics, sensors and control systems to perform previously manual tasks.	Increase efficiency and productivity, enhance quality control, reduce costs, improve safety, and reduce waste.
Robotics	Robotics involves the use of automated machines and robotic systems to do tasks, such as handling raw materials and packaging.	Increase efficiency of production, reduced costs and improve hygiene in food handling
Biotechnology	Involves the use of living organisms or their derivatives to enhance production and quality and includes techniques such as genetic modification, fermentation and enzyme production.	Enhance food safety and quality, increase food crop production, improve sustainability, lower production costs and alter/improve health benefits of food sources.

Source: Adapted from Siemens, 2023 and Coronel, 2022.

3. DRIVERS OF TECHNOLOGICAL CHANGE

Several key drivers are accelerating technological change within the food processing industry. Foremost among them are evolving consumer habits and the pressure on producers to enhance production efficiency. Consumers are increasingly gravitating towards more sustainable and personalised food options, with rising demand for alternative protein sources and organic products, driven by environmental and health concerns. There is a clear preference for foods with reduced salt, sugar, and fat content, coupled with healthier additions such as fibre, minerals, and vitamins. The COVID-19 pandemic has further accelerated digital transformation across the food value chain, pushing the adoption and integration of digital technologies into manufacturing and industrial processes to enhance efficiency. In addition, retailers now demand higher volumes at lower costs, prompting food producers to integrate digitalisation, automation, and robotics to optimise their production processes to remain competitive (Geijer, 2019; Start Us Insights, 2024).

Rising concerns about food scarcity, particularly in developing nations where population growth is coupled with declining food and water resources, have prompted the adoption of AI, vertical farming, and biotechnology as solutions. AI-driven crop management offers the potential to boost annual growing cycles by 17 to 20 times, increasing food output by up to 300 times per square foot compared to conventional farming techniques. For example, a vertical farm in Dubai operates with 95% less water usage than traditional farms and produces over one million kilograms of food without relying on pesticides, herbicides, or chemicals. Furthermore, in the food and beverage industry, around 14% of food is lost between harvest and retail. To combat this, the Portuguese firm Sonae is employing edge technology, artificial intelligence, and hyperspectral analysis to minimise food waste through 100% traceable food quality and grading (Siemens, 2023).

A key challenge facing the agro-processing sector is the growing impact of climate change. Alongside efforts to enhance efficiency, there is a strong push towards adopting sustainable farming practices and climate-resilient technologies. The food production industry significantly contributes to climate change, accounting for approximately 35% of global anthropogenic greenhouse gas emissions. Within this value chain, the production of animal-based products – such as meat, poultry, and dairy – remains the largest source of emissions (Jain & Xu, 2021). To respond to such climate change challenges, the adoption of regenerative agriculture (a farm management concept that involves maintaining soil health) and smart farming (use of technology to informed resource allocation/dispersion), solar dryers, no-till tractors, bio-stimulants, farm management apps, precision spray drones, drip irrigation and anaerobic digestion are becoming more prevalent (Who Owns Whom, 2023).

4. INTERNATIONAL TECHNOLOGICAL TRENDS

4.1. Artificial Intelligence

AI refers to computer systems that simulate human intelligence through machines. AI technologies encompass machine learning, deep learning, and natural language processing, which enable tasks such as pattern recognition. In the food processing value chain, AI is increasingly being used to optimise food systems management, sorting, product development, quality control, and industrial hygiene. Recent research highlights AI's effectiveness in monitoring food quality, safety, and packaging, with intelligent packaging systems capable of assessing food freshness. Popular AI methods adopted in the food industry include expert systems, fuzzy logic, artificial neural networks, adaptive neuro-fuzzy inference systems, and machine learning (Mavani et al., 2022).

In the United States, the Department of Agriculture (USDA) has been working alongside scientists from the Agricultural Research Services Western Human Nutrition Research Centre at the University of California to create the AI Institute for Next Generation Food Systems, which is funded by the USDA (US$20 million). The purpose of the institute is to dedicate research for the acceleration of AI in the production processes of food, using molecular breeding to improve crop yields, ensure the quality and disease resistance of crops, and using AI technology such as robotics to reduce resource use and enhance the safety of food. Specifically in food processing, AI is being geared towards informing decisions on health and sanitation to reduce pathogens and reduce energy use and food waste and find optimal solutions to transportation and storage related issues (USDA, 2020).

In other areas, companies such as Nestlé have invested in the use of AI in food sorting and coffee plantation optimisation, and Coca-Cola has invested in AI to predict consumer trends and to improve quality checks of beverages.

4.2. Augmented reality and virtual reality

Augmented reality (AR) and virtual reality (VR) is becoming an increasingly popular form of technology, especially in the electronic and gaming sectors. The technology makes use of computer-generated content based on the real world. There is an increasing trend towards using AR technology in manufacturing processes such as sending repair instructions over mobile devices and selecting parts in warehouses. The use of AR and VR are, however, in the early stages, but it does have the potential to provide workers with real-time information and assist with decision-making and work procedures. Chinese retailer Yihaodian has started to use AR to create virtual supermarkets where products are selected and delivered to the customer's home. This innovation could present an opportunity for food manufacturers to sell directly to consumers without the need for retail supermarkets (Barnes and Higginson, 2020).

4.3. Robotics and automation

Automation has long been integral to the food processing industry due to the necessity of mass production. However, the recent rise of collaborative robots (cobots) is transforming both primary and secondary food processing, driven by advancements in AI. These cobots represent a significant improvement over earlier forms of automation, as they are designed to work alongside human operators, alleviating workers from physically demanding and hazardous tasks. In the industry, cobots are increasingly used to transport products and materials between various stages of production.

For instance, Nestlé reported success with 14 cobot installations on its packaging lines by 2018. Similarly, Axiom Foods Inc., a mid-sized snack food manufacturer, adopted two cobots in 2016, transitioning from fixed to flexible automation. These cobots, employed to pack finished products into shipping containers, have proven to be a cost-effective solution due to their speed and precision. Unilever is also using cobots on its packaging lines, utilising their ease of programming, AI capabilities, and integrated cameras to ensure product quality while gathering data to optimise operational efficiency over time (Barnes and Higginson, 2020).

5. TECHNOLOGICAL TRENDS IN SOUTH AFRICA

The food processing sector with its close ties to the agricultural and food retailing sector makes up a strategically important part of the country's industrial development. Although the industry is very labour intensive, digital technologies have started to gain traction in South Africa, especially for larger food processing firms. The following subsection looks at some of the technological developments emerging in South Africa.

5.1. Technological changes in the food processing value chain

According to Barnes and Higginson (2020), the adoption of digital technologies has only recently gained momentum in the strategic plans of larger South African food processing companies. Current advancements include the creation of platforms designed to share information with agricultural suppliers, particularly small-scale producers, to enhance the quality and consistency of their crops, ensuring a stable supply of materials to processors. In additional, blockchain technologies are being explored to track products throughout the value chain. In line with global trends, these innovations are characterised by collaboration between suppliers, distributors, and tech start-ups, focusing on developing solutions across the food value chain, from agriculture to market distribution.

A range of technologies – including solar dryers, no-till tractors, bio-stimulants, farm management apps, precision spray drones, drip irrigation, and anaerobic digestion – are playing a pivotal role in

improving the sustainability of agribusiness. In South Africa, one prominent innovation is the Farmers Friend app, developed by IQ Logistica, which supports farm management via mobile devices. It provides tools for field mapping, contract management, weather updates, soil moisture tracking, and harvest reporting. In response to climate change, new technologies and practices are emerging. In June 2022, McCain Foods, a major global producer of frozen potato products, unveiled plans for a South African potato farm that will adopt regenerative agriculture practices, building on a similar project in Canada. Likewise, Woodlands Dairy has introduced a system to help farmers monitor soil health and optimise water use (Who Owns Whom, 2023). Clover has also adopted an advanced Environmental Management System that leverages IoT to monitor and enhance its environmental performance. This system enables Clover to quantify its carbon footprint and set measurable targets for reducing water and energy consumption throughout its operations (Clover Dairy, n.d.).

Industry leaders have also made significant investments in adopting IoT technologies. Tiger Brands, for instance, has integrated automated systems in its packaging lines, featuring robotic arms for sorting and packing. The company has also partnered with Siemens to implement a comprehensive digitalisation strategy across its manufacturing operations. This initiative includes upgrading outdated control systems to Siemens' modern solutions, which improve automation, reporting, and material tracking capabilities. In 2023, Tiger Brands further advanced its innovation efforts by launching the Sensorium, a multi-purpose innovation centre designed to foster innovation and technology integration. This facility is part of a R42 million investment aimed at enhancing research and development, with a focus on using advanced technologies like IoT to optimise product development processes (SA Instrumentation & Control, 2022; Tiger Brands, 2023). In addition, Clover is exploring smarter manufacturing and distribution processes using cloud-based technologies integrated with IoT. This transformation is aimed at streamlining operations and improving productivity, aligning Clover with global best practices in the food and beverage industry (ITWeb, 2023).

Cold chain technologies have become integral to South Africa's food processing sector, including refrigerated vehicles, cold storage facilities, reefer containers, mobile cold storage solutions, and precision chilling systems. Specifically, post-harvest infrastructure like precision chilling for perishable goods has greatly extended product shelf life, improved quality, reduced waste, and increased profitability (William, 2024). As environmental concerns take centre stage, South Africa's cold chain industry is increasingly prioritising sustainability. Energy-efficient refrigeration systems and renewable energy sources are now becoming standard. Companies are investing in solar-powered cold storage facilities and are exploring eco-friendly refrigerants to lower their carbon footprints. For instance, Energy Partners Refrigeration introduced an ammonia-based refrigeration system at Sovereign Foods' Hartbeespoort facility. This system incorporates variable speed drives for compressors and condensers to allow precise control and energy management, while a heat recovery system reclaims energy from the compressor oil cooling process to preheat hot water tanks, reducing dependence on traditional boilers (Long, 2024).

Moreover, IoT-enhanced cold chain technologies have improved cold storage management within South Africa's food sector, while blockchain adoption is bolstering traceability and transparency. In March 2024, MSC South Africa inaugurated a cutting-edge 15 000-square-meter cold storage facility in Durban, aimed at optimising the handling of perishable goods and supporting both imports and exports (Cape Business News, 2024).

However, despite some areas of innovation, the South African food processing industry has yet to fully leverage the opportunities presented by digital transformation and remains largely unprepared for widespread adoption. While digital technologies promise efficiency gains, concerns persist around their high costs, especially for small, medium and micro enterprises (SMMEs), potential impact on

employment, the scarcity of localised content in local languages, cultural resistance, and limited access to critical information across the agricultural and food processing value chains. These factors contribute to the industry's slow uptake of technological advancements, inhibiting its ability to fully modernise (Barnes and Higginson, 2020; Platt, 2024).

5.2. Institutional support

The South African Association for Food Science and Technology (SAAFoST)[1] is a key professional body focused on advancing the field of food science and technology within South Africa. The association's activities play a crucial role in facilitating knowledge exchange, education, and research in the food processing industry. SAAFoST organises conferences, workshops, and events to promote networking and share the latest scientific and technological developments. It also provides educational resources and training to enhance the skills of professionals in food science and technology. More recently, SAAFoST has intensified its involvement in research and development initiatives, fostering partnerships between academia and industry to stimulate innovation in food processing technologies. Its work also includes advocacy for high standards in food safety and quality, alongside efforts to support the next generation of food scientists through scholarships and mentorship programmes.

5.3. Government support

The Department of Trade, Industry and Competition (the dtic) promotes technological advancement and innovation in the food processing sector through the Agro-Processing Support Scheme (APSS). This initiative was launched in 2017 (and relaunched in 2022) and seeks to expand production capacity, enhance employment opportunities, modernise infrastructure, and boost sectoral productivity. The APSS provides a cost-sharing grant ranging from 20% to 30%, with a maximum allocation of R20 million over a two-year investment period (the dtic, 2019, 2024).

Additional government support for technology development in the industry comes from entities such as the Council for Scientific and Industrial Research (CSIR) through its Industry Innovation Partnership Fund, the Technology Innovation Agency, and the Industrial Development Corporation (IDC). The IDC specifically aids the sector via its Agro-Processing and Agriculture Strategic Business Unit. It invests in projects and businesses that establish new or enhance existing local manufacturing capabilities. The overarching goal is to develop a competitive industry in the food, beverage, forestry, and agro-derivative sectors, leveraging local and regional resources to meet domestic demand and enhance participation in international trade (IDC, n.d.).

6. CONCLUSION

The food processing sector is undergoing significant technological transformation at a global level, driven by innovations such as artificial intelligence, automation, vertical farming, and the IoT. These advancements are reshaping industry practices, enhancing operational efficiencies, and responding to the increasing global demand for sustainable food production. The integration of these technologies not only addresses critical ESG challenges but also aims to reduce the sector's ecological footprint.

This study highlighted key technological trends in the food processing industry, illustrating how digitalisation is facilitating the connection of machinery and equipment to IoT devices, thereby streamlining operations and improving productivity. Environmental concerns, including the need to

[1] For more see: https://www.saafost.org.za

mitigate climate change, are propelling the adoption of sustainable practices, such as regenerative agriculture and smart farming technologies, to enhance resilience within the sector.

In South Africa, significant investments in innovative technologies are evident, with companies adopting AI for quality control and operational efficiency, as well as IoT solutions to enhance traceability and transparency. Government initiatives, such as the dtic's APSS and support from institutions like the IDC and SAAFoST, are pivotal in fostering technological advancements and ensuring industry competitiveness. However, concerns are raised around the cost of these technologies, especially for SMMEs in the food value chain and the impact these technologies could have on jobs in the industry.

As the food processing sector continues to evolve, the push towards automation, digitalisation, and sustainable practices will be essential for meeting domestic demand and expanding global trade participation. The successful navigation of this transformative phase will require collaboration between government, industry stakeholders, and academia to develop a skilled workforce capable of adapting to the changing technological landscape. Ultimately, the sector's commitment to innovation and sustainability will play a crucial role in shaping its future trajectory and contribution to economic development, especially in light of polices such as the European Union's Carbon Border Adjustment Mechanism and other climate-related policies that will undoubtedly have an impact on the manufacturing sector's exports.

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