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igitalising food manufacturing



Shahin Rahimifard, Steve Brewer, Guillermo Garcia-Garcia and Sandeep Jagtap ***discuss the importance of digitalisation in food manufacturing to increase efficiency and optimise life-cycle environmental performance.***

Introduction

The Food and Agriculture Organisation (FAO) of the United Nations has highlighted that up to 70% more food must be produced by 2050 to meet the needs of the growing population and changing dietary demands[1]. Furthermore, climate change has caused the loss of a third of the Earth's arable land over the past 40 years[2] and around one-third of food produced globally for human consumption is wasted, with significant environmental, economic and social ramifications[3]. Global food security requires immediate and substantial social, economic and industrial reform to alleviate the strain on natural habitats and current food supply chains. Actors across food supply chains must evolve their practices to address chronic global productivity and environmental challenges.

To address these issues, different businesses across food supply chains are evolving their practices to reduce waste, meet the food security challenge and address changing consumer needs, aided by the emerging technologies of the Fourth Industrial Revolution (Industry 4.0). Industry 4.0 incorporates advanced manufacturing techniques to create interconnected manufacturing systems with the ability to communicate and analyse the collected information to make better decisions[4].

In this context, digital technologies can bring significant advantages to food manufacturing and the broader society. Industrial leaders, technology developers, professional bodies, government officials and academics can take the necessary steps to transform the food supply chain's sustainability and resilience based on the opportunities offered through Industry 4.0 and associated digital technologies. However, while such improved connectivity promotes greater collaboration and customer service, it also presents new challenges and obstacles.

This article underlines the numerous possibilities digital technologies offer to food manufacturing and how they can support Life-Cycle Assessment (LCA) studies to improve environmental performance in the food sector. It also aims to provide actionable insights supporting the required next steps for incorporating the opportunities offered through Industry 4.0 to reduce life-cycle environmental impacts and provide a competitive advantage. These opportunities can be divided into three major categories: real-time resource efficient production, resilient and productive food supply chains, and the use of digital technologies for improved consumer engagement.

Real-time resource efficient production

New technological developments are making food manufacturing smarter and therefore improving the efficiency of operations. Sensor technology, image recognition, robotics and connectivity via the Internet of Things (IoT) are driving further automation[5]. Automation generates greater efficiency and a reduction of waste, improved hygiene and traceability, and increased consistency of products. While these technologies can help reduce costs, their

contribution to managing complexity, controlling operations and improving responsiveness is equally important. Figure 1 shows the connection of different elements via IoT in a system based on the Industry 4.0 concept.

Several additional advantages of implementing state-of-the-art technologies in food manufacturing include the reduction of duplication of work in supply chains, easier data collection and faster data sharing. Additionally, where labour availability is a problem, digitalisation can make more jobs automated. All these benefits can generate important economic advantages for the companies willing and able to adopt such technologies. For instance, it has been estimated that there is a £55.8bn opportunity for the UK food and drink sector over the next ten years through the adoption of digital technologies.

Although digitalisation can secure organisational competitive advantage and enhance competitiveness, the adoption of new technologies is not rapid because the industry is struggling with several factors: a lack of skills, the cost and complexity of integrating these tools, the need to digitise data and older cost models that do not accurately reflect the economic advantages of the uptake of digital technologies[6].

With regard to environmental analyses, the digitalisation of food manufacturing can significantly support LCA studies in the food sector. Faster and easier data collection means that LCA databases can be updated much more rapidly and that different actors in food supply chains can share their data quickly and easily. As current LCAs significantly rely on background data collected by other actors, digitalisation offers significant advantages to the LCA field. Furthermore, automation can also more quickly help to detect data errors and update older data, so the life-cycle inventories are always accurate and up to date.

Resilient and productive food supply chains

Traditional food supply chains, such as the generic use case represented in Figure 2, have become more complicated in recent years, with multiple international actors creating complex networks. As a consequence, data increasingly plays a critical role in managing food supply chains effectively and efficiently.

Digitalisation enables the rapid collection of data, access to collected data and sharing of the data much more quickly than with previous systems that relied on staff recording the information and reporting it in paper documents. Digitalisation can aid in shifting from traditional linear supply chains (with limited use of data and new technologies) to digitally connected supply chain networks driven by connectivity and the rapid use of data[6].

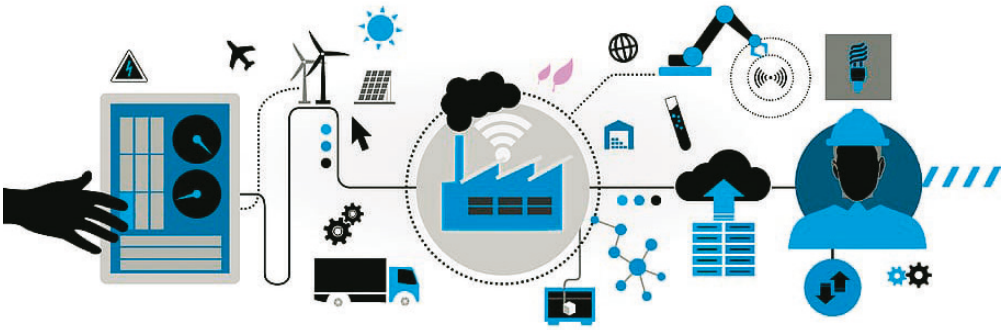


Figure 1. Example of interconnected elements in an IoT system. *(Piqsels, CC0)*

However, adopting these technologies in the food industry necessitates strong engagement across the sector. There are important policy considerations and a need for training and tailored support. To realise the potential of these technologies, industry leaders need to be well informed about the options and benefits of digital technologies. Strategy development is critical to ensure a positive return on investment. The industry also needs the security of agreements on data sharing standards and governance.

Simple and quick data sharing between food businesses also facilitates undertaking new LCA studies. Food companies need data from the upstream businesses of the food supply chain. For instance, food manufacturers need production, storage and transportation data to calculate the life-cycle environmental impact of a product they produce. For this, they need to gather data from farms, fisheries, warehouses, trucks and other intermediaries. Similarly, to complete the full LCA picture of a food product, data must be collected regarding its purchase, consumption and end of life (e.g. from retailers, consumers and waste management facilities). Digitalisation can significantly simplify and speed-up this process while ensuring data accuracy.

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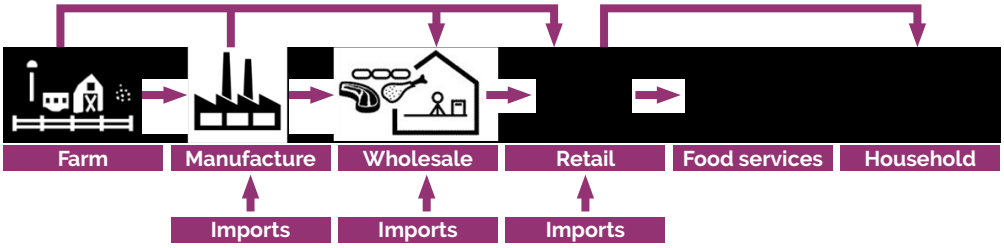


Figure 2 A generic food supply chain

Improvements in consumer engagement

As customer bases fragment, new channels open and new products enter the market. Personalisation and customisation offer new opportunities to capture and retain customers. Digital technologies help address changing consumption patterns and support businesses adopting new business models. Effective design of new food products starts with a thorough analysis of the customer and the demand[7]. Improved monitoring of consumer trends to assist in developing new food products, such as through point of sale data analytics and social media analytics, adds to the rich potential in this area. Localised and distributed food supply chains, i.e. the reduction of factory size but an increase in the number of factories (Figure 3), offer significant advantages, such as reduced transportation and being able to more easily develop new tailored products[8]. Retailers carrying out some of the production at the point of sale and kitchens becoming future factories are all part of the changing landscape. Co-creation with consumers, although not widely used, offers new opportunities for engagement. While some technologies, like machine learning capabilities, advanced data analytics and sensor technologies, can help companies adapt more efficiently and effectively to changing consumer demands, there is a reluctance, particularly on the part of traditional product developers, to use these technologies due to stringent needs for food safety and reliance on older models and habits.

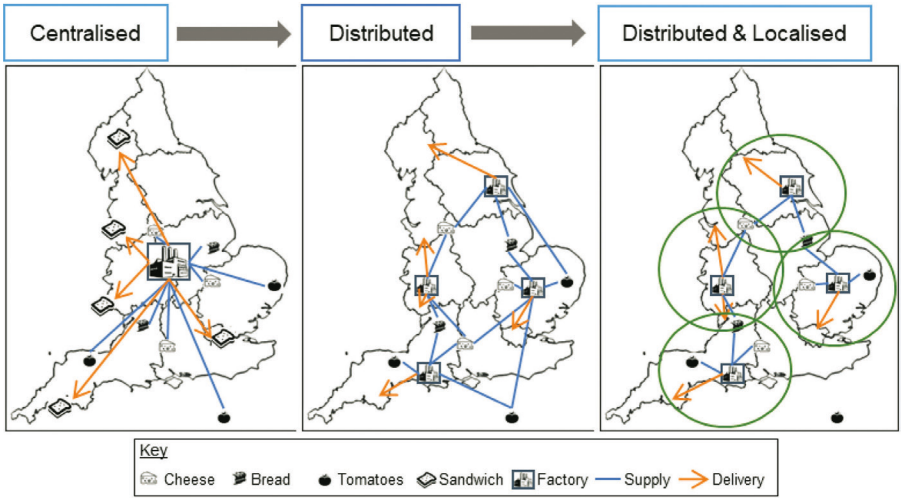


Figure 3 ***Centralised, distributed and distributed & localised food manufacturing*** *(Gimenez-Escalante et al., 2020)*[8]

As customers also demand more environmental information about the products they buy, LCA can meet this need and consequently provide a competitive advantage to food businesses. A business that offers clear environmental data about the product on its labelling, and even an environmental certification, can help attract new customers and retain existing customers. An example of this is the Environmental Product Declaration (EPD), a voluntary declaration of the life-cycle environmental impact of a product following ISO 14025 standards.

Challenges and next steps

Several barriers are hindering the adoption of new technologies in the food industry, reducing the potential of the sector. Table 1 shows the main challenges to digitalising the food manufacturing industry. These multifaceted challenges embody different areas related to business staff, costs, data, safety and customers. Table 1 also identifies the required next steps to address these challenges and support the digitalisation of the food industry.

Table 1 ***Current challenges and next steps to digitalise the food industry***[9].

Current challenges	Next steps
SKILLS there is a lack of technical ability and also uncertainty over how to attract young people with digital skills to the sector as well as how to reskill and upskill the current workforce	Increase opportunities for training and education not only for the development of new digital technologies in the food sector but also in enabling the current workforce to use innovative digital tools
COST AND COMPLEXITY there is uncertainty over the cost and effort necessary for replacing manual infrastructure linkages across the food supply chain	Public investment in digital and wireless infrastructure to build capacity and capability to support the effective and inclusive implementation and use of digital technologies
DOCUMENTATION while data exists, many small and medium enterprises (SMEs) currently keep their information on paper, making digitalisation a challenge	Actors across the supply chain need to be incentivised through strategic investment and policy intervention to adopt digital technologies to reduce physical paperwork
BUSINESS MODELS current cost models do not reflect the possible savings achieved by using new digital technologies nor do they accurately measure the return on investment (ROI)	Generate new cost-benefit analysis tools to promote innovative business models that maximise the new capabilities offered through digital technologies
DATA STANDARDS AND SECURITY there is a lack of agreed and regulated structure for data standardisation across the supply chain, as well as insufficient trust and collaboration for organisations to feel protected in sharing their data	Develop common standards in taxonomy for data sharing, security, access and storage
MINDSET there is a lack of experimental and innovative mindset in testing and adopting digital technologies	Generate peer benchmarking information and knowledge on increasing productivity, reducing resource consumption and waste generation through the adoption of digital technologies
FOOD SAFETY new types of players entering the supply chain must be monitored and controlled	Create new food safety, quality and traceability standards based on the capabilities of new digital technologies
CROSS-SECTOR LEARNING the food sector is more challenging than other sectors because of its particular attributes, making it difficult to adopt digital technology best practices from outside the sector	Establish cross-sector partnerships for knowledge sharing on best practices to harness the potential of big data analytics for process optimisation and new food product development
COMMUNICATION WITH CONSUMERS current methods for conveying essential information about food products to consumers are inadequate	Develop user-friendly cost-effective digital tools to support the behavioural change to improve sustainable food consumption

Conclusions

Taking advantage of digital technologies is vital to the prosperity of the food sector. The incorporation of such technologies will support the food industry in becoming more efficient and sustainable, reducing its current huge environmental impact. Furthermore, the automation provided by technologies, such as image recognition, sensing devices, AI, robotics and connectivity via IoT, is pushing digitalisation forward, supporting fast and efficient data collection and sharing between different actors in the food supply chain. It significantly aids in the data collection phase of LCA studies (i.e. life-cycle inventory), which is generally the most labour-intensive phase. Finally, transitioning from the current state of the food industry to Industry 4.0 requires a collaborative approach and the involvement of players from across the supply chain, academia and government. Although a challenging task, immediate action is needed to modernise and transform the food industry with the latest digital technologies. ■

Article and references available online at **onlinelibrary.wiley.com/doi/10.1002/fsat.3603_5.x**

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