Turkeys and data: How sustainable logistics is growing smarter

For the transition to a sustainable economy to succeed in its entirety, logistics must be considered in addition to raw materials and manufacturing. Artificial intelligence will play a central role in improving the exchange of data between the individual links in the supply chain and in regulating processes and costs at the various stages of production. The meat industry, with its hygienic and increasing ethical requirements for animal welfare, is set to greatly benefit from the digital revolution.

Keywords
sustainable food supply chain, transparency, food waste awareness, artificial intelligence, AI, interoperability

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Sustainable Food Supply Chains Through Artificial Intelligence

Conceptual visualization using the example of turkeys to promote animal welfare and food quality

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The concept visualizes a sustainable food supply chain through the use of artificial intelligence, using the example of turkeys to promote animal welfare and food quality. The technology push through artificial intelligence along the food supply chain is identified as a driver. In terms of market pull, it becomes clear that stakeholders are demanding transparency and the avoidance of food waste. The focus is on the parameters of production processes, use of resources and deriving possible positive effects. The target group comprises stakeholders in the food supply chain and includes producers at the processing and production stages, distributors, retailers and consumers.

Drivers for sustainable food supply chains

On the one hand, developments through artificial intelligence (AI) can be understood as a "technology push". In the supply chain, AI is currently used primarily for optimization in the areas of design, planning, scheduling and for predicting production volumes [1, 2]. In recent years, time series or big data analyses have primarily been used to detect anomalies in production data. The applications therefore primarily cover strategic areas rather than operational ones. It can also be seen that AI applications have thus far been implemented selectively and not comprehensively along the entire supply chain. In order to change this, data, trust and a cultural change are required [1]. The use of explainable AI (XAI) can present results of AI to users in a comprehensible manner and promote trust [3].

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On the other hand, development potential based on "market pull" is evident. Stakeholders such as political decision-makers, suppliers, producers and consumers are increasingly interested in sustainable food supply chains. Possible measures to achieve this include environmentally friendly decisions, optimization of distribution channels and restructuring [4]. Consumer trends show that transparency is the strongest trend. It has a significant impact on logistics, as this trend influences the entire value chain. In addition, food waste awareness, which includes discarded food and losses caused by inefficient processes and processing steps within the logistics chain, is also becoming significant due to strong growth in consumer trends [5].

Holistic data networking in supply chains

In the automotive industry, the proprietary data ecosystem, Catena-X, which is based on GAIA-X, enables collaboration within an industry sector [6, 7]. This promotes a data-driven value chain that meets the challenges of the industry. Another existing solution is the Manufacturing-X initiative, which strengthens sustainability, resilience and competitiveness of the industry with an intelligently networked data network across industrial sectors [8].

Supply chain from turkey as livestock to turkey meat as a food product

Based on the initial situation described above, this concept focuses on the parameters of production processes and resource use along the value chain from

Figure 1: *Traditional food supply chain, without food quality restrictions and without AI integration (2023, own illustration).*

turkey as livestock to turkey meat as a processed food product, in order to visualize a sustainable food supply chain through the use of AI. According to Karwowska, there is little data on food waste in the meat industry. At the same time, the meat industry is characterized by a negative impact on the environment [9]. The Meat Atlas of 2021 shows that avoidable losses within the food supply chain from livestock to food are mainly present in the process steps leading up to slaughter [10].

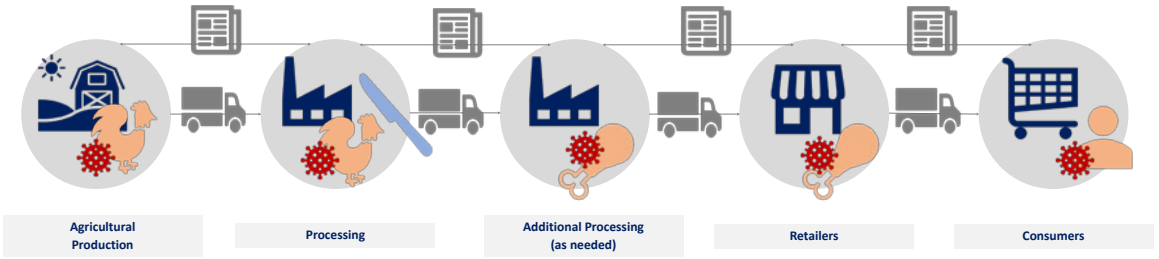
Visualization of sustainable food supply chains

Figure 1 visualizes a classic food supply chain, which consists of actors from different stages of the value chain working together. In the supply chain, there is a flow of materials and information [11] (characterized by the transport processes). The visualization covers the food supply chain and includes producers, the processing and production stages through to distribution via retailers to the end consumer.

A potential challenge within the first processes of the food supply chain that is not recognized predictively can result in it being passed on along the material flow. A non-centralized exchange of information can hinder the recognition of such an eventuality. Measures may not be initiated promptly enough, meaning that the problem is no longer resolved and the consumer consumes a food item which may be unsafe. This is visualized in **Figure 2**.

The conceptually developed sustainable supply chain is based on the networking of all players across the supply chain. In this network, it is possible to centrally store and intelligently link the production data of those involved in the process and to exchange information between the players along the food supply chain. In addition, an exchange between all players about process flows can promote understanding of the needs, requirements and processes of others. On the one hand, the use of AI (both in the supply chain as a whole and in its individual sectors) creates opportunities to predictively identify and resolve challenges. On the other hand, the networking and exchange of data can also promote a centralized flow of information so that food which may be unsafe can be removed from the process at an early stage and the possibility of it reaching the consumer can be eliminated. **Figure 3** visualizes the approach.

Figure 2: *Traditional food supply chain, with food quality restrictions but without AI integration (2023, own illustration).*



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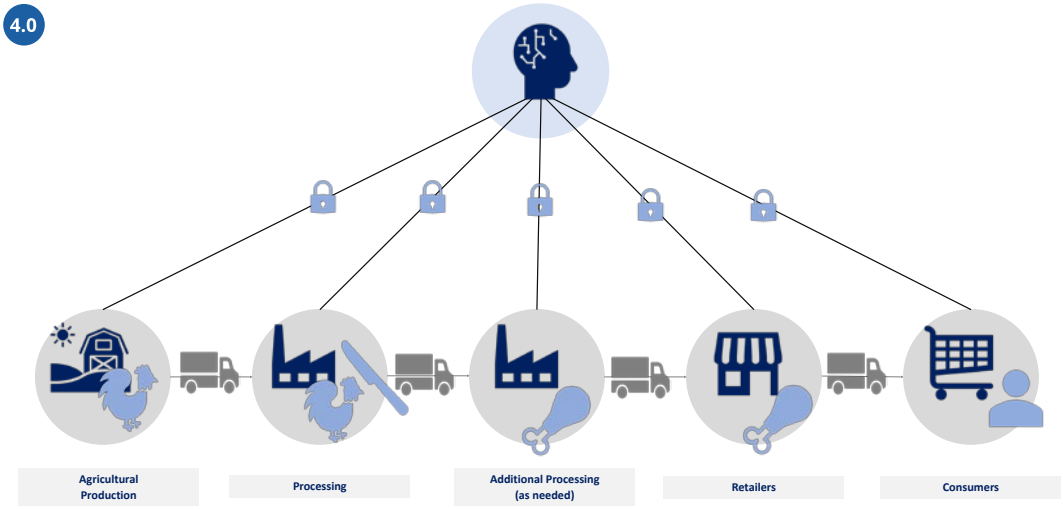


Figure 3: *Sustainable food supply chain without food quality restrictions but with AI integration (2023, own illustration).*

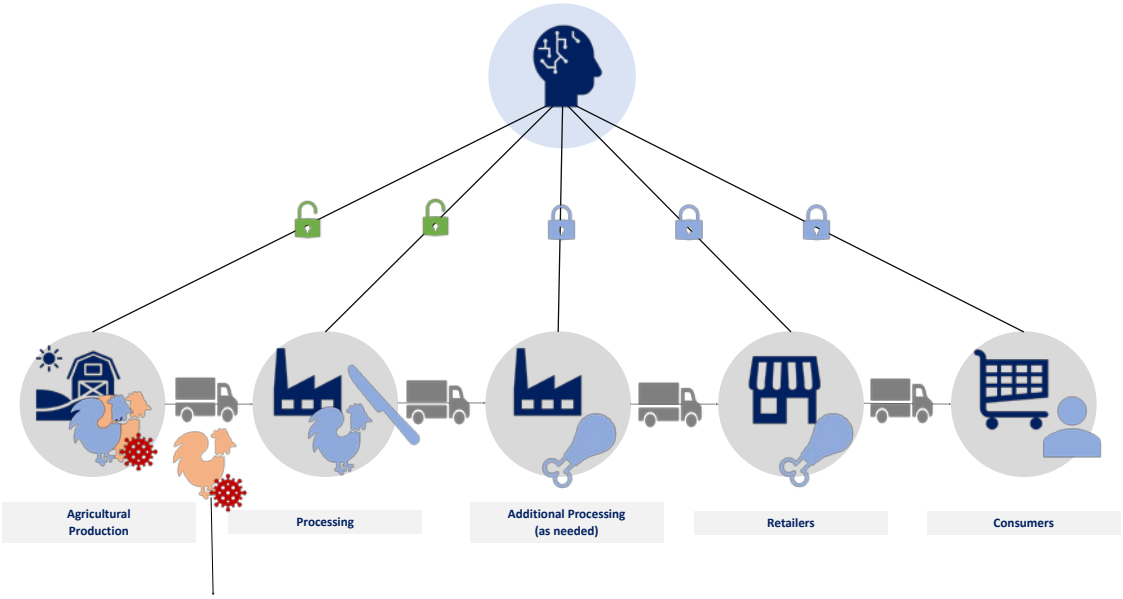
It is also possible to store data centrally along the food supply chain without other actors having access to it, thereby preserving the data sovereignty of the individual actors in the supply chain. This means that each link in the value chain can decide on the receipt and use of data [12]. However, standardization, compatibility and interoperability of systems and processes promote effectiveness within the supply chain [13]. The resulting benefits are illustrated in **Figure 4**.

The visualization demonstrates how e.g. a diseased animal that would lead to an unacceptable food quality after further processing is detected through the use of AI in agricultural production. A direct exchange of processing information ensures that this animal is not processed and is removed from the supply chain. The AI can be guided by visual characteristics by working with image classification, image segmentation and object recognition. In this way, non-compliant incidents can be detected efficiently and at an early stage. Production and consumption parameters are also relevant in order for the AI to recognize processes that are outside the ideal range in good time. This can be achieved through regression, time series analyses or the detection of anomalies.

Effects of a sustainable food supply chain

By implementing sustainable food supply chains using the example of turkey as livestock to turkey meat as a

Figure 4: *Sustainable food supply chain with food quality restrictions and with AI integration (2023, own illustration).*



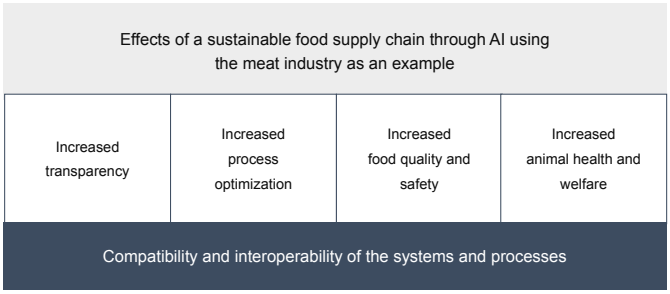


Figure 5: *Effects of a sustainable food supply chain with AI integration (2023, own illustration).*

processed food product, four possible effects are derived. These effects can be summarized as the promotion of transparency, process optimization, food quality and safety as well as animal health and welfare. **Figure 5** visualizes these and shows that the compatibility and interoperability of the systems and processes along the supply chain should be fulfilled in order to ensure the highest possible effectiveness [13].

Possible effects of promoting transparency can be the implementation of a central exchange of information or the reduction of workload due to the availability of continuous information. Increased data transparency allows process steps along the food supply chain to be planned and executed in an optimized manner. An example of this is the distribution of turkeys from the finishing phase to the slaughterhouse. The transparency of the animals' weight data enables efficient route planning within the supply chain. As a result, turkeys can be slaughtered at the ideal slaughter weight, which not only reduces costs, but also makes the finishing period more sustainable and is therefore also beneficial to animal welfare.

The predictive identification of potential challenges and the reduction of rejects along the supply chain can be used as arguments for promoting food quality. Improving animal health and increasing animal welfare primarily boosts agricultural production and downstream processes. The early detection of possible diseases, for example, serves as a measurable parameter for this effect.

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