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# Production and logistics 4.0 in the food industry in the Czech Republic

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***Keywords*:** automation, food chain, Industry 4.0, logistics, production.
***Abstract:*** The food industry is the most important sector of the national economy of the Czech Republic, which significantly contributes to the fulfillment of fundamental macroeconomic aggregates such as gross domestic product, employment, exports and others. The food industry is currently facing pressure from customers for higher quality and safety while maintaining low prices. At the same time, however, they must ensure high safety and productivity of their production and logistics flows when there is a shortage of manpower. Another aspect is the sustainability of logistics and supply chains, i.e. the requirement for new materials, packaging and technologies enabling maximum processing and use of inputs. From this point of view, the application of Industry 4.0 elements to the food industry appears to be a necessary step for the company's competitiveness. The article summarizes the results of a questionnaire survey that took place in the period April-May 2023 through the Internet tool Survio. A structured questionnaire was sent to 206 food businesses in the Czech Republic. The enterprises were selected according to the database of the Ministry of Agriculture. 69 enterprises returned correctly completed questionnaires, which makes the return rate 33%. Questions were directed to the area of process stability as a result of two crises, the Russian-Ukrainian crisis and the Covid-19 pandemic. Further to the field of automation, digitization and robotization to evaluate the current state of involvement of food production in Industry 4.0.

## 1 Introduction

The agricultural and food sector is a key branch of the Czech industry.The main pillars of competitive food production are food safety and quality. An integral condition of food safety is the safety of production and logistics processes within the entire food chain. This is guaranteed on the one hand by the fulfillment of legislative measures, on the other hand by voluntary certificates and standards. Food production is influenced by the European and mainly domestic market, where the origin of food is more important to consumers than before. From this point of view, an important aspect is transparency in production and logistics, which needs to be ensured within the entire value chain. That is, from the reception of the raw material and its storage to the delivery of the food to the final consumer. As Lukiewska and Juchniewicz emphasize, the food sector is the basis for the growth of Central European national economies from a long-term and sustainable perspective [1]. In recent years, the world has increasingly faced resource scarcity, population growth and climate change, and thus the role of agri-food chains in sustainability issues is growing [2]. In 2020, the food industry was one of the few sectors that managed to achieve the effects of the COVID-19 pandemic. The industrial production of the food industry increased by 0.7% in 2020, from industrial activity increased by 1.6% and financial results by 3.2%. In 2021, the food industry continued to grow, despite additional energy and raw material costs. In the first eleven months of 2021, the food turnover reached industry CZK 314.6 billion, which was 10.6% more than in the same period of 2020 [3]. The food industry is currently facing pressure from customers for higher quality, safety by managing value streams while maintaining low prices. At the same time, however, they must ensure high safety and productivity of their processes when there is a shortage of manpower. In order to ensure the quality control and safety of food products, and further reduce the need for manpower, many production and logistics flows in the food industry are monitored and implemented using automation [4]. Another aspect is the sustainability of logistics chains, i.e. the requirement for new materials, packaging and technologies enabling maximum processing and use of inputs. Supply chains cross the borders of many countries and are based on the cooperation of international organizations. This fact has an impact on competitiveness, as the wide network and complexity of the links in the chain limit traceability and transparency to the desired level [5]. From this point of view, the application of Industry 4.0 elements to the food industry appears to be a necessary step for the company's competitiveness. Malík points out that the world has already encountered major global problems such as

economic crisis and military conflict. The elements of industrial revolution 4.0 can certainly improve the management of production and logistics processes in times of economic crisis [6]. The Fourth Industrial Revolution (called Industry 4.0) is progressing exponentially, driven by the advent of a range of digital technologies and other innovative technological advances [7]. There are numerous challenges facing the modern food and agriculture industry that urgently need to be addressed, including feeding a growing global population, mitigating and adapting to climate change, decreasing pollution, waste, and biodiversity loss, and ensuring that people remain healthy. At the same time, foods should be safe, affordable, convenient, and delicious [8]. New technologies and elements of Industry 4.0 present new opportunities for food businesses to implement traceability systems for aggregating a wide range of data to material and information flows within the entire chain [9]. These technologies would then have a direct impact on the management of material, financial and information flows. The production and logistics processes of the food industry are subject to a number of legislative measures related to product safety. The various stages comprised can be classified as agricultural production and livestock production, food industry, distribution, and consumption. Each stage, except the consumption, adds a specific value to the final product [10]. The main pillars of Industry 4.0 are automation, robotization and digitization. Based on this, there is also talk of logistics 4.0. Processes performed by robotics and automation also provide greater efficiency and a better work environment [11]. Industry 4.0 is a direction that affects production and logistics processes, but it can also be implemented in the areas of trade, agriculture, healthcare and logistics in general. The elements of Industry 4.0 in logistics processes then represent the concept of Logistic 4.0, which is intended to help increase the performance of individual logistics activities and processes [12]. The introduction of Industry 4.0 has many impacts also on the whole supply chain and requires companies to rethink the way they design and manage their supply chain [13]. In the agri-food sector, demands for SCM are increasing due to the requirement to shorten activities and processes throughout the chain. Another requirement is quality control, monitoring of long-distance flows of agri-food commodities, management of these flows with respect to different expirations of food materials and raw materials [14]. The food supply chain is made up of producers, traders and processors who bring the product from supply to demand through logistical processes [15].

Food Logistics 4.0 is a term derived from Industry 4.0, focusing on all aspects of food logistics management based on cyber-physical systems. This concept aims that the integration of real-time information and new elements and technologies will lead to more efficient flow management and logistics for food commodities [16].

## 2 Methodology

The goal of the contribution is to point out the degree of use of automation and robotization in the food industry, as pillars of Industry 4.0. A number of scientific methods were used in the creation of the contribution. Analysis and synthesis of foreign professional research and their comparison were key methods for critical literary research. The established hypotheses were verified using a quantitative questionnaire survey. The questionnaire was constructed with closed questions in the Survio software tool. Contacts for food companies were drawn from the database of the Ministry of Agriculture. All results were evaluated according to company size. In total, 69 companies took part in the survey, medium-sized companies were most often represented (33.3%; 23 companies). The questions tested the hypothesis: H0. There is no statistically significant relationship between the answers to the monitored question and the size of the company H1: There is a statistically significant relationship between the answers to the monitored question and the size of the company The evaluation was carried out at a significance level of $\alpha$ = 5%. The basic statistical methods were descriptive statistics, Fisher's exact and modified test and Spearman's correlation coefficient.

## 3 Result and discussion

The main priority of companies in agri-food chains is product safety and quality. The application of automation technology based on Industry 4.0 contributes to the realization of a sustainable food security regime [17]. The author collective monitored the degree of involvement of the company in the process of automation of operation, where 1 represented complete involvement, up to 4, which represented zero involvement. Table 1 shows that micro-enterprises have zero automated operations, and 53.8% of these enterprises do not plan to implement at all (7 enterprises), on the contrary, large enterprises have automated operations in 31.3% of cases (5 enterprises). On the contrary, there is no large enterprise that does not at least plan for automation. To verify the relationships, it is not possible to use the $\chi 2$ test of independence in the contingency table due to the large number of underrepresented categories, as well as the modified Fisher's exact test due to the size of the table. However, since we can consider both variables as ordinal variables, we can use Spearman's correlation coefficient (R = -0.478; p-value <0.001). Since we know that 1 = full automation and 4 = zero automation, with no implementation plan, it can state that as the size of businesses increases, the level of automation increases statistically significantly. Small and medium-sized food manufacturers are currently facing pressure from customers and stakeholders to shorten delivery times and be environmentally friendly in order to maintain a competitive position in the global market. While the adoption of Industry 4.0 is still at an early stage among SMEs, its potential impact on sustainability is expected.

The implementation of the elements of Industry 4.0 in these types of business is still at an early stage, but its potential impact on sustainability is expected [18].

*Table 1 The degree of involvement in automation according to the size of the company*

| Choose the degree of involvement of your business in the process of automation of operations | Company size by number of employees: | | | | Total |
|---|---|---|---|---|---|
| | Micro enterprise 1-9 employees | Small business 10-49 employees | Medium enterprise 50-249 employees | A large company with over 250 employees | |
| The company already has an automated operation | 0 (0%) | 5 (29.4%) | 7 (30.4%) | 5 (31.3%) | 17 (24.6%) |
| The company is in the phase of implementing automation elements | 2 (15.4%) | 5 (29.4%) | 13 (56.5%) | 9 (56.3%) | 29 (42%) |
| The company is considering automating in the short term (1-2 years) | 4 (30.8%) | 4 (23.5%) | 2 (8.7%) | 2 (12.5%) | 12 (17.4%) |
| Thee company is not considering automation | 7 (53.8%) | 3 (17.6%) | 1 (4.3%) | 0 (0%) | 11 (15.9%) |
| Total | 13 (100%) | 17 (100%) | 23 (100%) | 16 (100%) | 69 (100%) |

Table 2 shows at which countries the production automation systems were or will be purchased from. Initially, this question was answered by all monitored companies, i.e. even those that do not plan automation at all (just for interest - these companies chose the answer Asia). We considered it appropriate to evaluate this question only for those businesses that are already automated, or at least plan to do so. In that case, there are 58 enterprises. Overall, the most common answer was "Other EU countries". Interestingly, after filtering out businesses that do not plan to automate at all, no one mentioned Asia. There is a statistically significant relationship between the size of the company and the country of origin of the systems (Fisher's modified test; p-value = 0.044). Smaller companies more often prefer Czech systems, on the contrary, large companies prefer systems from other EU countries. Specific elements of automation depend on the type and size of production. In their study, Bader and Rahimifard [19] present a solution to improve the application of industrial robots in food production through the definition of a methodology to identify a flexible automation solution for a specific production requirement. present a solution to improve the introduction of robots for food production through a methodology for identifying a flexible automated solution to a specific production requirement.

*Table 2 Origin of automation or planned automation*

| Systems for traffic automation were/will be procured from: | Company size by number of employees | | | | Total |
|---|---|---|---|---|---|
| | Micro enterprise 1-9 employees | Small business 10-49 employees | Medium enterprise 50-249 employees | A large company with over 250 employees | |
| Czech Republic | 5 (83.3%) | 9 (64.3%) | 9 (40.9%) | 4 (25%) | 27 (46.6%) |
| Other EU countries | 1 (16.7%) | 5 (35.7%) | 13 (59.1%) | 12 (75%) | 31 (53.4%) |
| Total | 6 (100%) | 14 (100%) | 22 (100%) | 16 (100%) | 58 (100%) |

Consumers as well as other members of the food chain require accurate information in real time. Especially in cases of threat to the health of consumers, immediate traceability of the origin of food is required. Digitalization allows food supply chains to be highly connected, efficient, and responsive to customer needs and regulation requirements [20]. Table 3 shows the stages of the digitization process. Digitization elements are used by 15.4% of micro enterprises, but even 50 % of large enterprises, another 31.3% are currently implementing these elements. As in the previous case, we will verify the relationship between the variables using the Spearman correlation coefficient. In the case of the degree of digitization, we consider 1 = full digitization, 2 = implementation at present, 3 = planned digitization and 4 = rejection of digitization. Based on the test performed (Spearman's correlation coefficient; r = -0.346; p-value = 0.004), we demonstrated a statistically significant relationship between the degree of digitization and the size of the company. As the size of enterprises increases, the relevance of digitization increases. The results of this investigation are also confirmed by Kosior's study [21], where it states that the use of digitization elements to manage production and logistics flows in EU food industry

enterprises is low compared to other sectors and industries. He further states that, in general, a higher degree of digitization was typical for large and very large enterprises that had the necessary resources and were able to use the potential of digital technologies.

*Table 3 The degree of the company's involvement in the digitization process*

| Indicate the degree of involvement of the enterprise in the digitization process | Company size by number of employees | | | | Total |
|---|---|---|---|---|---|
| | Micro enterprise 1-9 employees | Small business 10-49 employees | Medium enterprise 50-249 employees | A large company with over 250 employees | |
| The company already uses elements of digitization | 2 (15.4%) | 6 (35.3%) | 11 (47.8%) | 8 (50%) | 27 (39.1%) |
| The company is in the phase of implementing digitization elements in operation | 2 (15.4%) | 6 (35.3%) | 7 (30.4%) | 5 (31.3%) | 20 (29%) |
| The company is considering digitization in the short term (1-2 years) | 4 (30.8%) | 2 (11.8%) | 3 (13%) | 3 (18.8%) | 12 (17.4%) |
| The company is not considering digitization | 5 (38.5%) | 3 (17.6%) | 2 (8.7%) | 0 (0%) | 10 (14.5%) |
| Total | 13 (100%) | 17 (100%) | 23 (100%) | 16 (100%) | 69 (100%) |

Thanks to digitization, which is still on the rise, production models integrate smart technologies such as robotics, artificial intelligence (AI), the Internet of Things (IoT) and others [22]. Digitization represents process change and restructuring in business and production approaches. The author team was also interested in what steps the company takes when implementing or considering digital transformation. Businesses that said they were not considering digitization at all were excluded from this survey. The results are then presented in table number 4. Overall, companies most often approach "a higher level of use of production data analysis and their integration into the user interface". On the contrary, at least to the creation of new business models. Even if there are some differences in the data and large enterprises have a higher representation of individual steps, even if the enterprise is planning or has implemented digitization of operations, there are no statistically significant differences between the size of the enterprise and the implementation of individual steps. Studies [23,24] that deal with the development of digitization elements in the agri-food sector emphasize that digitization significantly helps to increase traceability in the entire food chain. Zhou [25] then states how food firms can improve their sustainability performance through digital traceability practices.

*Table 4 What steps the company has implemented in connection with digitization*

| Steps the company has implemented in connection with digitization | Company size by number of employees: | | | | |
|---|---|---|---|---|---|
| | Micro enterprise 1-9 employees | Small business 10-49 employees | Medium enterprise 50-249 employees | A large company with over 250 employees | Total |
| Total | 8 (100%) | 14 (100%) | 21 (100%) | 16 (100%) | 59 (100%) |
| Changing the information communication strategy at the input and output | 4 (50%) | 13 (92.9%) | 12 (57.1%) | 12 (75%) | 41 (69.5%) |
| Creation of new business models | 3 (37.5%) | 1 (7.1%) | 4 (19%) | 7 (43.8%) | 15 (25.4%) |
| Use of process management in process restructuring | 2 (25%) | 8 (57.1%) | 10 (47.6%) | 9 (56.3%) | 29 (49.2%) |
| Building an integrated software platform connecting all elements and processes in the enterprise | 4 (50%) | 12 (85.7%) | 15 (71.4%) | 12 (75%) | 43 (72.9%) |
| A higher degree of use of production data analysis and their integration into the user interface | 4 (50%) | 11 (78.6%) | 16 (76.2%) | 14 (87.5%) | 45 (76.3%) |

*Table 5 Fisher´s exact test*

| Fisher's exact test | **P-value** |
|---|---|
| Changing the information communication strategy at the input and output | **0.065** |
| Creation of new business models | **0.086** |
| Use of process management in process restructuring | **0.492** |
| Building an integrated software platform connecting all elements and processes in the enterprise | **0.365** |
| A higher degree of use of production data analysis and their integration into the user interface | **0.285** |

Table 6 shows the digitization rates used by businesses. They most often use the production planning system. This is also confirmed by Cho's study [26], which says that production planning is a key part of production management of manufacturing enterprises The use of digitization elements in the case of enterprise size differs in all cases mentioned. The mentioned elements are more often used by large enterprises, small enterprises most often use only the production planning system. However, even 93.8% of large enterprises have these systems.

*Table 6 Digitalization rates used by business*

| Do you use these digitization elements in your operation? | Company size by number of employees: | | | | |
|---|---|---|---|---|---|
| | Micro enterprise 1-9 employees | Small business 10-49 employees | Medium enterprise 50-249 employees | A large company with over 250 employees | Total |
| Total | 13 (100%) | 17 (100%) | 23 (100%) | 16 (100%) | 69 (100%) |
| Warehouse Management System | 1 (7.7%) | 9 (52.9%) | 17 (73.9%) | 13 (81.3%) | 40 (58%) |
| Production Planning System | 5 (38.3%) | 11 (64.7%) | 15 (65.2%) | 15 (93.8%) | 46 (66.7%) |
| MES | 0 (0%) | 6 (35.3%) | 9 (39.1%) | 10 (62.5%) | 25 (36.2%) |
| EDI | 1 (7.7%) | 11 (64.7%) | 19 (82.6%) | 12 (75%) | 43 (62.3%) |

The industrial world has been experiencing digital transformation and implementation of Industry 4.0 elements and technologies in recent decades. Nevertheless, some sectors of the manufacturing industry lack automation and digitization, in particular the main problem is the design and successful implementation of warehouse automation [27,28]. This assertion is confirmed by research results, where the use of the Warehouse Management System is still insufficient.

## 4 Conclusions

The food sector is a strategic sector that plays a primary role in ensuring food security and self-sufficiency. The specifics of this industry are food chains with direct links to the agricultural industry and end customers. Like other companies in the processing industry, the food industry is also under pressure for higher process efficiency, rationalization of resources and reduction of production costs. Most food production takes place through mass or batch production. This provides the basis for the use of Industry 4.0 elements, especially process automation. A key factor in food production is traceability throughout the entire chain. Another Industry 4.0 element of digitization can then be a tool for assurance. The research results confirm that the use of automation elements depends on the size of the company. Likewise, the relationship between the use of digitization elements and the size of the company was statistically proven. Other foreign studies also confirm that the level of use of digitization in the food sector is still low. It is mostly associated with the introduction of production planning systems. The use of the MES system within the investigated food companies is assessed as insufficient. This system can provide up-to-date records of measurements of a wide range of quantities and notifications for continuous production. And it provides a solid basis for traceability throughout the food chain. In further research, the author team would like to focus on a more detailed analysis of the production planning system and material flows in connection with Industry 4.0.

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