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Innovation and Industry 4.0 in building the international competitiveness of food industry enterprises: The perspective of food industry representatives in Poland

Katarzyna Łukiewska[1]

Abstract

The aim of the research is to determine the impact of innovations and Industry 4.0 solutions on the international competitiveness from the perspectives of representatives of food industry enterprises. The empirical layer used information collected on the basis of a survey using the CATI method conducted on a representative sample of representatives of food industry enterprises. Descriptive statistics, the Kruskal-Wallis test, Mann-Whitney test, multiple comparison test and box-plot plots were used to analyse the data. The study confirmed that implementing certain innovations and solutions, both intangible and tangible, is important for maintaining and improving competitiveness on the international market. This applies particularly innovative, modern ways of reaching the customer, developing innovative products, the use of IT systems and the use of innovative methods in advertising and promotion. The conclusions present direct implications for managers of food enterprises who formulate competitive strategies.

Keywords

- competitiveness
- food industry
- innovation
- Industry 4.0

JEL codes: F00, L66, O30.

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Introduction

The international competitiveness of entities is an important and topical issue of interest to scientists, researchers, economic practitioners and politicians. Its importance was emphasised in many studies, including those on the development strategies of the European Union (EU), including the Lisbon Strategy and its continuation Strategy 2020 (Balcerzak, 2015). The scientific discourse examines various aspects of competitiveness, including competitive potential, competitive strategies and instruments, and competitive position. From a cognitive and practical point of view, an important research problem is to determine the factors that make some entities perform well on the market and be competitive. Łukiewska and Juchniewicz (2021) indicate that permanently changing environmental conditions cause key competitiveness factors to evolve over time. Currently, changes are taking place in global economies, which lead to new conditions for entities to compete on increasingly demanding international markets. There is a rapid development in information and communication technologies, which puts pressure on enterprises to implement innovations and conduct business as part of the fourth revolution (Boikova et al., 2021). As a result, in order to adapt to the changing reality and new requirements of the environment, entities should look for new forms of competition with market rivals. The literature on the subject increasingly emphasises that it is innovations and new technologies that will largely determine the ability of entities to maintain or improve their competitive position (e.g., Baierle et al., 2022; Boikova et al., 2021; Kafetzopoulos et al., 2015; Silva et al., 2023).

New operating conditions also apply to the food industry. Its role in the economy and society is emphasised by many economists (e.g., Bigliardi & Galati, 2013; Gardijan & Lukač, 2018; Turi et al., 2014; Wilson, 2018). They draw attention to the importance of this sector in economic and environmental development, but also in shaping social well-being, meeting the basic needs of the population and ensuring food security. As Stefansdottir and Grunow (2018) and Akyazi et al. (2020) the changing environment and the emergence of new business models also pose new requirements in the agri-food industry. On the one hand, the food industry is not considered by researchers to be a sector with high research intensity (Martinez, 2000), but rather a quite mature and technologically unadvanced industry (Alawamleh et al. 2022). On the other hand, as Hassoun (2024) and Benharkat et al. (2023) point out, the emergence of new solutions in recent years and the rapid development of a wave of advanced technologies have influenced almost every industry, including agriculture and the food industry. According to Herrero et al. (2020) and Sadeghi et al. (2022), advanced technologies have revolutionised food systems and the food system in many countries. Some authors (Galanakis et

al., 2021; Radu et al., 2021; Weersink et al., 2021) indicate that the shift towards greater automation and digitalisation has been accelerated by labour shortages and other disruptions caused by the COVID-19 pandemic.

The changes taking place in the environment have resulted in the emergence of new trends in the food industry, as well as the emergence of new opportunities to introduce innovations and improvements to agricultural production and food processing. This creates unexplored potential that could allow the use of Industry 4.0 innovations and solutions in creating a competitive advantage in the food industry. Hassoun (2024) shows that while intensive research has been undertaken on the potential implementation of Industry 4.0 technologies in various fields, research findings on the application of Industry 4.0 in food-related sectors are still limited.

Therefore, the literature on the subject lacks empirical research confirming or denying the impact of innovative solutions on competitiveness in the food industry. The conclusions that have been formulated for other industries cannot be clearly translated to the food industry. Competitive factors depend on the specificity of production and the market in which the entities operate. Hence, the aim of the research is to determine the impact of innovations and Industry 4.0 solutions on the international competitiveness from the perspective of representatives of food industry enterprises. Additionally, the following research questions were asked:

RQ1: In the opinion of representatives of the food industry, which innovations and solutions in the field of Industry 4.0 are of high, medium and low importance in building international competitiveness?

RQ2: Does the perceived importance of innovations and solutions in the field of Industry 4.0 in building international competitiveness differ in enterprises producing food and those producing beverages?

RQ3: Does the perceived importance of innovations and solutions in the field of Industry 4.0 in building international competitiveness differ in enterprises with small, medium and large exports of food products to foreign markets?

The discussion presented in the article constitutes an attempt to reduce the cognitive gap identified in the literature on the subject. In a practical dimension, learning and applying appropriate innovations and solutions in the field of Industry 4.0 can contribute to better adaptation to the requirements of the environment, as well as gaining an advantage and increasing the international competitiveness of food producing enterprises and the entire food industry.

The article is structured as follows: The literature review indicates the factors affecting the competitiveness of enterprises, the essence of innovation and Industry 4.0, and discusses the connections between these categories and competitiveness. The research methods section presents the methodological

approach, data collection and quantitative tools used. The results are then presented and discussed. The conclusions summarise the article, include implications for practice, as well as highlighting the limitations of the study, and outlining possible directions for further analysis.

1. Literature review

1.1. International competitiveness and the factors that shape it

The complexity and multidimensionality of the competitiveness phenomenon mean that there is no clearly developed and universally accepted definition. At the level of enterprises and industries, it is generally understood as the ability to obtain benefits in a market with increasingly intense competition (Maroto-Sanchez & Cuadredo-Roura, 2013) or the ability to compete in a competitive environment, and to achieve growth and profitability (Sipa et al., 2015). The specificity of market conditions means that competition between enterprises takes place on the international market. Even companies that do not undertake foreign operations compete with foreign rivals on the local and national markets. The international competitiveness of enterprises and industries is shaped by various factors. In the literature on the subject, there are many approaches to determining them, but they are basically divided into external and internal (Bhawsar & Chattopadhyay, 2015; Laureti & Viviani, 2011). The external factors include economic, natural-geographic, political, legal, socio-cultural, and industry factors (Dolzhansky & Zagorna 2006; Jambor & Babu, 2016; Kuchmieiev, 2023). In turn, internal factors most often include organisational and management factors, financial and economic factors, the production potential of the enterprise, logistic components and marketing orientation (Kuchmieiev, 2023; Reshetnikova & Kalyuzhna, 2016; Yankovyj, 2013).

Research by other authors (Szczepaniak & Ambroziak, 2015) shows that the basis for the international success of the Polish food industry was the inclusion of the country in the European Single Market in 2004 with the consequent full opening of markets and freedom of trade with EU countries. The key source of international competitiveness was primarily price and cost advantages. However, the literature on the subject emphasises that these advantages are gradually exhausted, and new strategies are needed to maintain and strengthen the competitiveness of Polish agribusiness (Szczepaniak & Szajner, 2020).

1.2. Innovation and Industry 4.0 as factors of competitiveness

Viewing innovation as a source of competition is a relatively new approach. The forerunner of the concept itself was Schumpeter (1961). Innovations were also discussed by economists such as Drucker (1993), Kotler (1994) and Fagerberg (2005). Currently, in the EU, the so-called Oslo Methodology is used to define, classify and measure innovation. According to the commonly used definition presented in the Oslo Manual (2018, p. 20), innovation is: "a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has "has been made available to potential users (product) or brought into use by the unit (process)". Broadly speaking, innovations can refer to the introduction of new products or changes in various areas of an enterprise's activity. As Alawamleh et al. (2022) point out, in the food industry, innovations can occur at any stage across the food chain, but mainly in the following areas: unique ingredients, natural food innovations, new production process, food quality improvements, packaging techniques and preservation technologies, and innovative ways of delivery or marketing.

New opportunities for innovation are being created by the current digital revolution, which is also called the 4.0 revolution. This term, as indicated by Dossou et al. (2022), refers to a new way of working, communicating and relating, based on the connectivity provided by the implementation of the Internet and the use of information through automatic data collection and processing. Characteristics of Industry 4.0 are: automation, digitalisation, decentralisation, virtualisation, big data, acquisition, processing and transmission of data in real time (Gokalp et al., 2016; Koumas et al., 2021). According to Kergroach (2017), Industry 4.0 enables smart production by providing data and tools to streamline factory operations and better manage risks in the supply chain, from product logistics through inventory management to machine maintenance. According to Blunck and Werthmann (2017), this can lead to process optimisation, better asset utilisation, increased production efficiency and improved quality.

At present, many economists emphasise the impact of new solutions on the development and maintenance of a highly competitive position of economic entities (including Hermundsdottir & Aspelund 2021; Montobbio, 2003; Pereira et al., 2013; Porter, 2000). Although innovation is widely considered to be a way to improve the competitiveness of enterprises, this relationship is not clearly supported by empirical research. The limited number of analyses in this area do not resolve the impact of innovation on competitiveness. A review of the existing literature on the subject shows that there are studies confirming such a relationship. These include the study by Kafetzopoulos et al. (2015) among Greek manufacturing and service enterprises, which shows

that there is a positive and significant relationship between product innovations and process innovations and competitive advantage. The relationships were examined on the basis of 433 surveys using exploratory factor analysis, confirmatory factor analysis and structural equation modelling. Some studies also confirm the positive impact of innovation on company results, including their efficiency, export volume or market position (Evangelista & Vezzani, 2010; Gonzalez & Chacon, 2014; Gunday et al., 2011, Martinez-Costa & Martinez-Lorente, 2008). However, the literature on the subject also includes studies stating that there is no evidence of the impact of innovation on the competitiveness of entities. A study by Łukiewska and Juchniewicz (2021) conducted using panel models did not confirm any causal relationship between innovation and the international competitive position of the food industry in EU member states. At the same time, the relationship between labour productivity, labour costs and competitive position was confirmed. This study contributes to existing knowledge by examining and presenting the impact of Industry 4.0 innovations and solutions on the competitiveness of the food industry based on an original, nationwide empirical study on a representative sample. It not only systematises the current state of literature on this issue, but also includes economic practitioners, i.e. representatives of food industry enterprises, in the discussion.

2. Research methods

In the research procedure used in this study, the first stage involved analysing and critiquing international literature (Figure 1). This analysis of scientific achievements regarding the issues of competitiveness and competitiveness factors allowed the categories affecting the international competitiveness of the food industry to be determined, including Industry 4.0. innovations and solutions. A further review of the literature (including Kosior, 2018; Oslo Manual, 2018; Ustundag & Cevikcan, 2017) led to the development of a list of 15 factors in this field that may be important in building international competitiveness of food industry enterprises. These include:

- C01 – development of innovative products,
- C02 – use of innovative raw materials (e.g., spirulina, chia seeds),
- C03 – implementing innovative intelligent packaging,
- C04 – implementing innovative packaging made of renewable or biodegradable raw materials,
- C05 – the use of nanotechnology in creating packaging,
- C06 – creating new technologies and manufacturing techniques, including production automation,

– C07 – the use of intelligent robots and machines,
– C08 – computerisation of logistics,
– C09 – innovative, modern ways of reaching the customer,
– C10 – innovative, modern management systems,
– C11 – application of IT systems,
– C12 – starting cooperation with research centres,
– C13 – implementing innovative methods of distribution,
– C14 – use of innovative methods in advertising and promotion,
– C15 – applying data mining analysis and evaluating large databases.

On the basis of the literature review, an original structured interview questionnaire was developed as a research tool.

The next stage involved running the survey. In the survey conducted in 2022, the target group includes representatives of economic entities whose activities are included in section C of PKD 2007 Industrial processing, Division 10. Production of food products and Division 11 – Production of beverages. To obtain representative data, a stratified random selection of the research sample was used. The criteria for stratification were the Polish Classification of Activities and the size of the enterprise. In addition, the size of the research sample, in the course of calculations using the formula for the minimum sample size and adopting the confidence coefficient at the level of 95%, and the maximum estimation error of 5%, were established at 376 units (enterprises food industry). The enterprises were located all over Poland. The sample structure was dominated by those employing fewer than 10 people (82%). The second group consisted of small enterprises (14%). The smallest group were medium-sized and large enterprises (4%). It should be emphasised that such an asymmetry in the size of enterprises is consistent with the average size of

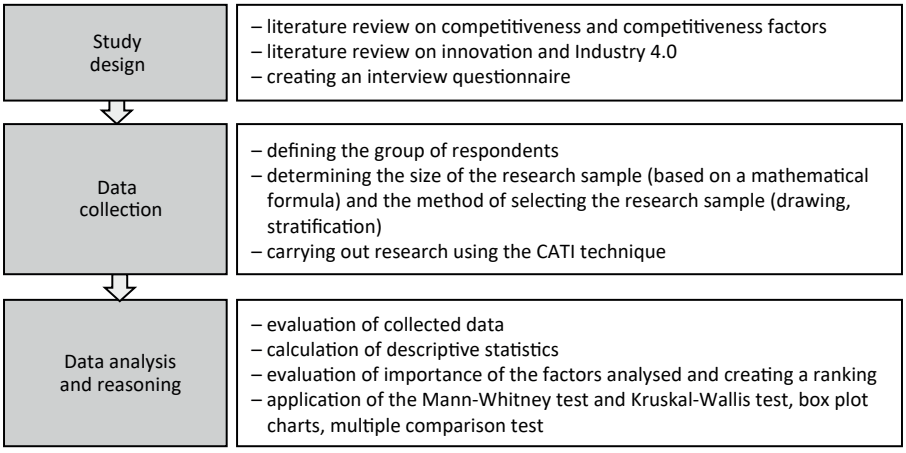


Figure 1. Research process

Source: own study.

the population of Polish enterprises in the food industry. When examining the structure of the sample according to the period of operation on the market, it was found that most of them had at least twenty years of experience (75%). Almost 16% of the entities surveyed had operated on the market for 10–20 years, and 9% for less than 10 years. Beverage producers accounted for over 5.05%, and food producers almost 94.95%. The study was performed using the CATI – Computer Assisted Telephone Interviewing technique.

A five-point Likert scale was used to assess the importance of components. Descriptive statistics were used to assess the significance of the elements, including the arithmetic mean and the median, lower quartile, upper quartile, dominant, standard deviation and coefficient of variation. Based on the arithmetic mean, a ranking of the analysed components was created and grouped according to their importance in building international competitiveness (Table 1).

Table 1. The importance of factors in building international competitiveness

Range of arithmetic mean scores	Importance of competitiveness factors
4.20–5.00	very high
3.40–4.19	high
2.60–3.39	medium
1.80–2.59	low
1.00–1.79	very low

Source: own elaboration based on Çelik and Oral (2016), and Renault et al. (2018).

The responses were then analysed taking into account the subsector (food and beverage producers) and the share of exports in the company's sales (< 10%, 10–40%, > 40%). The statistical tests were applied to determine whether there were any statistically significant differences between the groups in their assessment of competitive factors. In the first case, the non-parametric Mann-Whitney test was used to test the equality of distribution of the two populations:

$$\begin{aligned} H_0&: \theta_1 = \theta_2 \\ H_1&: \theta_1 \neq \theta_2 \end{aligned} \tag{1}$$

Test statistics takes the form:

$$Z = \frac{R_1 - R_2 - (n_1 - n_2)(n_1 + 1)/2}{\sqrt{(n_1 n_2 (n+1)/3}} \tag{2}$$

where: n_1, n_2 – number of samples, n – number of all observations, R_1 – sum of ranks awarded to the values of the first attempt.

When differences in assessment between factors were observed based on the test, the median, quartiles, minimum and maximum for the individual analysed groups (food producers and beverage producers) were presented on box-plot charts.

In the second case, the Kruskal-Wallis test was used. This test is the non-parametric analogue of a one-way ANOVA, which can be used when assumptions of normality and/or homoscedasticity were not met (Hecke, 2012; Muhammad et al., 2021). The test allowed for testing the null hypothesis that the k samples are from the same population (with the same medians θ):

$$H_0: \theta_1 = \theta_2 = \cdots = \theta_k$$
$$H_1: \text{not all } \theta_i \text{ are equal } (i = 1, 2, \ldots, k) \quad (3)$$

The test statistics take the form:

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(N+1)$$
$$N = \sum_{i=1}^{k} n_i \quad (4)$$

where: n_i – number of observations in i group, N – number of all observations, k – number of compared groups, R_i – sum of ranks in i group.

The H statistic has an asymptotic distribution with the degrees of freedom equal to the number of groups k minus 1. In the events of differences in factor assessments, a multiple comparison test was used to check which groups had differences. The test involves comparing the average ranks for each pair of groups. On this basis, p-value matrices were created. The assessments of the analysed groups were also presented in box-plot plots.

3. Results

In the empirical study, representatives of food industry enterprises were asked for their opinion on the importance of Industry 4.0 innovations and solutions selected based on the literature in building the international competitive advantage of the enterprise (on a 5-point Likert scale). A ranking of elements was created based on the arithmetic mean (Figure 2), the distribution of responses was presented (Figure 3) and the basic positional measures of the received ratings were determined (Table 2). The assessment of factors was analysed, also taking into account the specificity of production (food production and beverage production) and the share of exports in sales (Table 3, Figure 4, Table 4, Figure 5).

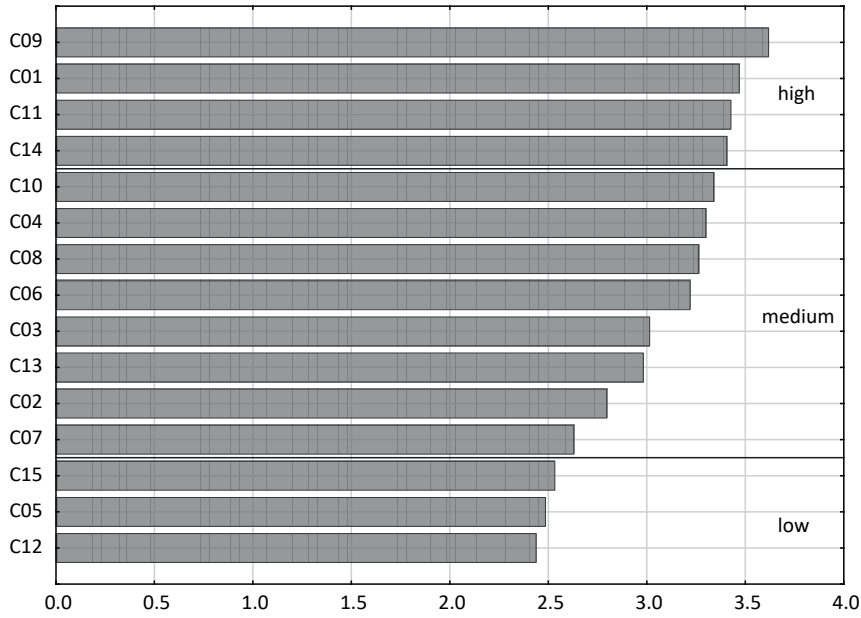


Figure 2. Ranking of the importance of Industry 4.0 innovations and solutions in the competitiveness of food industry enterprises according to the arithmetic mean

Source: own calculations based on research.

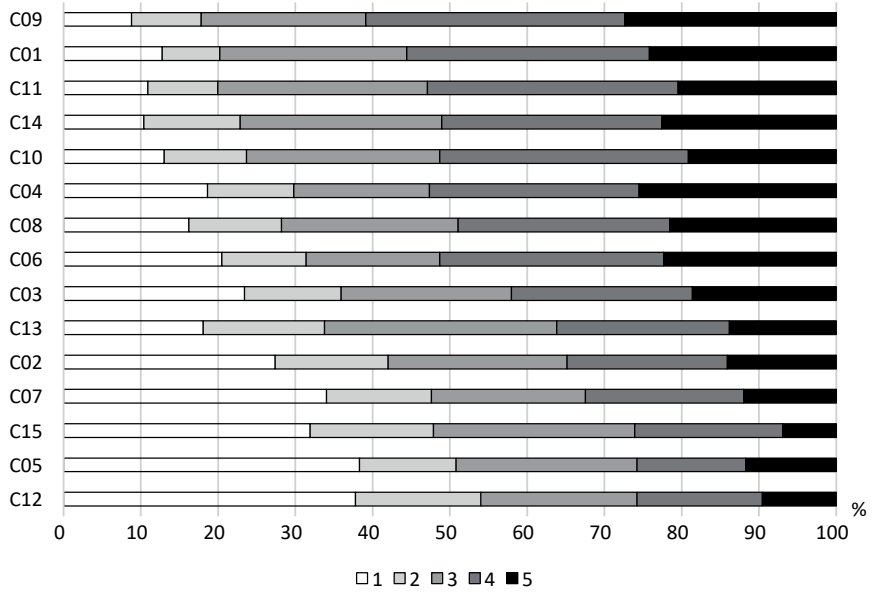


Figure 3. Distribution of assessments of the importance of innovations and solutions of Industry 4.0 in the competitiveness of food industry enterprises

Source: own calculations based on research.

Table 2. Descriptive statistics assessing the importance of Industry 4.0 innovations and solutions in the competitiveness of food industry enterprises

Component	M	Me	Q1	Q3	D	SD	CV (%)
C09	3.62	4	3	5	4	1.22	33.81
C01	3.47	4	3	4	4	1.29	37.06
C11	3.43	4	3	4	4	1.22	35.67
C14	3.40	4	3	4	4	1.25	36.80
C10	3.34	4	3	4	4	1.27	37.96
C04	3.30	4	2	5	4	1.44	43.58
C08	3.26	3	2	4	4	1.36	41.62
C06	3.22	4	2	4	4	1.44	44.70
C03	3.01	3	2	4	4	1.43	47.46
C13	2.98	3	2	4	3	1.29	43.23
C02	2.80	3	1	4	1	1.41	50.30
C07	2.63	3	1	4	1	1.43	54.46
C15	2.53	3	1	4	1	1.30	51.34
C05	2.48	2	1	4	1	1.42	57.00
C12	2.44	2	1	4	1	1.38	56.66

Note: M – arithmetic mean, Me – median, Q1 – lower quartile, Q1 – upper quartile, D – dominant, SD – standard deviation, CV – coefficient of variation.

Source: own calculations based on research.

3.1. Factors of high importance in building international competitiveness

The study shows that, in the opinion of respondents, the most important element in building international competitiveness were innovative, modern ways of reaching customers (C09). The arithmetic mean of the ratings for this factor was 3.62. The most frequently assigned answer was a rating of 4 (33.51% of respondents), but over 27.39% of the respondents assigned a rating of 5. Respondents also attributed great importance in building international competitiveness to the development of innovative products (C01), the use of IT systems (C11) and the use of innovative methods in advertising and promotion (C14). The arithmetic mean score was 3.40–4.47. The median indicates that 50% of respondents rated the importance of these factors as at least 4.

Table 3. Mann-Whitney test results and arithmetic mean by subsector

Component	Subsector	Mann-Whitney test			Arithmetic mean
		sum of rank	Z	*p*-value	
C01	F B	66969.50 3906.50	3066.50	0.48	3.46 3.63
C02	F B	67212.00 3664.00	3309.00	0.86	2.79 2.84
C03	F B	66348.00 4528.00	2445.00	0.04**	2.98 3.68
C04	F B	66307.50 4568.50	2404.50	0.03**	3.26 4.00
C05	F B	66460.00 4416.00	2557.00	0.07*	2.45 3.05
C06	F B	66549.00 4327.00	2646.00	0.11	3.19 3.79
C07	F B	66852.00 4024.00	2949.00	0.34	2.61 2.95
C08	F B	66657.00 4219.00	2754.00	0.17	3.24 3.68
C09	F B	66441.00 4435.00	2538.00	0.06**	3.59 4.16
C10	F B	66840.50 4035.50	2937.50	0.33	3.32 3.63
C11	F B	66705.00 4171.00	2802.00	0.20	3.41 3.79
C12	F B	66192.50 4683.50	2289.50	0.02**	2.39 3.21
C13	F B	66556.50 4319.50	2653.50	0.11	2.96 3.47
C14	F B	66538.00 4338.00	2635.00	0.10*	3.38 3.89
C15	F B	66312.50 4563.50	2409.50	0.03**	2.50 3.16

Note: F – food producers, B – beverage producers; ** and * significances at the 0.05 and 0.1 levels, respectively.

Source: own calculations based on research.

Based on the Mann-Whitney test, significant differences were observed in the perception of innovative, modern ways of reaching the customer among food and beverage producers. A *p*-value of less than 0.1 allowed the null hy-

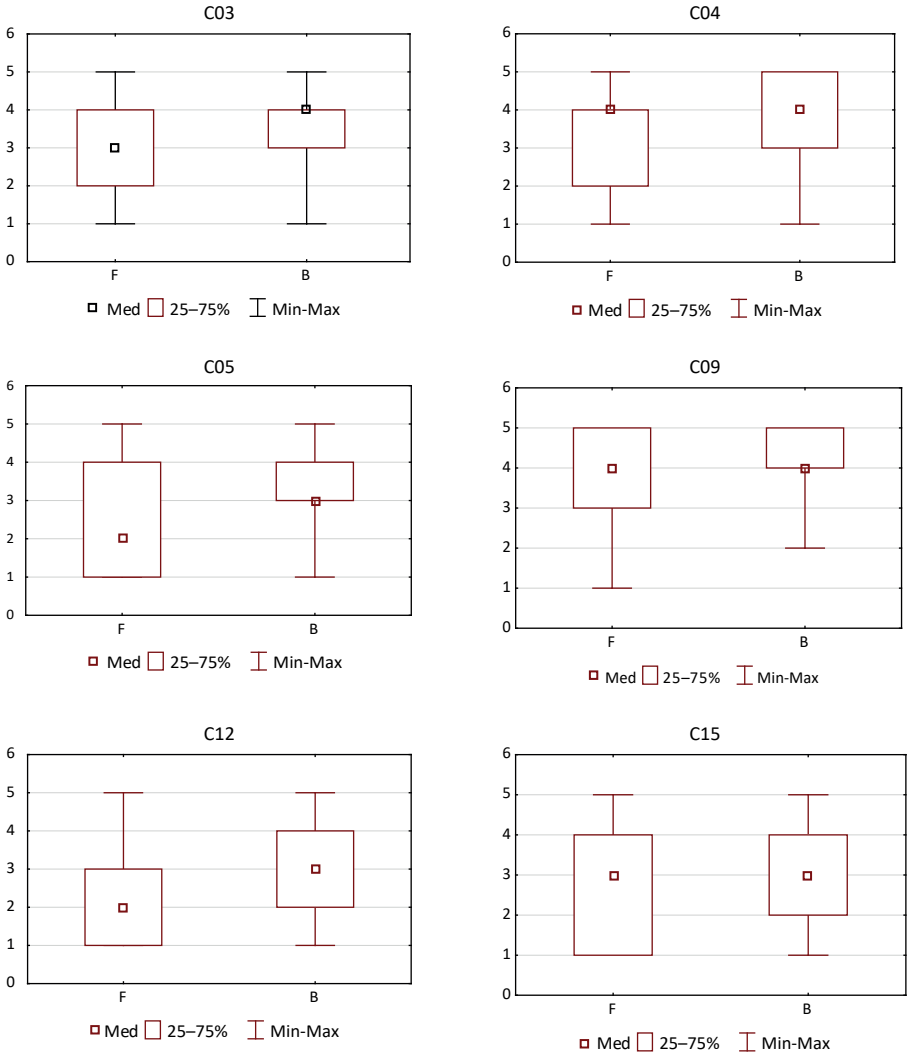


Figure 4. Box-plot charts by subsector

Note: F – food producers, B – beverage producers.

Source: own calculations based on research.

pothesis to be rejected in favour of the alternative hypothesis about the significance of differences between the ratings of this factor from both groups. Based on the arithmetic mean and positional measures presented in box-plot charts, it can be concluded that beverage producers attributed greater importance to innovative, modern ways of reaching the customer than food producers. The arithmetic mean of the grades in the first group was 4.16,

and the first quartile was 4. In the second group, the arithmetic mean of the grades was 3.59, and the first quartile was 3.

Moreover, based on the Kruskal-Wallis test, significant differences were observed in the perception of the importance of using IT systems among enterprises with a small, medium and large share of exports (*p*-value = 0.0233). The multiple comparison test does not clearly determine which groups have differences. However, based on the arithmetic mean and positional measures presented in the box-plot chart, it can be concluded that respondents representing enterprises with a small share of exports assigned the least importance to this factor (arithmetic mean 3.37, median 3).

3.2. Factors of medium importance in building international competitiveness

The study shows that, according to representatives of food industry enterprises, the average importance in building international competitiveness is played by innovative, modern management systems (C10), the implementation of packaging made from renewable or biodegradable raw materials (C04), computerisation of logistics (C08), and the creation of new technologies and techniques manufacturing, including automation (C06). The arithmetic mean of the ratings for the indicated factors was 3.22–2.34, and the median was 3–4. Respondents also assigned average importance to factors such as implementation of intelligent packaging (C03), implementation of innovative distribution methods (C13), use of innovative raw materials (e.g., spirulina, chia seeds) (C02), and the use of intelligent robots and machines (C07). Based on positional measures, it can be concluded that 50% of respondents rated these indicators at least 3, and 25% at least 4.

Table 4. Kruskal-Wallis test results and arithmetic mean by share of exports in sales (< 10%, 10–40%, > 40%)

Component	Export	Kruskal-Wallis test				Arithmetic mean
		sum of rank	mean of rank	H	*p*-value	
C01	< 10% 10–40% > 40%	60958.50 5512.50 4405.00	186.42 220.50 183.54	2.4910	0.2878	3.44 3.84 3.50
C02	< 10% 10–40% > 40%	61193.50 5408.00 4274.50	187.14 216.32 178.10	2.0049	0.3670	2.78 3.16 2.67

cont. Table 4

Component	Export	Kruskal-Wallis test				Arithmetic mean
		sum of rank	mean of rank	H	*p*-value	
C03	< 10% 10–40% > 40%	60979.00 5157.00 4740.00	186.48 206.28 197.50	0.9909	0.6093	2.99 3.24 3.13
C04	< 10% 10–40% > 40%	61593.50 5085.50 4197.00	188.36 203.42 174.88	0.8934	0.6397	3.30 3.48 3.13
C05	< 10% 10–40% > 40%	61466.50 4883.50 4526.00	187.97 195.34 188.58	0.1155	0.9439	2.47 2.60 2.50
C06	< 10% 10–40% > 40%	59802.50 5730.50 5343.00	182.88 229.22 222.63	7.1081	0.0286**	3.15 3.64 3.75
C07	< 10% 10–40% > 40%	59754.00 5218.00 5904.00	182.73 208.72 246.00	9.0475	0.0108**	2.55 2.92 3.42
C08	< 10% 10–40% > 40%	60239.00 5094.50 5542.50	184.22 203.78 230.94	4.8985	0.0864*	3.20 3.48 3.83
C09	< 10% 10–40% > 40%	60749.50 5403.50 4723.00	185.78 216.14 196.79	2.1075	0.3486	3.59 3.88 3.71
C10	< 10% 10–40% > 40%	60263.00 5317.00 5296.00	184.29 212.68 220.67	4.0719	0.1306	3.29 3.56 3.71
C11	< 10% 10–40% > 40%	59767.50 5565.00 5543.50	182.78 222.60 230.98	7.5213	0.0233**	3.37 3.72 3.92
C12	< 10% 10–40% > 40%	60391.00 5148.00 5337.00	184.68 205.92 222.38	3.6374	0.1622	2.39 2.72 2.83
C13	< 10% 10–40% > 40%	60723.00 5404.00 4749.00	185.70 216.16 197.88	2.1229	0.3460	2.95 3.28 3.08
C14	< 10% 10–40% > 40%	62228.50 4947.00 3700.50	190.30 197.88 154.19	2.8244	0.2436	3.43 3.44 3.04
C15	< 10% 10–40% > 40%	60392.50 5352.50 5131.00	184.69 214.10 213.79	3.2920	0.1928	2.48 2.88 2.83

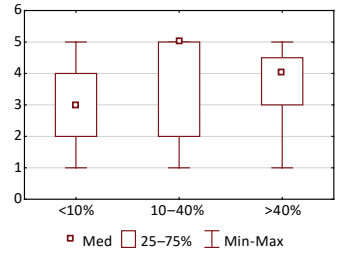
Note: ** and * significances at the 0.05 and 0.1 levels, respectively.

Source: own calculations based on research.

C06

Multiple comparison test (*p*-value)

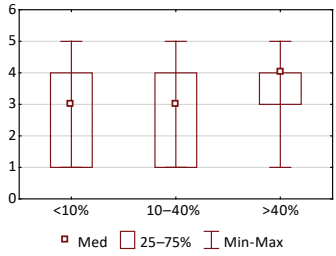
Export	< 10%	10–40%	> 40%
< 10%	–	0.12	0.25
10–40%	0.20	–	1.00
> 40%	0.25	1.00	–



C07

Multiple comparison test (*p*-value)

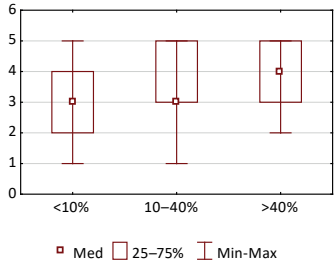
Export	< 10%	10–40%	> 40%
< 10%	–	0.75	0.018**
10–40%	0.75	–	0.69
> 40%	0.018**	0.69	–



C08

Multiple comparison test (*p*-value)

Export	< 10%	10–40%	> 40%
< 10%	–	1.00	0.13
10–40%	1.00	–	1.00
> 40%	0.13	1.00	–



C11

Multiple comparison test (*p*-value)

Export	< 10%	10–40%	> 40%
< 10%	–	0.23	0.11
10–40%	0.23	–	1.00
> 40%	0.11	1.00	–

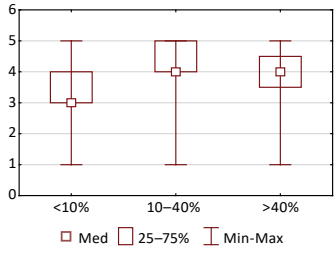


Figure 5. Multiple comparison test and box-plot charts by share of exports in sales (< 10%, 10–40%, > 40%)

Source: own calculations based on research.

The results of the Mann-Whitney test indicate differences in assessing the importance of implementing smart packaging and implementing packaging from renewable or biodegradable raw materials among food and beverage producers. The arithmetic mean and positional measures indicate that beverage producers rated the importance of both factors higher. Based on the Kruskal-Wallis test, significant differences were also observed in the perception of the importance of computerisation of logistics, the creation of new technologies and manufacturing techniques, including automation and the use of intelligent robots and machines, depending on the level of exports in the company's sales. The multiple comparison test indicates that in enterprises with a low proportion of exports, the importance of using intelligent robots and machines is significantly lower than in enterprises with a high share of exports. This is also confirmed by the box-plot plot. Positional measures also indicate that representatives of enterprises with a small share of exports attribute relatively less importance to the computerisation of logistics and the use of intelligent robots and machines in building international competitiveness.

3.3. Factors of low importance in building international competitiveness

In the study, respondents assigned the least importance to solutions such as the use of data mining analysis and the evaluation of large databases (C15), the use of nanotechnology in the creation of packaging (C05), and commencing cooperation with research centres (C12). The arithmetic mean of the ratings for the indicated factors was 2.44–2.53, and the median was 2–3. It is also worth emphasizing that these factors were characterised by the greatest diversity of responses. The coefficient of variation was 51.34–56.66%. The results of the Mann-Whitney test indicate differences in the assessment of the importance of the above factors among food and beverage producers. The arithmetic mean and positional measures indicate that their importance was rated higher by beverage producers. However, no statistically significant differences were found in the perception of these factors among enterprises with small, medium and large levels of exports.

4. Discussion

The results of the analysis confirm the observations of Muszyński and Muszyński (2018), according to which appropriate actions towards the recip-

ient contribute to increasing profits. According to Vecchio et al. (2022), the concept of customer relationship management (CRM) is becoming increasingly popular, in which a set of procedures and tools is used to build long-term relationships with customers. It is also noted that new or improved products meet the requirements of current and potential customers and ensure diversity of the offer (Hoonsopon & Ruenrom, 2012). Thanks to this, the company can expand its target audience, introduce new distribution channels, strengthen its market position, increase profitability and, consequently, improve its competitiveness (Li et al., 2012; Mu et al., 2009; Sethi & Sethi, 2009). The importance of information systems has been highlighted by Triantafyllou (2022), among others, according to whom such systems can help manage information from both the internal and external environment of the business and thus increase its efficiency and competitiveness. In turn, innovative methods of advertising and promotion help facilitate communicate with customers, change purchasing behaviour and increase competitive advantage (Ali & Maryam, 2012; Ulanat & Jacob, 2017).

In the literature on the subject, considerable attention is paid to innovations in production processes, mainly relating to new technologies and production techniques, including automation. According to Gunday et al. (2011), innovations of this type lead to an increase in total sales and exports and an increase in product innovation, and according to Gonzalez and Chacon (2014), also to an increase in the company's efficiency. According to Bahrin et al. (2016), introducing innovations in production processes in the food industry can involve loading/unloading, assembly, packaging, palletizing, pick-and-place, sorting, stacking and placing operations at very high speeds and significantly impact food safety and cleanliness, increasing resource efficiency, simplifying maintenance, and reducing human injuries. Some authors also emphasise the importance of intelligent solutions in the food industry. According to Barbara et al. (2022), the use of artificial intelligence reduces costs by optimizing operations and improves profitability. Artificial intelligence can detect, predict or diagnose undesirable situations in industrial systems, replace or reduce human controls in food production and delivery processes that are often unreliable and time-consuming (Kumar et al., 2021), and minimise downtime and the persistence of unsafe situations (Bécue et al., 2021). The use of smart sensors in food packaging has a positive impact on food safety and quality, and provides customers with appropriate information (Benharkat et al., 2023). It is also indicated that new innovative enrichment of food with nutritional values allows the creation of products that can meet the requirements of modern customers (Alawamleh et al., 2022). For many years, the literature on the subject paid much less importance to non-technological innovations (Juchniewicz, 2011). However, as the importance of knowledge increases and paradigms change, their role in the functioning of enterprises is increasingly recognised.

The literature on the subject recognises the potential of big data analytics, especially in the context of improving the operational efficiency of the food supply chain or understanding the market and consumer trends, as well as developing new products and services (Jagtap & Duong 2019; Kamilaris et al. 2017). Constantiou and Kallinikos (2015) show that a growing number of companies are accelerating the implementation of their big data analytics initiatives to develop critical insights that can ultimately provide them with a competitive advantage. In terms of nanotechnology, great potential is seen in food production. As indicated by Chausali et al. (2022), packaging based on nanotechnology enables safe transportation of food products without spoiling the taste, nutritional properties and quality, and also prevents contamination and sustains mechanical, physiological, physical and chemical properties of food products. According to Cerqueira et al. (2018), knowledge of the use of nanotechnology in food packaging is growing and is expected to have a significant impact on the operations of food companies in the future. The literature on the subject also indicates that cooperation with research units is particularly important for small and medium-sized enterprises because it provides an opportunity to implement research projects, transfer knowledge and gain an advantage on the market. As Milczarek and Gręboszk-Krawczyk (2019) point out, in practice, however, barriers to cooperation exist between entrepreneurs and representatives of science, and these are mainly of a communication nature, such as a negative image of science in the opinion of entrepreneurs or the perception of activities resulting from cooperation with scientists as not being significant for running a business.

To sum up, it can be noted that in the literature there are mentions of the positive impact of selected innovations and solutions of Industry 4.0 on the functioning and results of enterprises. This study confirms the importance of these elements for building the international competitiveness of food industry enterprises (in the opinion of their representatives). An important added value is also the creation of a ranking of the importance and gradation of these factors (high, medium, low importance).

Conclusions

The study fills the gap in the literature on the impact of innovations and solutions of Industry 4.0 on the international competitiveness of food industry enterprises. The study shows that, according to representatives of food industry companies, the use of some innovations and solutions of Industry 4.0 can significantly contribute to boosting the international competitiveness of this entities. This applies in particular to innovative, modern ways of reaching

the customer, developing innovative products, the use of IT systems and the use of innovative methods in advertising and promotion. According to the respondents, there is also the relationship between international competitiveness and such elements as innovative, modern management systems, implementation of packaging made of renewable or biodegradable raw materials, computerisation of logistics and the creation of new technologies and production techniques, including automation, implementation of intelligent packaging, implementation of innovative distribution methods, use of innovative raw materials, and the use of intelligent robots and machines. However, this relationship can be considered medium importance. In the study, the respondents attributed the least importance to solutions such as the use of data mining analysis and the evaluation of large databases, the use of nanotechnology in the creation of packaging, and the initiation of cooperation with research centres. It was also observed that innovative, modern ways of reaching the customer, implementing intelligent packaging, implementing packaging from renewable raw materials, using data mining analysis and evaluation of large databases, using nanotechnology in creating packaging and starting cooperation with research centres will be relatively more important for beverage producers than food producers. Moreover, in enterprises with a low importance of exports in their sales, relatively less importance in building international competitiveness was attributed to the use of IT systems, computerisation of logistics, and the use of intelligent robots and machines.

The research carried out here has not only cognitive but also practical value. The conclusions provide direct implications for managers of food enterprises who formulate competitive strategies. The primary message is that implementing innovations and solutions, both intangible and tangible, is important for maintaining and improving competitiveness on the international market. In particular, new solutions should concern practices related to reaching customers, promotion and advertising, products and computerisation. The study is important not only for companies operating on the foreign market, but also those on the domestic market when competing with food importers.

The study has some limitations. Firstly, it uses subjective and qualitative data based on surveys. To increase credibility, the study was conducted on a relatively large, representative group. Moreover, the analysis carried out does not take into account the full profile of the activities of food industry enterprises. For this reason, future research should be extended to include, for example, the age or size of the enterprise and/or should consider these factors simultaneously. The assessment of the innovations and solutions of Industry 4.0 presented here should be treated as part of research on the factors impacting international competitiveness of enterprises producing food and beverages and the entire food industry. Further research should also analyse other factors, including competitive potential, current food trends and contemporary economic processes.

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