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DIGITALIZATION: INTERCONNECTION WITH THE SCIENTIFIC AND RESEARCH SPHERE - ONE OF THE MAIN STRATEGIC DIRECTIONS OF QUALITY MANAGEMENT BY AGRICULTURAL LAND USERS

Abstract: *This paper aims at a quantitative and qualitative study of the advantages of digitalization for quality management by agricultural land users in view of the directions of modernization considering the specifics (favorability) of the conditions for agriculture. Originality and novelty of this research consists in its providing precise quantitative data on digitalization and analyzing its influence on agricultural products' quality with application of the mathematical tools. Detailed data on digitalization of agriculture and the components of quality of food products are used, which ensures the most precise, correct, and informative data. Also, differences between countries with unfavorable farming conditions and countries with favorable farming conditions are taken into account. This allows obtaining the fullest conclusions and compiling practice-oriented recommendations. It is proved that favorable conditions of the environment (positive influence of the natural and climate factors) reduce the value and need for digitalization. It is of the largest interest for countries with unfavorable conditions for farming and countries that have a deficit of food products – digitalization open for this countries a possibility of development of their own highly-efficient agricultural production.*

Keywords: *Quality; Digitalization; Strategic Management; Quality Management; Agricultural Land Users; Food Products; Food Security; Food Export and Import.*

1. Introduction

Food security is a priority for humans and the most important direction of state regulation of economy. The global importance of food security is emphasized and confirmed by its inclusion in the list of sustainable development goals, adopted by the United Nations (2020). These goals were supported by countries around the world and reflected in the national concepts of the long term socio-economic development. Though provision of food security is indirectly connected to most of the goals of sustainable development, it is formulated and envisaged in Goal 2 "Zero hunger", which envisages development of food and agricultural sector of economy for the purpose of fighting hunger and poverty.

A guarantee of food security in the present and the future is increase of quality of food products, which should be achieved primarily in agriculture (and then in the agricultural complex on the whole). During the whole history of humanity, quality and accessibility (by quantity and price) of food were largely determined by the influence of the natural and climate factors, which predetermine

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instability of agriculture and limited opportunities of quality management by agricultural land users.

Formation of market relations and marketization of agriculture improved the practice of quality management by agricultural land users in countries with developing and transition economies in the recent decades. The advantages for quality were achieved due to increase of flexibility of business processes, motivation and stimulation of labor, and, as a result, increase of efficiency. However, the potential of the market mechanism in stimulating the increase of quality of agricultural products has been depleted.

Technological progress in developed countries allowed reducing the dependence of agriculture on the natural and climate factors and expanded the opportunities of quality management by agricultural land users. That's why perspectives of provision of food security in the modern science and practice are usually connected to further digitalization and expansion of the use of its capabilities. Though in the existing works and publications scholars agree regarding the necessity for digitalization of agriculture, the scientific knowledge on this topic has certain gaps, which hinder the practical application of digital technologies in agriculture for the purpose of increase of quality of food products.

One of the gaps is limitation of literature sources by acknowledgment of the necessity for digitalization with the foundation on expert opinions. Without a precise quantitative measuring, the view of perspectives of digitalization of agriculture remains generalized. The consequences of digitalization for quality of agricultural products could be weak, not justifying the expenditures for modernization of technologies and equipment. Absence of solid scientific proofs restrains the implementation of the leading technologies by agricultural land users, which experience the deficit of financial resources.

The gaps also include uncertainty regarding the sources of creation of advantages for quality of agricultural products by means of digitalization. Digitalization includes several directions of quality management by agricultural land users, which could be very detailed. For achieving high effectiveness of digital modernization of quality management by agricultural land users, it is necessary to determine strategic (ensuring the largest advantages for quality) and additional (generating the least advantages for quality) directions of digitalization. Comprehensive (without differentiation of directions) digitalization could be inaccessible (due to deficit of resources) and ineffective in agriculture.

Another gap is connected to insufficient attention to the specifics of the agricultural land users' activities. In countries with favorable conditions for farming (positive influence of the natural and climate factors), it is expedient to perform robotization of the production processes for growth of efficiency. In countries with unfavorable conditions for farming (negative influence of the natural and climate factors), it is necessary to develop "smart" productions with authomatization of all business processes, for starting agriculture "from scratch". In particular, these could be draught-affected territories or northern territories, where agriculture was traditionally considered impossible and where food was always imported.

This work is to fill the above gaps. The goal is to perform a quantitative and qualitative study of the advantages of digitalization for quality management by agricultural land users in view of the directions of modernization considering the specifics (favorability) of the conditions for agriculture. The working hypothesis of the research is that interconnection with the scientific and research sphere and education is one of the main strategic directions of quality management by agricultural land users based on digitalization.

Originality and novelty of this research consists in its providing precise quantitative data on digitalization and analyzing its influence on agricultural products' quality with application of the mathematical tools. Detailed data on digitalization of agriculture and the components of quality of food products are used, which ensures the most precise, correct, and informative data. Also, differences between countries with unfavorable farming conditions and countries with favorable farming conditions are taken into account. This allows obtaining the fullest conclusions and compiling practice-oriented recommendations.

This work consists of the following parts: introduction, literature overview, materials and methodology, results, and conclusions. The main part "Results" consists of the following parts: 1) components of quality of food products and sources of its increase based on the corresponding directions of digitalization; 2) Scenarios of quality management by agricultural land users depending on digitalization in the global economy in the period until 2024; 3) Strategic foundations of quality management by agricultural land users based on optimization of the initiatives in the sphere of digital modernization.

2. Literature Review

The topic of digitalization of agriculture and transition to Agriculture 4.0 is studied in the works Bratukhina et al. (2020), Popkova et al. (2017), Shahin (2019), Sozinova (2018), Stolyarov et al. (2020).

Sagarna Garcia and Pereira Jerez (2019) consider agri-food projects and perform analysis of the procedures within the digital revolution. Trivelli et al. (2019) deem it necessary to for precision agriculture to perform a transition to Industry 4.0 and determine and substantiate the presence of technological ties in the agri-food sector.

Quality of food products, its essence, and components are studied in the following works. Yormirzoev et al. (2019) opposes quality of food products to food patriotism by the example of Russian consumers' preferences in cheese, after a ban on import of food products. Chen and Lee (2018) state that clothing of a restaurant's employees influences the consumers' opinion of quality of food.

Emond and Taylor (2018) note the importance of measuring safety of food products and development of the culture of food quality (providing the results of a global survey on training in agriculture). Sadílek (2019) describes consumer preferences in quality labels of food products (by the example of the Czech Republic). Brečić et al. (2017) note the importance of the characteristics of internal and external quality of food products in various segments of consumers. Kölzer et al. (2019) think that consumers' influence on quality of frozen food is high (by the example of Germany).

The theoretical and methodological foundations and applies issues of quality management by agricultural land users are shown in the works Cheglakova et al. (2019), Soboleva et al. (2017a), Soboleva et al. (2017b), and Sofiina (2020). Maseta et al. (2017) offer a methodology of evaluation of nutrition value of protein supplements based on corn. Song et al. (2017) perform an evaluation of influence of management of quality of supply chain on the efficiency of food companies and note the positive intermediary role of certification and reputation of food products.

Psomas et al. (2018) think that the cost of measuring the quality in food companies could be high, which reduces the effectiveness of quality management (by the example of Greece). Siddh et al. (2017) study the quality of supply chain of fresh agricultural products. Siddh et al. (2018) offer a structural model of quality of the supply chain of perishable food products for improving a company's sustainable activities.

Hong et al. (2020) recommend managing the quality of supply chain for increasing the effectiveness of companies in food industry and note the restraining role of social joint regulation (based on the data from China).

Significance of quality management by agricultural land users for provision of food security is emphasized in the following works. Adeyeye (2017) points out the important role of technologies of processing and storing of food products in provision of food security and accessibility of food products (by the example of Africa). Momanyi et al. (2019) notes the gaps in food security, consumption of food products, and malnutrition in households along the baobab belt (by the example of Kenya).

Ferjani et al. (2018) offer a methodological approach to evaluation of the agriculture's contribution to food security with the help of the system of decision support on the strategy of food security (approbated by the example of Switzerland). Blades (2017) analyzes Routledge guide on food safety. Chhikara et al. (2019) study the nutrition and phytochemical potential of sorgo in food industry for provision of food security.

Fan et al. (2017) connect food security and quality of nutrition in the urbanizing world based on the 2017 Global food policy report. Gilmour (2019) enumerates the future challenges and achievements of food safety (by the example of China). Yahaya et al. (2018) consider the sustainable practice of intensification of agriculture for the purpose of provision of food safety in rural regions to be necessary (by the example of Northwestern Ghana).

Thus, the performed literature review has shown that thematic spheres of the set problem are studied in detail, but separately – which creates certain gaps at the junction of the spheres of knowledge. The first gap is insufficient quantitative description of quality of agricultural products and domination of descriptive studies over the work with data on the topic of quality management by agricultural land users. The second gap is the "narrow" and generalized treatment of digitalization and the absence of its connection to quality management by agricultural land users, as well as generalized study of agricultural products' quality.

The third gap is deficit of researchers' attention and poor elaboration of the specifics of quality management by agricultural land users in countries of the world depending on favorability of the conditions for farming. This paper aims at filling the described gaps. The advantage of this paper is high detalization and the systemic research of quality management by agricultural land users and the perspectives of its improvement based on digitalization depending on favorability of the farming conditions.

3. Materials and methodology

For obtaining the most detailed and correct results, the research objects for this research are countries that are classified into two categories by the criterion of favorability of farming conditions:

- Food importers – countries with unfavorable farming conditions, due to the negative influence of the natural and climate factors, which causes a deficit of food and aggravates the problem of food security;
- Food exporters – countries with favorable farming conditions, due to the positive influence of the natural and climate factors, which leads to excess of food, stimulates its export, and decreases the problem of food security.

The volume of food import in countries of the first category and the volume of food export in countries of the second category are shown (by the example of the world's largest exporters and importers of food) in Figure 1.

Figure 1. Volume of food export and import in the world's largest food importers and exports, USD billion

Source: compiled by the authors based on Humboldt (2020), Mapsofworld (2020)

As shown in Figure 1, by the volume of import among the countries of the first categories, the largest values are observed in China (USD 160 billion) and USA (USD 149 billion); the lowest food import among top countries is observed in Russia (USD 28 billion). The largest food exporters are the Netherlands (USD 94 billion) and Germany (USD 86 billion), and the lowest volume of food export among top countries is observed in Belgium (USD 44 billion).

As for the information and empirical basis of this research, it should be noted that there is a deficit of data on the topic of quality of food products. The key source of statistics on this topic is Food Security Report, which is published annually by The Economist Intelligent Unit and which contains detailed information on food security of most countries of the world. The data are divided into three logical parts: quantitative accessibility, pricing accessibility, quality and safety.

Information that is the most valuable for this research could be found in the part of quality and safety; it characterizes nutrition value of food products: accessibility of micro-elements, quality of protein, and food safety. That's why the above indicators are used here. The sources of increase of quality of food products based on digitalization are the indicators from World Digital Competitiveness Ranking, which is published annually by IMD:

- Interconnection with the scientific and research sphere and education (indicator "Knowledge");
- Infrastructural provision of innovations and digitalization (indicator "Technology");
- Systemic digitalization of production and distribution (indicator "Future readiness").

The initial data for the research on the largest food importers and food exporters as of 2020 (by the results of 2019) are shown in Table 1.

Table 1. Components of food quality and sources of its increase based on digitalization in top countries in 2020.

Category	Country	Sources of increase of quality based on digitalization, points 1-100			Components of quality of food products, %		
		nterconnection with the scientific and research sphere and education	nfrastructural provision of innovation and digitalization	Systemic digitalization of production and distribution	Accessibility of micro-elements	Quality of protein	Food safety
-	-	Knowledge	Technology	Future readiness	Micronutrient availability	Protein quality	Food safety
		x_1	x_2	x_3	y_1	y_2	y_3
Food importers	China	78.067	72.856	80.743	66.0	67.3	95.0
	USA	90.998	89.364	98.427	73.6	85.8	99.5
	Japan	74.687	75.080	77.347	61.6	71.7	99.3
	South Korea	83.360	79.658	89.662	68.1	77.2	99.9
	India	63.721	54.978	54.946	40.5	18.3	92.8
	Mexico	53.505	53.589	52.930	71.0	59.4	99.5
	Russia	75.017	58.451	56.539	72.7	71.8	98.0
Food exporters	Netherlands	81.807	88.413	91.352	71.8	91.0	100.0
	Germany	83.072	71.008	83.358	70.1	75.5	100.0
	Brazil	45.742	49.166	55.919	72.6	79.3	98.7
	France	76.024	80.265	70.066	74.9	84.3	100.0
	Spain	70.906	72.177	71.935	67.7	78.8	99.9
	Canada	87.849	80.633	82.816	77.3	77.5	99.6
	Belgium	74.990	75.717	75.554	71.5	73.2	100.0

Source: compiled by the authors based on The Economist Intelligence Unit (2020), IMD (2020)

The research methodology is based on the mathematical tools of economics. Contribution of the described sources to increase of quality of food products based on the digitalization directions is determined with the use of regression analysis. Equations of multiple linear regression are compiled, in which the resulting variables (y) are the components of food products' quality, and the factor variables (x) are sources of increase of quality based on digitalization.

Scenarios of quality management by agricultural land users depending on digitalization in the global economy in the period until 2024 are determined based on the obtained equations of regression. Direct average and standard deviations are calculated for factor variables (x) from Table 1. Based on them, 100 random numbers are generated, and histograms of their normal distribution are built, which reflect the values and their probability. Then the values are put into regression equations to form the most

probable (from the values with the highest probability) and optimal (from the values that maximize growth of dependent variables) scenario.

4. Results

4.1 Components of quality of food products and sources of its increase based on the corresponding directions of digitalization

Dependencies of the components of food products' quality on the sources of its increase based on digitalization in top countries by food export and import in 2020 are shown in Figures 2-4.

As shown in Figure 2, in countries that import food, increase of the level of interconnection with the scientific and research sphere and education by 1 point leads to increase of accessibility of micro-elements by 0.09%. Increase of the level of development of the infrastructural provision of innovations and digitalization by 1 point leads to increase of accessibility of micro-elements by 0.94%. Increase of the level of systemic digitalization of production and distribution by 1 point leads to decrease of accessibility of micro-elements by 0.53%.

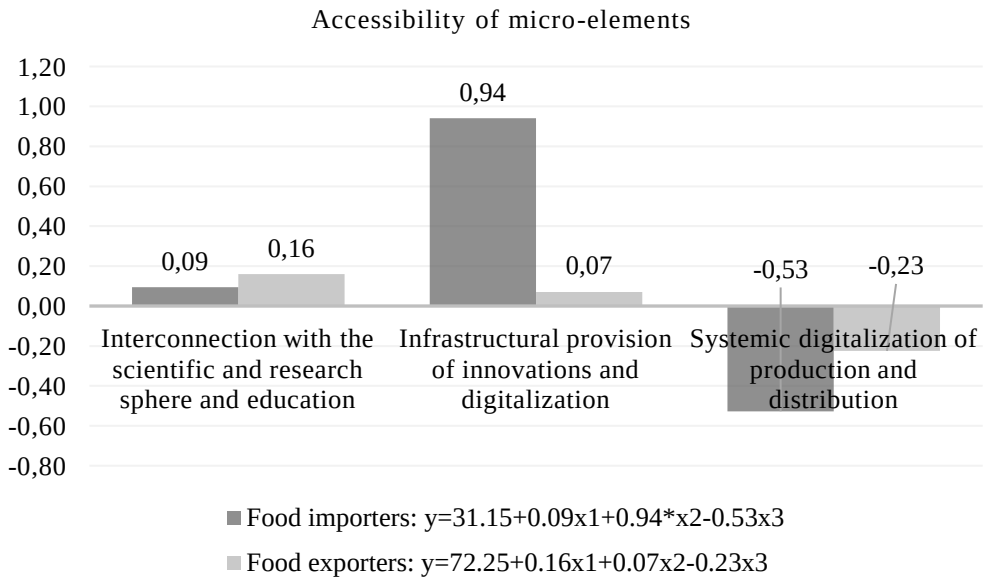

Figure 2. Regression dependence of accessibility of micro-elements on digitalization, %.
Source: calculated and compiled by the authors.

In countries that export food, increase of the level of interconnection with the scientific and research sphere and education by 1 point leads to increase of accessibility of micro-elements by 0.09%. Increase of the level of development of the infrastructural provision of innovations and digitalization by 1 point leads to increase of accessibility of micro-elements by 0.94%. Increase of the level of systemic digitalization of production and distribution by 1 point leads to decrease accessibility of micro-elements by 0.53%.

Therefore, the largest perspectives for increase of accessibility of micro-elements in countries that import food are connected to development of the infrastructural provision of innovations and digitalization.

As shown in Figure 3, in countries that import food, increase of the level of interconnection

with the scientific and research sphere and education by 1 point leads to increase of quality of protein by 0.22%. Increase of the level of development of the infrastructural provision of innovations and digitalization by 1 point leads to increase of quality of protein by 3.15%. Increase of the level of systemic digitalization of production and distribution by 1 point leads to decrease of quality of protein by 1.66%.

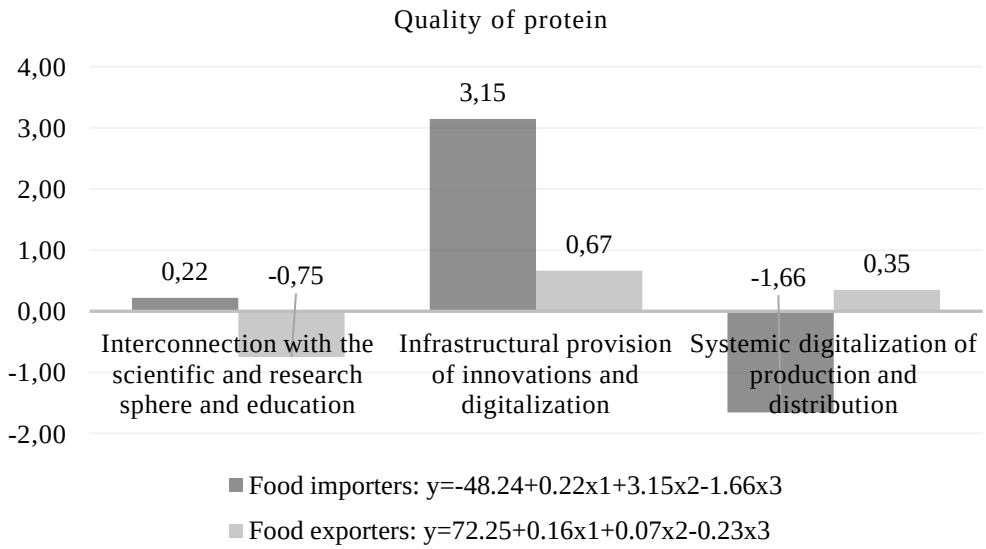

Figure 3. Regression dependence of quality of protein on digitalization, %.
Source: calculated and compiled by the authors

In countries that export food, increase of the level of interconnection with the scientific and research sphere and education by 1 point leads to decrease of quality of protein by 0.75%. Increase of the level of development of the infrastructural provision of innovations and digitalization by 1 point leads to increase of quality of protein by 0.67%. Increase of the level of systemic digitalization of production and distribution by 1 point leads to increase of quality of protein by 0.35%.

Therefore, the largest perspectives of increase of quality of protein in countries that import food are connected to development of the infrastructural provision of innovations and digitalization.

As shown in Figure 4, in countries that import food, increase of the level of interconnection with the scientific and research sphere and education by 1 point leads to decrease of food safety by 0.15%. Increase of the level of development of the infrastructural provision of innovations and digitalization by 1 point leads to increase of food safety by 0.71%. Increase of the level of systemic digitalization of production and distribution by 1 point leads to decrease of food safety by 0.38%.

In countries that export food, increase of the level of interconnection with the scientific and research sphere and education by 1 point leads to increase of food safety by 0.26%. Increase of the level of development of the infrastructural provision of innovations and digitalization by 1 point leads to decrease of food safety by 0.17%. Increase of the level of systemic digitalization of production and distribution by 1 point leads to decrease of food safety by 0.18%.

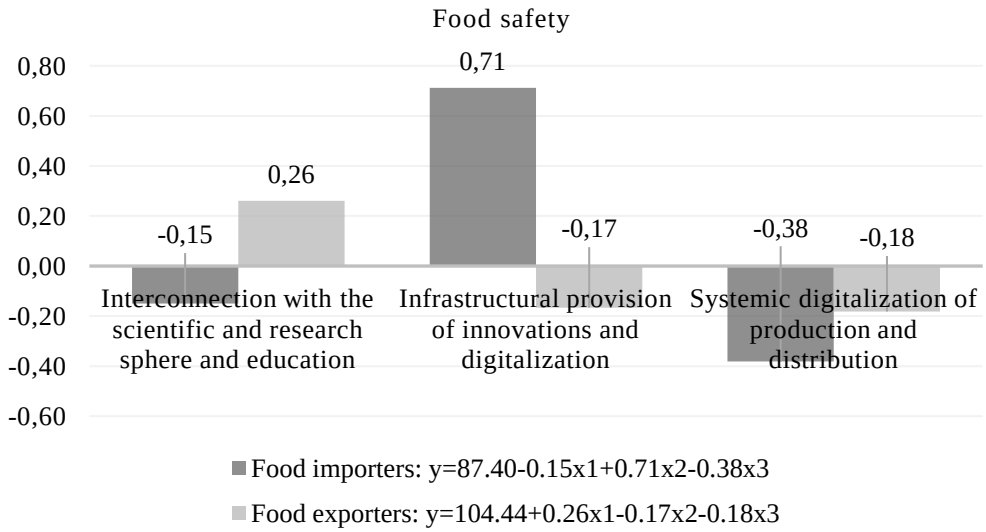

Figure 4. Regression dependence of food safety on digitalization, %.
Source: calculated and compiled by the authors

Therefore, the largest perspectives for increase of food safety in countries that import food are connected to development of the infrastructural provision of innovations and digitalization. Average regression dependencies of food quality and digitalization are shown in Figure 5.

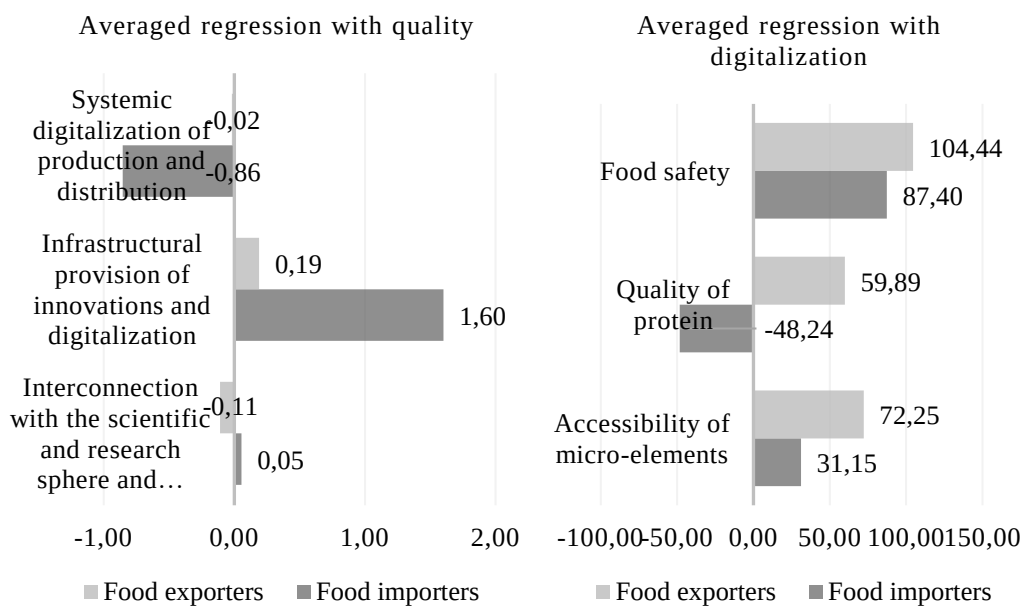

Figure 5. Average regression dependencies of food quality and digitalization, %.
Source: calculated and compiled by the authors

As shown in Figure 5, the key source of increase of quality of food products (in the unity of all components of nutrition value) based on digitalization is infrastructural provision of innovations and digitalization. Average regression of this source with quality in countries that export food constitutes 0.19%, and in countries that import food – 1.60%.

The perspectives for increase of food safety based on digitalization are very wide: average regression in countries that export food constitutes 104.44%, and in countries that import food – 87.40%. Quality of protein could be increase by means of digitalization only in countries that export food (average regression – 59.89%). Accessibility of micro-elements also could be increased due to digitalization: average regression in countries that export food constitutes 72.25%, and in countries that import food – 31.15%

4.2 Scenarios of quality management by agricultural land users depending on digitalization in the global economy in the period until 2024

In order to compile future scenarios of quality management by agricultural land users depending on digitalization in the global economy, let us use the forecast values of the sources of increase of quality based on digitalization in the period until 2024 (based on the data from Table 1) in food importers (Figure 6) and food exporters (Figure 7).

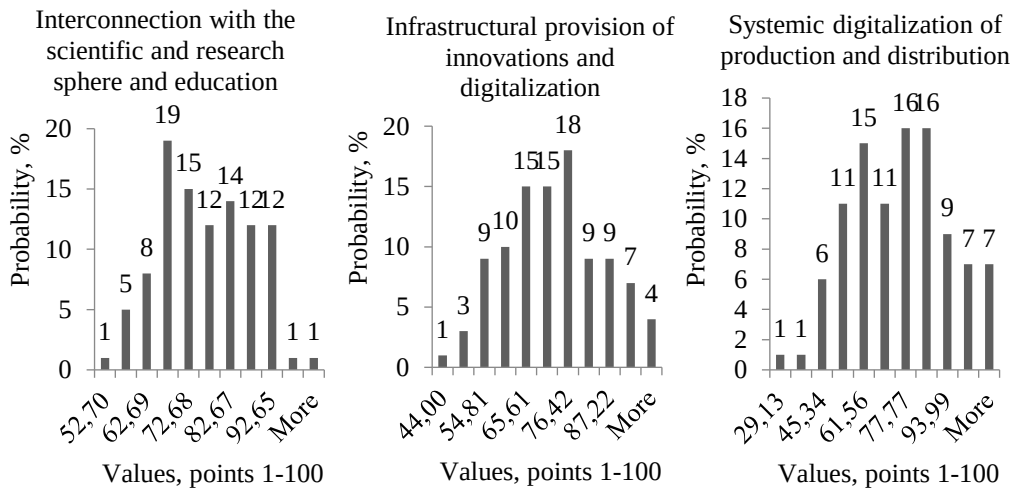

Figure 6. Histograms of normal distribution of forecast values of the sources of increase of quality based on digitalization in countries that import food in the period until 2024.
Source: calculated and compiled by the authors

Based on the data from Table 1, it has been calculated that in countries that import food the interconnection with the scientific and research sphere and education in 2020 constitutes 74.19 points (standard deviation - 12.38 points) on average. The most probable (probability - 19%) forecast value of this indicator constitutes 67.68 points, and the optimal value among the most probable values (probability - 12%) – 92.65 points. Infrastructural provision of innovations and digitalization constitutes 69.14 points (standard deviation – 13.70 points) on average. The most probable (probability - 18%) forecast value of this indicator constitutes 76.42 points, and the optimal value among the most probable values (probability - 7%) – 92.63 points. Systemic

digitalization of production and distribution constitutes 72.94 points (standard deviation – 18.27 points) on average. The most probable (probability - 16%) and optimal forecast values of this indicator coincide, constituting 77.77 points.

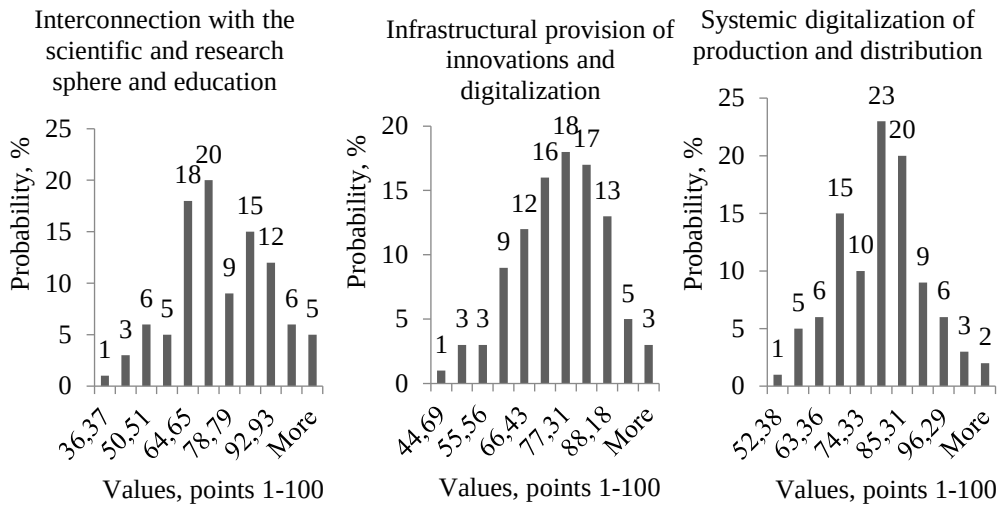

Figure 7. Histograms of normal distribution of the forecast values of quality increase based on digitalization in countries that export food in the period until 2024.
Source: calculated and compiled by the authors

Based on the data from Table 1, it has been calculated in in countries that import food in 2020 the interconnection with the scientific and research sphere and education constitutes 74.34 points (standard deviation – 13.83 points) on average. The most probable (probability - 20%) and optimal forecast values of this indicator coincide, constituting 71.12 points.

Infrastructural provision of innovations and digitalization constitutes 73.91 points (standard deviation - 12.40 points) on average. The most probable (probability - 18%) forecast value of this indicator constitutes 77.31 points, and the optimal value among the most probable values (probability - 13%) – 88.18 points. Systemic digitalization of production and distribution constitutes 75.86 points (standard deviation – 11.48 points) on average. The most probable (probability - 23%) and optimal forecast values of this indicator coincide, constituting 79.82 points.

By putting the selected forecast values of the factor variables in regression curves in Figures 2-4, the following scenarios of quality management by agricultural land users depending on digitalization in the period until 2024 are compiled (Table 2).

For better representation, the main results of the scenario analysis from Table 2 are presented in Figure 8-9.

As shown in Figure 8, in countries that import food in the period until 2024 the interconnection with the scientific and research sphere and education should grow by 24.88%, infrastructural provision of innovations and digitalization by 33.98%, and systemic digitalization of production and distribution – by 6.62%. Due to this, accessibility of micro-elements will grow by 32.9% (up to 86.1%), quality of protein will grow by 108.4% (up to 134.42%), and food safety will grow by 12.41% (up to 109.84%).

Table 2. Scenarios of quality management by agricultural land users depending on digitalization in the period until 2024.

Category	Variable	Basic value in 2020	The most probable scenario		Optimal scenario	
			Value according to scenario in 2024	Growth in 2024, %	Value according to scenario in 2024	Growth in 2024, %
Food importers	x_1	74.19	67.88	-8.51	92.65	24.88
	x_2	69.14	76.42	10.53	92.63	33.98
	x_3	72.94	77.77	6.62	77.77	6.62
	y_1	64.79	68.50	5.73	86.10	32.90
	y_2	64.50	78.03	20.98	134.42	108.40
	y_3	97.71	102.01	4.39	109.84	12.41
Food exporters	x_1	74.34	71.12	-4.33	71.12	-4.33
	x_2	73.91	77.31	4.60	88.18	19.31
	x_3	75.86	79.82	5.22	79.82	5.22
	y_1	72.27	71.10	-1.61	71.87	-0.56
	y_2	79.94	86.01	7.59	93.26	16.66
	y_3	99.74	95.59	-4.16	93.79	-5.97

Source: calculated and compiled by the authors

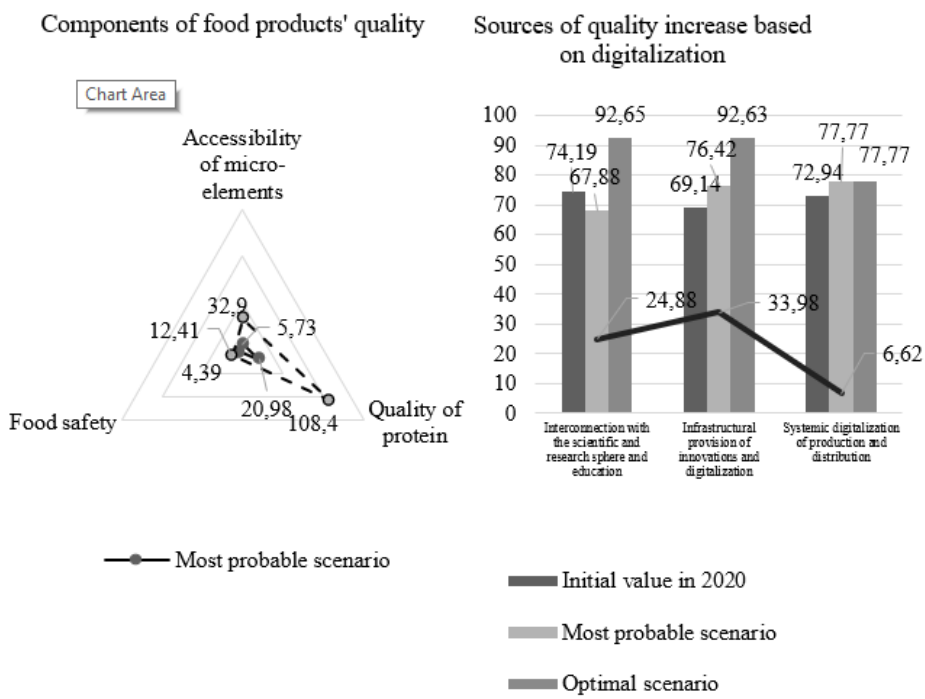

Figure 8. Scenarios of increase of food products' quality based on digitalization in countries that import food in the period until 2024.

Source: calculated and compiled by the authors

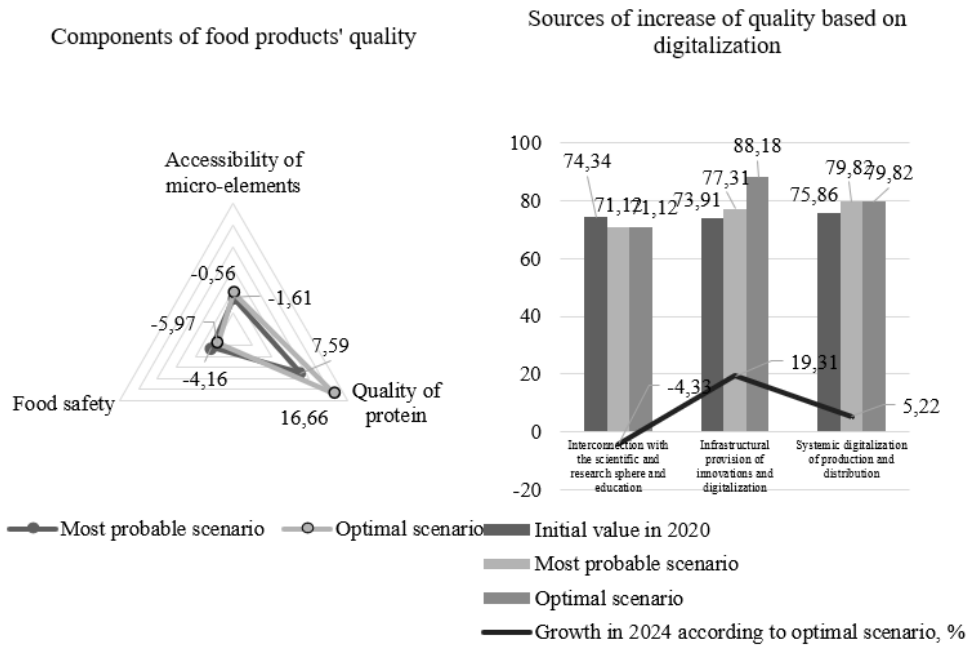

Figure 9. Scenarios of increase of food quality based on digitalization in countries that export food in the period until 2024.
Source: calculated and compiled by the authors

As shown in Figure 9, in countries that export food in the period until 2024 the interconnection with the scientific and research sphere and education should decrease by 4.33%, infrastructural provision of innovations and digitalization should grow by 19.31%, and systemic digitalization of production and distribution should grow by 5.22%. Due to this, accessibility of micro-elements will decrease by 0.56%, constituting 71.87%. Quality of protein will grow by 16.66% (up to 93.26%), and food safety will decrease by 5.97%, constituting 93.79%.

Thus, in countries that export food the opportunities for increase of food quality in the aspect of nutrition value based on digitalization are limited and contradictory. In countries that import food these opportunities are vivid and therefore are recommended for practical implementation.

4.3 Strategic foundations of quality management by agricultural land users based on optimization of initiatives in the sphere of digital modernization

In order to form a systemic idea of the perspectives of increase of quality of food products, let us consider the advantages of digitalization for quality in the expanded treatment, which is not limited by food value and which covers other, rather significant components (Table 3).

Nutrition value before digitalization of agriculture and in case of refusal from it is standard, with the risk of deficit of water and fertilizers due to insufficient control. In digital agriculture, it is increased due to precision irrigation, fertilization, and “smart” growing of each plant. Digitalization is especially useful for countries that import food, for it allows developing highly-efficient agriculture even on the territories with unfavorable farming conditions (influence of the natural and climate factors is negative).

Table 3. Advantages of digitalization for increase of quality of food products in the expanded treatment.

Expanded list of the components of food products' quality	Quality and food security:	
	Before digitalization and in case of refusal from it	In digital agriculture
Nutrition value	standard, with risk of deficit of water and fertilizers due to insufficient control	increased due to precision irrigation, fertilization, and "smart" growing of each plant
Corporate control of quality in production	fragmentary	full based on the Internet of Things, ubiquitous computing, Big Data, and AI
Sorting	slow and complicated	accelerated and simplified ("smart" sorting)
Marking and sales	manual marking and sales	use of RFID-technologies for convenience of sales and provision of full information on all products
Guarantee of ecological safety (certification)	from seller's words	with digital confirmation and possibility of remote inspection
Quality assurance	testing of samples (nitrates, pesticides, etc.)	digital information on the whole chain of added value is available
State control of quality	difficult, only selective inspections are possible	simplified, intellectual monitoring with full coverage of agriculture is possible

Source: developed and compiled by the authors

Corporate control of quality in production before digitalization of agriculture and in case of its refusal is fragmentary. In digital agriculture, it is full based on the Internet of Things, ubiquitous computing, big data, and AI. Sorting before digitalization of agriculture and in case of refusal from it is slow and complicated. In digital agriculture, it is quick and simplified ("smart" sorting).

Marking and sales before digitalization of agriculture and in case of refusal from it are performed with the use of manual labor. In digital agriculture, application of RFID-technologies for convenience of sales and provision of full information on all products is envisaged. Guarantee of ecological safety (certification) before digitalization of agriculture and in case of refusal from its takes place according to information provided by the seller. In digital agriculture – with digital conformation and possibility of remote inspection.

Quality assurance before digitalization of agriculture and in case of refusal from it envisages testing of samples (nitrates, pesticides, etc.). In digital agriculture, digital information on the whole chain of added value is available. State control of quality before digitalization of agriculture and in case of refusal from it is complicated, for only selective inspections are available. In digital agriculture, it is simplified, with intellectual monitoring with full coverage of agriculture.

Strategic foundations of quality management by agricultural land users based on optimization of initiatives in the sphere of digital modernization, according to the data from Table 2, are based on development of the infrastructural provision of innovations and digitalization. However, it should be noted that development of infrastructure, on the one hand, is performed by state regulators and thus depends on availability of assets in the state (federal) budget. On the other hand, it depends on the macro-economic situation, in particular on investment attractiveness of economy. For agricultural land users, infrastructural provision of innovations and digitalization is uncontrollable.

A more attractive and accessible alternative for corporate management, which is especially interesting in countries that import food, is development of interconnection with agricultural land users and the scientific and

research sphere and education. Implementation of this direction will allow training digital agricultural personnel based on corporate training and forming the basis for the next stage – systemic digitalization of production and distribution of food based on the progressive infrastructure.

Close interconnection between agricultural land users and the scientific and research sphere and education could be achieved by means of creation of food clusters with participation of universities, as well as formation of technological parks in the agrarian sphere of economy. Due to this interconnection, agricultural land users will receive access to the leading technologies and digital personnel, which allow for high innovative activity and which can use the advantages of digital technologies.

5. Conclusion

The following conclusions are made as a result of the performed research. Digitalization opens wide perspectives for increasing food products' quality. It has been shown – by the example of nutrition value, as the most important component of food products' quality – that digitalization allows increasing food safety (from 87.40% to 104.44%), quality of protein (by 59.89% on average), and accessibility of micro-elements (from 31.15% to 72.25%).

Countries that export food need digitalization to a lesser extent, for they have surplus of food and their food's quality is higher (accessibility of micro-elements on average in 2020 constitutes 72.27%, quality of protein – 79.94%, and food safety – 99.74%), than countries that import food (accessibility of micro-elements on average in 2020 constitutes 64.79%, quality of protein – 64.50%, and food safety – 97.71%).

Due to digitalization of the activities of agricultural land users in countries that import food in the period until 2024, there is a 11.66% probability of achievement of a vivid growth of food products' quality by means of increase of its nutrition value. According to the compiled forecast, accessibility of micro-elements will grow by 24.88%, quality of protein – by 33.98%, and food safety – by 6.62%.

The most perspective sources of increase of quality (nutrition value) of food products in countries that import food are development of the infrastructural provision of innovations and digitalization (average regression – 1.60%). Increase of interconnection between the scientific and research sphere and education is also in demand (average regression – 0.05%). This confirms the working hypothesis of the research – interconnection between the scientific and research sphere and education based on digitalization is one of the main strategic directions of quality management by agricultural land users.

The contribution of the performed research to development of economics consists in provision of the precise quantitative proofs of a large potential of digitalization in stimulation of growth of quality of agricultural products. The structure of quality of agricultural products is specified; nutrition value has the key role in it. It has been taken as an example for a research in view of its components. The digital sources of increase of quality of agricultural products are also differentiated and classified by the level of significance.

The theoretical value of the obtained results and conclusions consist in determining large differences in contribution of digitalization to increase of quality of agricultural products in countries that export and import food. It has been proved scientifically that favorable conditions of the environment (positive influence of the natural and climate factors) reduce the value and need for digitalization. It is of the utmost interest for countries with unfavorable conditions for farming and with deficit of food products – for them digitalization opens a possibility for developing their own highly-efficient agricultural production.

The practical significance of the research is explained by the fact that the obtained quantitative results are supplemented by a qualitative analysis. Thus it has been determined that despite the largest significance of infrastructural provision of innovations and digitalization for quality, the main strategic direction of quality management by agricultural land users is establishment of closer interconnection between the scientific and research sphere and education. This direction of digitalization is very perspective, for it is accessible for practical implementation by agricultural land users and does not require the direct participation of government and external subjects (e.g., foreign investors).

The empirical value of the research consists in development of the authors' practice-oriented recommendations for strengthening of the interconnection between the scientific and research sphere and education and agricultural land users within the strategic management of products' quality. Also, the stages of practical implementation of the strategic directions of management of agricultural products' quality have been specified.

After implementation of the main direction – strengthening of the interconnection between agricultural land users and the scientific and research sphere and education – two other strategic directions should be implemented: development of the infrastructural provision of innovations and digitalization and systemic digitalization of production and distribution of agricultural products. The determined algorithm opens a possibility for developing the corporate strategies and national "road maps" of managing the quality of agricultural products based on optimization of the initiatives in the spheres of digital modernization.

It should be concluded that advantages of digitalization for increase of food products' quality in the expanded treatment are based on the authors' expert evaluation – because of unavailability of the necessary statistical data. The research limitation by study of the advantages of digitalization for nutrition value of food products is a forced limitation of this research.

For obtaining more precise data on the topic of strategic management of quality by agricultural land users based on optimization of the initiatives in the sphere of digital modernization, more detailed statistical data are required, which – in case of impossibility of their obtaining – could be replaced with analytical data (materials of sociological and expert surveys). Collection of the lacking data on the topic of strategic quality management by agricultural land users based on digitalization and their analytics should be conducted in further studies in continuation of this work.

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