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INNOVATIVE PROCESSES' MANAGEMENT IN AGRICULTURE AND FOOD SECURITY: DEVELOPMENT OPPORTUNITIES

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Abstract. In this paper, the dynamics of the food independence of the Republic of Kazakhstan have been analyzed, and its quantitative assessment has been made. The results of the study show that over the years of its independence, Kazakhstan has made some progress in strengthening the country's food security. At present, the malnutrition among the population of Kazakhstan is considerably lower than that of other countries in the Central Asian region and is at the same level as in economically developed countries. At the same time, the study results show that there are problems in the country: the actual consumption of the most important food remains extremely low in relation to the determined standards. In general, 2013 – 2017 display positive dynamics of the food independence, and the indicators of crop yields sustainably grow. In many ways, this has become possible due to the introduction of innovative technologies in the agricultural production of the Republic of Kazakhstan. However, despite the growth of the innovative activity of agricultural enterprises, the level of development and implementation of agricultural technologies in Kazakhstan remains extremely low. Having studied the experts' opinions, the authors single out priority measures for the development of the agricultural innovation system aimed at strengthening the country's food independence: promoting the research program targeting small farmers, creating favorable infrastructure for food systems, contributing to the farmers' and scientists' knowledge flows: expanding the agricultural production and strengthening the human potential, encouraging the development of scientific, technological and innovative applications on key food safety issues.

Keywords: agricultural innovation system, agrotechnologies, food independence, food security, level of malnutrition, level of innovative activity.

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1. Introduction

The agriculture and the world food system face the challenge: to provide 9.7 billion people with food by 2050 in the context of the reduction in land and water resources (UN DESA, 2015; Moumen et al., 2019).

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Over the recent decades, the Republic of Kazakhstan has made considerable progress when fighting the food insecurity: in 2015 – 2017 the level of malnutrition was less than 2.5 % (in 2004 – 2006 this indicator was 5.9 %). Agricultural land can no longer be expanded because a considerable area of the global arable land has already been involved in production. The rest of the land is increasingly being lost as a result of urbanization or must be restored in order to preserve the habitat and bio diversity, as well as to create climate buffers.

In addition, the irrational overuse of freshwater resources as a result of irrigation causes the reduction in water supplies for the agricultural industry in the Republic of Kazakhstan, and the increased risk of the climate change and the uncertainty of the geopolitical landscape affect the food security.

The problems on the resources reduction and the population growth are worsened by changes in diet in many developing countries, including the Republic of Kazakhstan. Nowadays the consumption of animal protein and fresh products is increasing in the Kazakhs' diet. This, ultimately, will require a higher level of production of the main source of protein, carbohydrates and nutrients: crops.

The financial and energy crises deepened the poverty and had negative impact on the food security of developing countries. Over the past five or six years, international food prices have risen, which makes food less accessible to many people and attracts attention to deeper structural deficiencies in the global food production system.

In addition, over the past 40 years, technologies and methods of agriculture have caused the degradation of productive land, large greenhouse gas (GHG) emissions and considerable water pollution. All of these factors threaten the sustainability of food production.

Sustainable fighting hunger and malnutrition and protection from high and unsustainable food prices will require a fundamentally different approach to the agricultural development and food production. This implicates the creation of a comprehensive national framework for the sustainable management of natural resources, as well as the adoption of technologies and innovations required to improve the productivity, profitability, and sustainability of rural production systems.

In the global economic environment, the competitiveness of the Republic of Kazakhstan and the ability to maintain the most important natural resources will largely depend on its ability to introduce innovations in these aspects of the production system.

The urgency of the problem of innovative development of the Kazakh agriculture is due to the fact that the development of innovations will update the technological, as well as organizational and economic base of agriculture, and contribute to strengthening the country's food security and its integration into the world market.

2. Literature review

According to various publications on food safety, this concept is multifaceted, differently defined and interpreted. On the one hand, food security implies the availability of adequate supplies at the global and national levels. On the other hand, the problem is in the adequate and balanced nutrition and well-being (Eche, Hernández-Herrera, 2018).

The concept of food security emerged in the XX century during the global food crises (Bobe et al., 2019).

In the 1970s, food security was determined by fluctuations in the food availability, as well as instability in food grain prices (Consolidarea securitatii alimentare si nutritionale mondiale-Concluzii ale Consiliului, 2018).

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In this regard, it was believed that in order to maintain steady growth of food consumption, as well as to compensate for the fluctuations in food grain prices, an adequate global food supply was required at all times (Maitra, 2018). The emphasis on supply issues reflects a change in the organization of the global food economy, which is considered responsible for these crises (Béné et al., 2019).

Since that time the conceptualization and the measurement of food security have been intensively discussed (Briones Alonso et al., 2017). However, the subsequent works of a number of scientists (Butler, McFarlane, 2017; Dubé et al., 2014; Ericksen, 2008) provided a multidimensional understanding of food security and poverty.

These scientists stated that unequal access to food and its distribution due to the lack of economic resources and the capabilities of individuals were important aspects of food security. This differentiated the ability of a state to provide a constant supply of food at the national level and the ability of individuals or households to access available food (Chesnoiu, 2019).

Food security is a multidimensional operational structure, which had got more than 200 definitions by 1993 (Consolidarea securitatii alimentare si nutritionale mondiale-Concluzii ale Consiliului, 2018). This situation was clearly "unsustainable" and reflected the fact that the food security research often had a very specific context depending on which of the many technical perspectives and political issues were discussed (Ericksen, 2008).

The classical interpretation of food security defined in the 1970s was revised at the 1996 World Food Summit to reflect the importance of distribution, food quality, and equality of economic access (Amoroso, 2018).

The summit helped to normalize the multidimensional importance of food security, and stated that food security was a situation that existed when all people at all times had physical and economic access to sufficient, safe and nutritious food that met their dietary needs and food preferences for an active and healthy life (Frison et al., 2011). Despite the fact that scientists continue rethinking the concept of food security, this definition still remains the basis of research in the area of food security (Borch, Kjærnes, 2016).

The concept of food security was also largely studied in the context of human rights, means of existence (Eakin, 2017), women's problems and gender issues in the area of development (Ahmed et al., 2016), import substitution (Agababayev et al., 2020), food quality and safety (Zezza et al., 2017), organic agriculture, as well as sustainable environment (Muller et al., 2017).

These works transformed the concept of food security from the macroeconomic analysis of food supply into a microeconomic or intrafamily understanding of food distribution that takes into account gender equality, the environment and human aspirations and dignity (Allen, Prosperi, 2016).

The definition of food security was reconsidered for the last time in 2016 at the expert meeting of the Food and Agriculture Organization of the United Nations (FAO) that was challenged to develop the indicators measuring food security globally. The FAO experts state that food security is usually defined by the following aspects: food availability, food use, and food sustainability (Srinivas Sucharitha, Lee, 2018).

These aspects form a common basis for the definition developed by the FAO: "food security is a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2016b).

Many researchers note that to ensure food security and to realize the right to food, agricultural innovations are essential (Haile et al., 2017).

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The FAO plays a key role in promoting the importance of innovations in agriculture for improving food security, sustainable development, and promoting rural development. According to the FAO, agricultural innovations are a process that enables individuals or organizations to introduce new or existing products, processes or ways of organization for the first time in a particular context in order to improve their performance, competitiveness, and resistance to external shocks to solve a certain problem.

L.P. Pant states that resource-intensive farming systems, whichare among the main causes of massive deforestation, water scarcity, soil depletion, and high GHG emissions, cannot ensure sustainable food and agricultural production (Pant, 2019). It is necessary to have the innovative systems that protect and expand the base of natural resources while increasing the productivity.

Innovationsare not limited to technologies. They also include social, economic, institutional/organizational processes and policies that have impact on the activity of farms (Brooks, Loevinsohn, 2011).

The number of references that explain the role of innovations in agriculture is constantly increasing. The experience of certain countries related to the adaptation and innovations in the agricultural production is considered in the works of Brooks and Loevinson (2011), Cook (2010), a joint study of Clark, Bean, Raji, Loveridge, et al. (2017), etc.

The studies mainly rest on the qualitative analysis (Hermans, 2017), and avoid formal methods. However, recently more structured approaches to assessing innovation processes and opportunities in agriculture have attracted attention (Schut et al., 2015; Shagaida, Uzun, 2015). Such approaches can also help to meet stronger requirements to monitoring and evaluating in projects and programs.

At the same time, it is necessary to note the need in the further studies of the development of systematic instruments that make it possible to identify both stimulating and limiting factors of innovation.

3. Methods

The purpose of this study is to develop offers on creating the terms and conditions for the innovative development of the agricultural industry in order to ensure the food security in the Republic of Kazakhstan.

The main research methods are the comparative analysis of quantitative indicators characterizing the food security and the food independence, and the bibliometric analysis of scientific publications on the problems of innovative development of the agricultural industry.

Scientific references and analytical materials were searched for by using public sources of the FAO statistical database as the most complete global source of information in the area of food security and agricultural innovations, publications of the Ministry of Agricultural Development of the Republic of Kazakhstan, Committee on Statistics of the Ministry of National Economy of the Republic of Kazakhstan.

The FAO system of indicators was used to assess food security: the level of malnutrition, agricultural production per capita, as well as indicators based on the statistical data of the Statistics Committee – the level of food independence by products and the overall level of food independence of the country.

The food independence (FI) by products was defined by the method and
calculated by using the following formula (Shagaida, Uzun, 2015):

$$FI = (PV: PV) \times 100,$$

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where PV was the production volume + stock change (stock at the beginning of the year minus the one at the end of the year), and

PV was the volume of personal and industrial consumption.

Since the export volume was taken into account in the "production volume" indicator, the level of food independence by products could exceed 100 %.

4. Results

Kazakhstan has adopted a number of national development programs aimed at supporting the overall economic development as well as agricultural development. In 1997, the government set out its vision in the *2030 Kazakhstan* Strategy: prosperity, security and improvement of the Kazakhs' welfare. It emphasizes the importance to develop agriculture, forestry, and the food industry to settle such structural problems as employment and poverty. *2030 Kazakhstan*is implemented through a series of ten-year plans. The current one is a strategic plan for the development of the Republic of Kazakhstan until 2020, approved in 2010. It identifies agriculture and food industry as key areas of the economic diversification and food security: export of agricultural products, improvement of the productivity and processing of meat, milk, fruits and vegetables.

After revising the *2030 Kazakhstan* strategy, in 2012 the government adopted the *2050 Kazakhstan* Strategy in order to maintain high rates of the economic growth and improve sustainability. As for agriculture, the key issues of the new economic strategy include modernization of the agricultural sector, the development of agriculture and small and medium-sized enterprises (SMEs) in the area of agricultural processing and trading, improving water resources policy.

Ten-year plans are transformed into successive five-year development programs. In 2013, the Government of Kazakhstan approved the Agricultural Development Program for 2013 – 2020 (also known as *2020 Agribusiness*) aimed at improving the competitiveness of agricultural producers by improving the financial assistance, agricultural marketing and management efficiency.

In 2017, the government adopted a new State Program for the Agro-Industrial Development for 2017 – 2021 aimed at improving the agricultural production and export. Over the next four years, Kazakhstan expects an increase in the profitability of its grain industry by 30 – 40 % due to the introduction of a new state scheme for the distribution of grants, new organic standards, and a transition from growing wheat to corn and soybeans.

Recently, Kazakhstan and other CIS members have adopted the *2010 CIS Food Security Concept* in order to ensure food security as an integral part of the economic security and to preserve the sovereignty. The main purpose of this document is to form a coherent agro-industrial policy, as well as to timely respond to fluctuations at the world food markets. The concept provides the measures to ensure mutually beneficial trade relations, to create and operate markets for meat and dairy products, and the turnover of fruits and vegetables in the CIS.

In Kazakhstan, the main policy of the agricultural sector aims at reducing the dependence on food import and improving the domestic food production. The Ministry of Agriculture together with the Ministry of Industry and New Technologies introduced a number of incentives for local producers to improve the efficiency and local food consumption, to encourage the development of the national agro-industrial complex and agriculture within the economic diversification. As a part of the *2030 Kazakhstan* Strategy, the government has begun to provide direct assistance and subsidies to local food producers and processors.

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As a result of the taken measures, some progress was made in enhancing the country's food security. Thus, the malnutrition among the Kazakh population is considerably lower than that of other countries of the Central Asian region. At the same time, the average level of malnutrition is steadily decreasing (Table 1).

Table 1. Malnutrition (%) (for Three Years on Average) in the Countries of the Central Asian Region, Russia and Belarus

	2004 – 2006	2010 – 2012	2015 – 2017
Central Asian Region	11	6.7	6
Kazakhstan	5.9	2.7	< 2.5
Kyrgyzstan	9.7	7.8	6.5
Turkmenistan	4.8	4.9	5.5
Uzbekistan	14.5	8.2	7.4
Russia	< 2.5	< 2.5	< 2.5
Belarus	3	< 2.5	< 2.5

Source: compiled by authors

According to Table 1, the level of malnutrition in the Republic of Kazakhstan is less than 2.5 %, which is comparable to the indicators of economically developed European countries.

The food production and trade in the Republic of Kazakhstan have changed considerably over the past decade: the average volume of food production per capita for three years increased from $370 in 2004 – 2006 up to $430 in 2015 – 2017. The analysis of the dynamics of the food consumption by the Kazakh population showed that the actual consumption for seven out of top ten food products was below the defined standards (Figure 1).

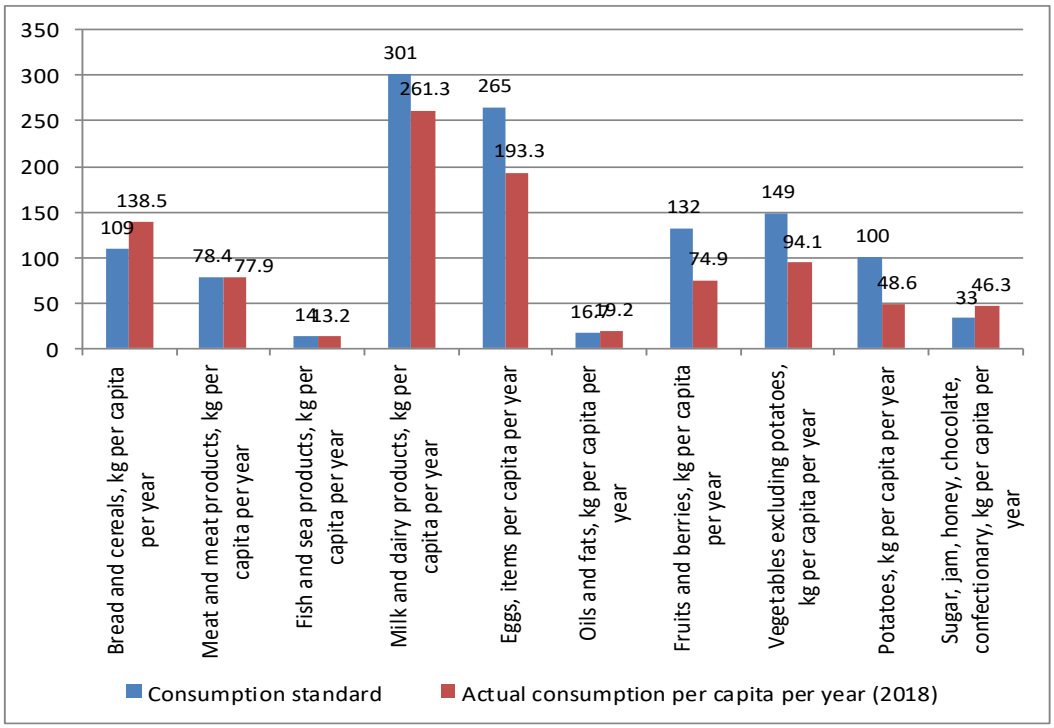

Fig. 1. Food Consumption in the Republic of Kazakhstan in 2018 (Prilozheniye k prikazu Ministra natsionalnoy ekonomiki Respubliki Kazakhstan ot 9 dekabrya 2016 goda No. 503; Komitet po statistike RK. Potrebleniye osnovnyh produktov pitaniya naseleniyem, n.d.)
Source: compiled by authors

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For the analyzed period of 2013 – 2017 Kazakhstan completely provided itself with grain crops, grain processing products, and sunflower seeds. In 2017, the food independence by all grain crops (except for buckwheat) was more than 100 %, i.e., Kazakhstan provides with grain not only its inhabitants, but also the population of other countries of the world.

It is necessary to note the positive dynamics in the self-sufficiency of potatoes, meat and meat products, eggs and egg products, grain processing products, and sunflower (Table 2).

Table 2. Food Independence by Main Types of Food in 2013 – 2017 in the Republic of Kazakhstan (Rasschitano avtorom po dannym Komiteta po statistike Respubliki Kazakhstan, n.d.)

Types of food	2013	2014	2015	2016	2017
Potatoes	95.9 %	97.6 %	95.8 %	98.4 %	103.6 %
Meat and meat products	76.1 %	79.3 %	81.8 %	82.7 %	81.3 %
Milk and dairy products	89.1 %	88.7 %	91.8 %	90.8 %	91.5 %
Eggs and egg products	96.7 %	98.5 %	101.5 %	102.2 %	105.7 %
Grain	141.9 %	138.7 %	130.9 %	138.1 %	138.7 %
Grain processing products	185.5 %	179.7 %	175.6 %	201.8 %	202.2 %
Fruits and berries	18.4 %	15.8 %	19.9 %	23.0 %	30.6 %
Beetroots	100.0 %	100.0 %	100.0 %	103.1 %	92.1 %
Sunflowers	109.6 %	131.7 %	134.0 %	136.6 %	163.3 %
Oil and oil containing products	80.3 %	81.7 %	70.1 %	70.1 %	79.7 %

Source: compiled by authors

During the analyzed period in the Republic of Kazakhstan there is a deficit in the production of fruits and berries: the domestic production does not cover the country's needs in fruits and berries. The deficient volumes of fruit and berry products are imported from other states of Central Asia, Russia, Iran and China.

In general, in 2013 – 2017 the food independence of the Republic of Kazakhstan increased for most food products, and is at a fairly high level. Fruits and berry products are an exception.

During the period under consideration, the grain yield increased from 11.6 dt/ha in 2013 up to 13.4 dt/ha, oil crops – from 8 dt/ha up to 9.7 dt/ha, sugar beets – from 267.7 dt/ha up to 274.4 dt/ha, potatoes – from 181.5 dt/ha up to 194.2 dt/ha, field vegetables – from 238.7 dt/ha up to 253.7 dt/ha, and melons and gourds – from 212.4 dt/ha up to 224.2 dt/ha.

In many ways, this became possible due to the introduction of innovative technologies in the agricultural production of the Republic of Kazakhstan. As compared to 2013, in 2017 the domestic expenditures of the enterprises for the R&D in the area of agricultural sciences increased by 899.9 million tenge and amounted to 6,528 million tenge. The largest amount of innovative expenditures made by agricultural enterprises themselves was noted in 2015,reaching 7,602.4 million. However, over the past two years, this figure has been steadily decreasing by an average of 7.3 % per year.

For 2013 – 2017 the level of innovation activity of agricultural enterprises increased from 8.5 %up to 9.6 % (Figure 2).

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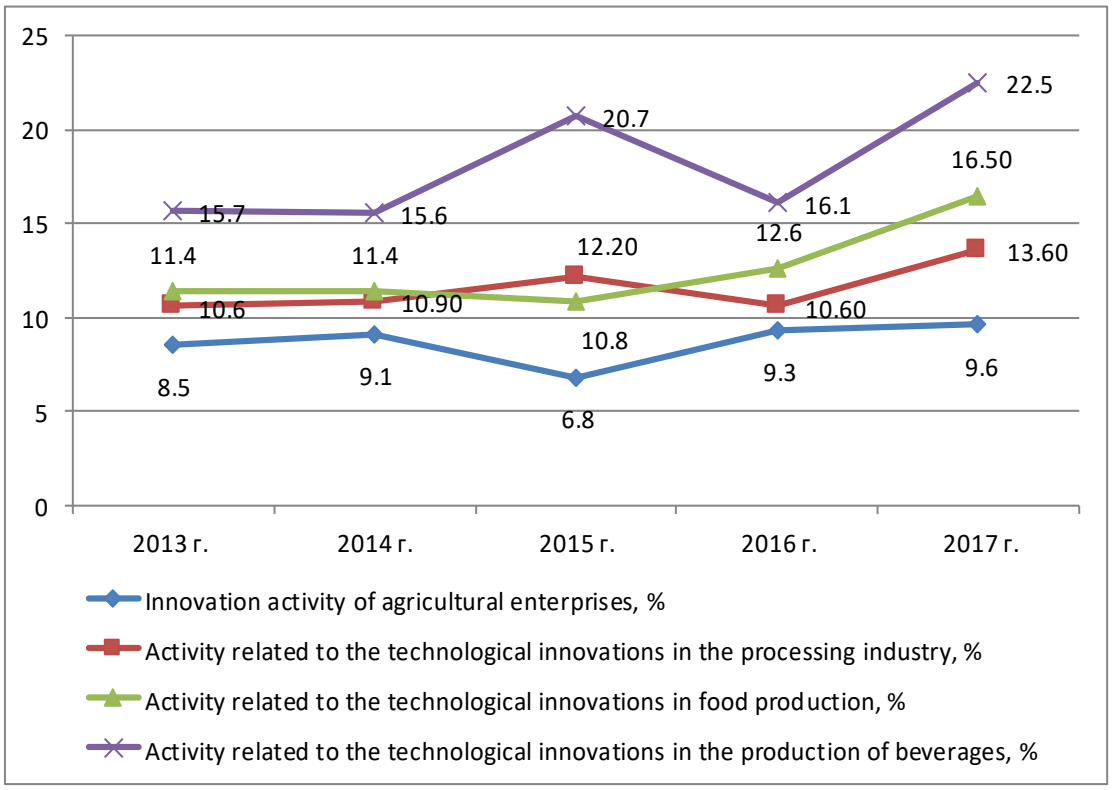

Fig.2. Innovation Activity in Agriculture and Processing Industry of the Republic of Kazakhstan in 2013 – 2017
Source: compiled by authors

Over the past five years, scientific organizations have got 3,197 protection documents of the Republic of Kazakhstan. More than 365 applications for alleged inventions have been filed, and over 775 patents were received for 2015 – 2017. Three inventions were registered with the Eurasian Patent Office. One certificate of discovery in the area of soil science was issued.

At the same time, the analysis of the situation in the agricultural sector of the Kazakh economy shows that the level of development and implementation of modern agricultural technologies and technologies for processing agricultural products remains extremely low.

5. Discussion

According to Daniel Gustafson, the FAO Deputy Director General for Programs, innovations are required in all segments of the food chain, and, what is as important, investments in innovations in the food system can pay off very well when creating jobs, if the whole value chain from the producer to the end user is considered.

Experts of the noncommercial JSC National Agrarian Science and Educational Centre (noncommercial JSC NASEC) note that the intensification of production is not real without the use and implementation, transfer of innovative technologies of the modern science, digital solutions, and international exchange.

In order to improve the efficiency of the agro-industrial production and ensure sustainability of the food system of the Republic of Kazakhstan, it is necessary to make further efforts on developing innovations and technological modernization of agriculture and the processing industry in the following areas:

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1) Promoting the research program targeting small farmers

The constantly changing ecological, environmental, as well biodiversity context requires continuous studies and developments in order to get and share the knowledge on maximizing agricultural yields and preserving the environment.

Studies at the national and international levels should cover a more complex set of tasks: new challenges (climate change, renewable energy sources and energy efficiency, biodiversity and resource management),on the one hand, and old ones, on the other hand (productivity growth and product quality), as well as promote diversification.

For example, at the national level, the Agricultural Academy of Bulgaria supports high quality agricultural studies and developments, and since 1994 the Thai Research Foundation has provided more than 800 research projects on food issues and made a special focus on the local community participation.

When developing programs for the sustainable development and promoting agricultural innovations, it is interesting to study the experience of the Swiss Federal Agricultural Administration – the leader of the Sustainable Food Systems Program within the Ten-year Framework Program on Sustainable Consumption and Production Models. This program is a multifaceted initiative on the transfer to more sustainable food systems that provide food security and nutrition for the present and future generations of the country.

In order to conduct joint research programs on food security, it is necessary to deepen the cooperation with international research institutions, such as the consortium of international agricultural research centers (CGIAR). The CGIAR is a global partnership uniting the research organizations involved in the studies to provide food security in the future. The studies are conducted by the network including 15 research centers, known as the consortium of international agricultural research centers. These centers are located around the world. As a rule, the centers operate in partnership with other organizations, including national and regional agricultural research institutes, civil society organizations, scientific circles, and the private sector.

The recent international discussions on the development of a new strategy and framework of the results for the CGIAR (previously the consultative group on international agricultural studies) for 2016 – 2030 emphasize more inter sectoral approach to research topics, taking due account of the socio-economic study and overcoming the lack of comprehensive agricultural research for the development purposes.

In this regard, joint studies remain a challenge: in addition to the supervision and coordination of international agricultural research, the CGIAR can potentially play more active role as an intermediary and a network agent, promoting innovative platforms at the strategic and international levels, especially contributing to the dialogue and clarification of complex sector phenomena and its context.

2) Creating favorable infrastructure for food systems

The infrastructure provides many scientific and technical applications that relate to aspects of the food system. For the local food system to prosper in the Republic of Kazakhstan, it may be necessary to create a large part of the food industry infrastructure for small and medium-sized farms. Farmers need centers to combine products, commercial kitchens to create value-added products (such as jams or sauces), slaughterhouses, and value-added meat processing enterprises. Producers also need access to various markets and sustainable agricultural land, and the food system is connected to the existing networks for the transportation, distribution, storage, and other critical needs. When planning new initiatives to stimulate the economic development, local governments should

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take into account their agricultural assets and types of the consumer demand, as well as the offers that are available in their region.

The first step to improving the local food infrastructure is to assess and understand the strengths and weaknesses of certain regions of the Republic of Kazakhstan. The example is the operation of the NC Growing Together (USA) project where a supply chain infrastructure map was made for all 100 North Carolina districts, and intermediate categories such as processing, distribution, cold storage, and aggregation were identified. The map is based on the industry data that are reliable for each district. However, constant local knowledge and participation are required to continuously check and add data. The data are searchable by district and by category and can be downloaded to an Excel spreadsheet for their analysis or use in the majority of commercial mapping programs.

The most important role in ensuring the food security of the country is assigned to information and communication technologies (ICT). For example, it is possible to see how the community supports ICT instruments in the Sauti ya wakulima project. The project implements the interdisciplinary methodology called the ERV (Enabling Reciprocal Voice) methodology, developed as a part of the interdisciplinary PhD research project at the Zurich University of the Arts (ZHdK). According to Eugenio Tisselli, the information technology expert and independent consultant from Barcelona, the methodology is based on using and sharing common smartphones, creating audio-visual documentation of the farmers' agricultural and social environment, published on the shared web platform. Audiovisual documentation consists of a photograph, an explanatory voice recording, and a keyword used to classify the content. These elements are enriched with the geographic reference information on an interactive web map. Since 2011, groups of farmers in the United Republic of Tanzania (the Bahamoyo District) have been involved in the proof of concept project. The farmers have documented their strategies for dealing with unstable weather phenomena, pests and diseases, as well as other aspects the farmers consider relevant for describing their agricultural realities.

In five years, Sauti ya wakulima was fully accepted by the farming communities, operates autonomously,and is supported by the Bahamayo agricultural administration and the farmers themselves. The farmers have created a rich knowledge base containing over 3,000 images and audio recordings.

This knowledge base also includes a detailed map of the local knowledge based on the farmers' interviews with the people living in their communities and beyond. The local government provided a group of participating farmers with grants and encouraged them to document farm exhibitions and agricultural fairs in other cities, including the largest agricultural fair in Morogoro. The ERV methodology was modernized in 2016 and is currently being expanded by Swissaid, the Swiss development organization, to cover thousands of small farmers in the Masashi region in the south of the United Republic of Tanzania deprived of food security.

3) Contributing to the farmers' and scientists' knowledge flows: extending the scales of the agricultural production and strengthening the human potential

Services on sharing the knowledge can help farmers to resolve a number of issues including the agronomic practice, natural resource management, livestock health protection and management, access to financial support, and markets and/or market intermediaries.

This is a striking example of the knowledge share impact on the agronomic practice when Ethiopian farmers grow teff grass (teff grass – national grain). Farmers traditionally disperse their seeds (i.e., the seeds are hand-scattered across the field) and hope that more seeds will generate more yield. The researchers in Ethiopia have shown that planting seeds in rows (rather than dispersing them) can increase yields by 50 – 80 %, reduce the number of seeds required for sowing by 90 %, as well as produce teff grass with larger leaves and stronger stems.

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It is necessary to develop innovative forms of production and share knowledge, e.g., community innovations, innovation platforms, and joint studies.

4) Encouraging the development of scientific, technological and innovative applications on key food safety issues. There is a wide range of research issues that should play a certain role in planning and implementing science, technology and innovations (STI) related to food security. They must be resolved at all levels – from international cooperation to farmers. Far from all topics will be equally relevant in all cases, but their importance and interaction are crucial to achieve the goal of eradicating hunger and malnutrition in a truly sustainable way.

• Synthetic biology

In the conditions of limited and contaminated arable land and water resources, the current efforts are focused on searching for new solutions to these problems, without creating an additional burden on the environment. However, the improved awareness of the role of nutritious food for the human health and the concept of "food as medicine" increased the demand for "functional food".

The "cellular agriculture" and "biosensors" are the two main instruments that help to ensure sustainability in the food and agricultural industries.

The cellular agriculture makes it possible to produce food with higher nutritional or medical value, as well as food with longer shelf life and without harmful ingredients, such as allergens for the susceptible population. The enrichment of soil or raw materials with engineering microorganisms acting as biosensors that contribute to the detection of pathogens or pollutants supplements resistance to pathogenic agents and improves the quality of food products of animal or vegetable origin.

These and similar innovative solutions contribute to the transfer of sustainable agricultural practice and food industry to a new era, where less resources are used to produce more healthy food.

• Artificial intelligence

Automated irrigation systems, crop health monitoring, livestock recognition systems, CBR systems for the fish industry, and many others are good examples of how artificial intelligence can be implemented in agriculture.
One of the brightest examples of how the artificial intelligence is used in agriculture is the innovative project of Veepro, the Dutch company, on creating an information center for dairy cattle.

Veepro has created an expert artificial intelligence system that can prescribe feed rations, medications, and health and well-being conditions for livestock. It may recommend mating partners to improve the genetic potential of the offspring. The expert system can make a comprehensive analysis of the health, the reproduction of individual or groups of animals, monitor production and recommend prompt measures to be taken for improving the productivity of the farm.

• Selection and support of local seed systems

A good example of the need in public investments for researching and distributing technologies are breeding programs and the support of local seed systems that allow distributing locally adapted genetic material that farmers would have the right to freely save, exchange and sell. The examples of seed bank programs include the Portuguese National Gene Bank and the Navdanya network of seed custodians and organic producers in 18Indian states.

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• Agroecology

The agri-environmental science has the potential to create more sustainable food system. There are more and more evidences that agri-environmental solutions can support or improve farmers' profits by providing environmental benefits such as lower soil erosion and water pollution. In addition, according to the studies, the agro-ecology may contain the solutions that simultaneously solve problems related not only to food, but also to energy and water. In the context of these predictions, more and more researchers working in the area of sustainable agriculture emphasize the need in a wider government support for the research.

It is necessary to create more local opportunities for the efficient research in the social and social sciences aimed at eliminating persistent inequalities, such as gender, race, institution, income, and geography.

For such programs to succeed, it is necessary, for example, to provide participatory approaches and secure farmers' rights. These programs need substantial funding and coordination, which should be carried out by specially created organizations.

Conclusions

The study results presented in this paper make it possible to make conclusions about the food security in the Republic of Kazakhstan and the possibilities of innovative agricultural development in order to improve the country's food independence:

• In general, in 2013 – 2017 the food independence of the Republic of Kazakhstan for most food products increased and is at a fairly high level. Fruit and berry products are an exception.

• Despite the positive dynamics of the food independence indicators, Kazakhstan still suffers food security problems: only three of 10 top foods are actually consumed more than the determined standards.

• In order to improve the economic, environmental and social indicators of the agri-food sector, it is necessary to have an efficient innovation system. Despite the proven positive impact of the agricultural R&D on the productivity growth and the contribution to the natural resources use sustainability, the development and introduction of agricultural technologies remain extremely low in the Republic of Kazakhstan.

• In order to strengthen food security, the efforts should be directed towards the development of the agricultural innovation system in the following areas: promoting the research program targeting small farmers, creating a favorable infrastructure for food systems, contributing to the farmers' and scientists' knowledge flows: expanding the agricultural production and strengthening the human potential, and encouraging the development of scientific, technological and innovative applications on the key food safety issues.

• Now there is an urgent need to increase investment in high-quality research that would be consistent with the production models adapted to the needs of small-scale farmers in Kazakhstan.

• STI, including the use of precision agriculture and early warning systems, can mitigate the food instability. New and the latest technologies, including synthetic biology, artificial intelligence and tissue engineering, can have potential implications for the future crop and livestock farming. However, using the potential of such technologies to ensure the food security requires investments in research and development, human capital, infrastructure, and knowledge flows.

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