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SMART TECHNOLOGIES OF FOOD PRODUCTION IN THE SYSTEM OF GLOBAL TECHNOLOGICAL WAVES

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Abstract: *The concept of a technological wave, as a set of technologies characteristic of a certain level of production development, and scientific and technological progress, as a transition from lower waves to more progressive ones, is characterized. The traits of 6 existing technological waves now are given, it is indicated that in developed countries technologies of the 5th wave are dominating and technologies 6 technological waves are being formed, but in Ukraine about 95% of the production volume belongs to the third (60%) and fourth (35%) technological waves when the share of products of higher technological waves is 4% only. The necessity of introducing e-agriculture in Ukraine, which is understood as the planning, development and application of information and communication technologies in agricultural production and food industry, is noted. The state of innovative development throughout the world is analyzed. It is concluded that the more developed a country is, the more attention it pays to investing in innovative development. For Ukraine, it is advisable to pay attention to the development of renewable energy sources and resource-saving technologies, as well as to more actively use digital and nanotechnologies, in particular artificial intelligence, in the production of food raw materials and products.*

Key words*: smart technologies, technological wave, innovative development, e-agriculture, precision agriculture, food industry, information and communication technologies.*

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Nations using advanced innovative production technologies and being at the highest levels of technological waves become centers of capital attraction and drivers of economic development. That is why it is so important, taking into account the problem of economic growth of the national economy and the innovative choice of Ukraine, on the basis of which effective participation of our state in the European integration processes is possible, to create adequate conditions and mechanisms for the transition to the 5th and 6th and technological waves.

According to today economic nomenclature, the technological wave is a combination of technologies characteristic of a certain level of production development; in connection with scientific and technological progress, when a transition from lower waves to higher, progressive ones occurs.

The concept of technological waves was formed at the turn of 1970-80. on the basis of the so-called concept of the techno-economic paradigm proposed by a number of economists (S.W. Becker, Arthur D. Little, G. Freeman, G. Mensch) [1; 2; 3]. This problem was thoroughly disclosed in the work of V.P. Seminozhenko [4]. However, to intensify the transition of Ukraine to new technological waves, further research is needed to substantiate measures aimed at ensuring this transition.

The purpose of this article is to summarize the characteristics of technological waves and determine the place of the food system in them.

Today the existence of 6 technological waves is generally accepted. At present, in the developed countries, the technologies of the 5th wave dominate and the technologies of the 6th wave are formed.

Characteristics of technological waves are summarized in Table 1.

Table 1. Characteristics of technological waves

Wave	Period	Principal resource	Principal branch	Key factor	Economic achievement	Social achievement	Leading nations
First	1770-1830	Water power	Textile industry	Textile machines	Mechanization of manufacturing	Improvement in labor conditions	Great Britain, France, Belgium
Second	1830-1880	Steam power, coal	Transport, iron and steel industry	Steam engine, steam driven machines	Incline in production scales, transport development	Gradual release of man from heavy manual labor	Great Britain, France, Germany, USA
Third	1880-1930	Electric power	Heavy machine building, electric industry	Electric motor	Concentration of banking and financial capital, emergence of radio communication, telegraphs, standardization of production	Improving the quality of life	Germany USA, Great Britain, France, Belgium, Switzer-land, the Nether-lands
Fourth	1930-1970	Energy of carbohyd-rate,com-mencement of atomic power	Automotive, non-ferrous metallurgy, oil refining, synthetic polymer materials	Internal combustion engine, petrochemistry	Mass and serial production	Development of communication, transnational relations, growth of consumer goods	USA, Western Europe, USSR, Japan, Canada
Fifth	1970-2010	Atomic power	Electronics and microelectronics, information techno-logy, genetic engi-neering, software, telecommunications, space exploration	Microelectronic components	Individualization of production and consumption	Globalization, the speed of communication and transfer	Germany, Taiwan, South Korea, EU, Sweden
Sixth	2010-2060	Bioresources, resource-saving technologies	Nanotechnology, molecular, cellular and nuclear techno-logies, nanobiotech-nologies, nanobio-nics, biomimetics, other nanomaterials: new medicine, home appliances, modes of transport and communications stem cell utilization, life sciences and organs engineering, restorative surgery and medicine	Microelectronic components, artificial intellect,CALS-technologies	Individualization of production and consumption, reduction of energy intensity and material production, construction of materials and production with predetermined properties	Significant improvement in the quality of life of humans and animals	USA, EU, Japan

Summarized by authors from [5, 6]

According to experts from the Organization for Economic Cooperation and Development, in the United States in the 80s-90s of the last century, almost 50% of the total increase in labor productivity was achieved due to high-tech sectors, in the UK, Canada, Japan - more than 30%, France and Italy - 25 % At the same time, the sectoral structure of "innovation countries" of the newest technologies until the mid-90s of the past century was identical - aerospace industry, automotive, electrical engineering - each of them accounting for 10 to 15% of all R & D expenditures in the United States, Japan and the EU. But in the mid-90s the situation qualitatively changed. In the US, the leader was the service sector, represented by information technology (20% of all R & D expenses), which pressed the aerospace industry (12%) and the automotive industry (11%). In the EU, electronics (15%) and the automotive industry (13%) became the leading ones [7].

Today the world is about to step into the sixth technological wave. Its contours are only beginning to take shape in the developed countries of the world. Experts believe that while maintaining the current pace of technical and economic development in 2020-2025, a new scientific, technical and technological revolution will take place, the basis of which will be the developments synthesizing the achievements of the above-mentioned basic directions. There are grounds for such forecasts. For 2010, the share of the productive forces of the fifth technological wave in the most developed countries averaged 60%, the fourth - 20%, and the sixth - about 5%. It is obvious that the ratio of the share of technological waves in the economy as a whole determines the degree of its development, internal and external stability. Initiative in the implementation of the sixth way was unequivocally intercepted by the United States. Some leading works in the post-Soviet countries cannot compete with this huge array.

The transition from the fifth technological wave to the sixth wave is primarily associated with the technological revolution and the total reorientation of industries and enterprises of industrialized countries to energy-saving technologies, waste management and multiple processing of natural resources. Structural changes in the economies of these countries are expressed in the accelerated development of economic sectors that produce complex engineering and science-intensive products, and in which the value added only in limited sizes includes unprocessed raw materials or low-skilled labor (engineering, computer science, electronics, biotechnology, etc.). At the end of XX century with the world production of mechanical engineering products in 1200 billion USD the share of industrialized countries accounted for 73%, including the EU - 29%, the USA - 25%, Japan - 19%. The share of these countries in world exports of machinery and equipment at this time was 85.5%, including the EU - 41%, the USA - 24, and Japan - 20.5% [7].

In the technological race, the developed industrialized countries concentrate their efforts on the accelerated development of those sectors of the economy, which, on the one hand, provide a decisive contribution to the increase in labor productivity, and, on the other hand, make it possible to maintain technological advantages over competitors.

The key areas of the sixth technological wave include: biotechnology, artificial intelligence systems, CALS technologies (Continuous Acquisition and Lifecycle Support - continuous information support for supplies and product life cycle), global information networks and integrated high-speed transport systems, computer tuition, formation of network business communities. These sectors are now developing in leading countries at an especially fast rate (sometimes from 20% to 100% per year).

The economic system of any country is characterized by the simultaneous functioning of several technological waves: the one that is born; prevailing; the one that is dying off. It is the new wave that is of strategic importance for the economy and is having an insignificant effect on GDP growth until a certain point, but it forms the direction of the country's development for decades to come.

According to experts, in Ukraine about 95% of the volume of production refers to the third (60%) and fourth (35%) waves, the characteristic features of which are the advanced development of the electric power industry and the use of oil as the main energy carrier. The share of products of higher technological waves in the economy of the country is 4% (Fig. 1). GDP growth due to the introduction of new technologies in Ukraine is estimated at only 0.7-1%, while in developed countries this figure reaches 60% and even 90%. In Ukraine, the third and fourth technological waves prevail, that is, the economy remains at an industrial stage, and therefore lags behind developed countries by one technological era.

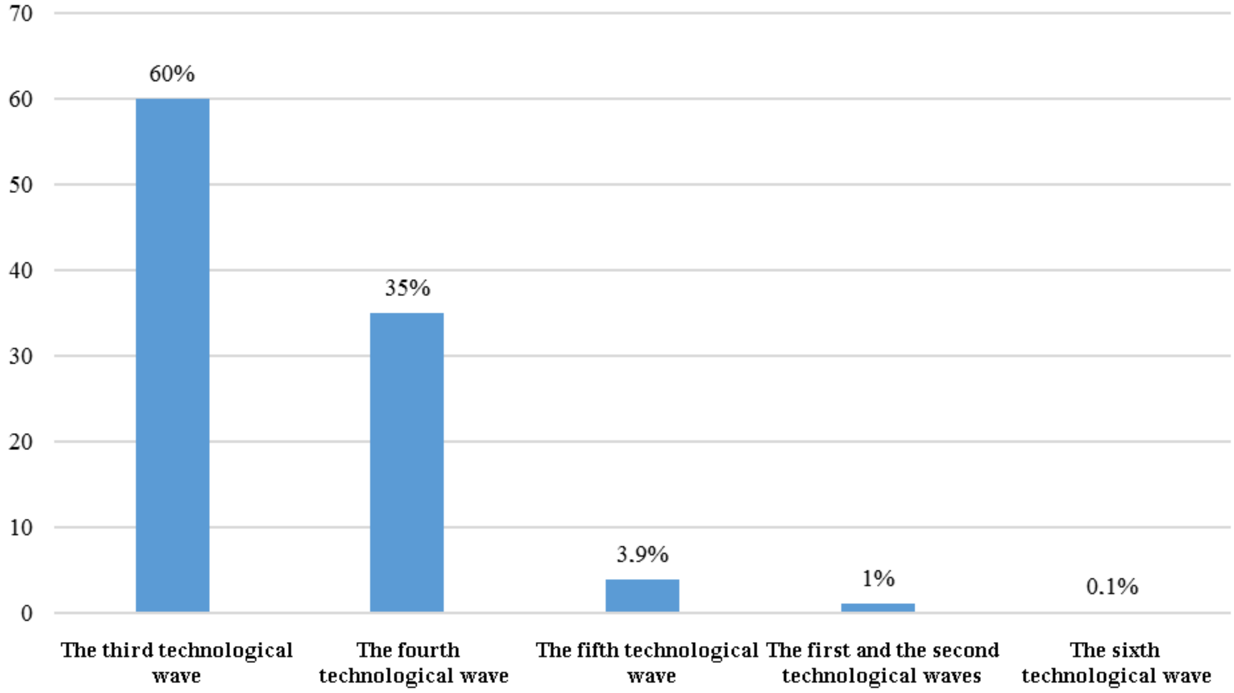

Figure 1. Amounts of industrial production in Ukraine by technological waves
Source: [8]

According to the Institute of Economic Forecasting of the National Academy of Sciences of Ukraine, today 75% of investments in Ukraine are invested in enterprises of the third technological wave, which include the production of building materials, ferrous metallurgy, metalworking, woodworking, shipbuilding and machine-tool construction. Another 20% of investments are sent to the enterprises of the fourth technological wave. In other words, 95% of investments are received by the third and fourth ones being industrial technological waves. Moreover, the lion's share of investment falls precisely on a low, third wave. It is clear that the investment policy of the state is directed, in fact, to the "conservation" of the structure of the economy and, unfortunately, the worsening of the said structure. The situation in the area of financing scientific and technical developments is similar: the fourth technological wave`s share is 70% and the fifth one`s is 23%; 30% of innovation costs fall on the third technological wave, 60% on the fourth, and only 8.6% on the fifth [8].

Actual realities of the Ukrainian economy do not allow the formation of complex innovative models of the fifth and sixth technological waves, characteristic for the highest stage of scientific and technological progress and used, for example, in the USA and Japan. The main reason for this situation is the sharp decline in innovation activity during the period of transformations.

Poor funding for science negatively affects innovative activity in industry. This confirms the fact that the number of new-Jen technological processes was 1991 7303 units, and in 2017 only 456, that is, decreased by more than 16 times. The science intensity of the country's GDP decreased from 2.44% in 1991 to 0.45% in 2017. World experience confirms that with the value of this indicator less than 0.4% of GDP, science in the country can perform a socio-cultural function only. When passing through this frontier, it acquires the ability to produce certain scientific results and perform a cognitive function in society. And only at the cost of science, exceeding 0.9% of GDP, its economic function is turned on.

The successful functioning of agricultural enterprises (the main suppliers of food raw materials) both in the domestic and foreign markets in the conditions of functioning of today's tough competition is impossible without the use of modern innovative communication technologies and the development of e-agriculture.

E-agriculture is the planning, development and application of innovative methods of using information and communication technologies (ICT) in rural conditions, primarily in the food and agriculture, including fisheries, forestry and livestock [9].

The Food and Agriculture Organization of the United Nations (FAO) and the International Telecommunication Union (ITU) adopted the term "e-agriculture" as a result the World Summits on the Information Society in 2003 and 2005. Since then, other terms have appeared, including "smart agriculture" and "digital agriculture". But these definitions emphasize the challenges posed by the emergence of a new generation of information and communication technologies (ICT), that is, they are limited to some uses of technology at the farm level, while FAO and ITU give a broader definition that covers various technological solutions to existing problems in agriculture and rural development. At the same time, the term "e-agriculture" implies not only the application of appropriate technologies in the food and agriculture sectors, but also emphasizes that achieving the goal of e-agriculture is inextricably linked with the creation of favorable conditions and capacity development.

The advantages of modern e-agriculture are:

- an increase in production – optimization of work with agricultural crops, including proper planting, watering, processing with pesticides and harvesting, directly affects the production volumes;
- rational water consumption: weather forecasts and soil moisture sensors allow water to be used only when and where necessary;
- obtaining real-time data and analyzing production situations – farmers can visualize data on production volumes, soil moisture, sunshine intensity and remotely in real-time to speed up the decision-making process;
- reduction of operating costs – automation of the processes of planting, processing and harvesting can reduce the amount of resources consumed, decline the likelihood of human error and cut overall costs;
- improving product quality – analysis of product quality and the results obtained, depending on the methods used, can teach farmers to adjust production processes in order to improve product quality;
- accurate assessment of the situation in the farm and in the fields – accurate tracking of production volumes in the fields over time allows us to make a detailed forecast of the future harvest and estimate the value of the farm;
- improving livestock technology – for earlier detection of any events related to reproduction and animal health, special sensors and equipment can be used. Location tracking can also improve the control and maintenance of livestock;
- reduction of environmental impacts – all environmental measures, including rational water consumption and an increase in production per unit area, directly positive impact on the environment;
- remote monitoring – local and commercial farms can monitor the situation on several fields at different ends of the globe at once via the Internet. Decisions can be made in real time anywhere in the world;
- monitoring equipment status – one can monitor and support the operation of agricultural equipment in accordance with production volumes, labor productivity and damage prediction.

Research by the University of Nebraska-Lincoln confirmed the interest of farmers in the introduction of precision farming technologies, which is the basis for the development of e-agriculture. Agricultural producers (numbering 126) who participated in the exhibitions of the Nebraska Extension in 2015 were surveyed. In general, they have 609.8 hectares of land, mainly located in Nebraska, a US state.

From the results of the study follows [10]:

- high rates of introduction of the latest technologies were revealed: in the field of agrochemical analysis of the soil% showed 98% of the surveyed farmers; introduction of high-speed Internet – 94% of respondents;

- implemented monitoring of yields, maps, GPS navigation of more than 80% of agricultural producers;
- introduced differential fertilization systems – 68% of farms;
- satellite and aerial photographs are becoming popular – they were introduced by about 30% of the surveyed farmers.

Another study published by Goldman Sachs predicts an increase in expected yield by 70% in the use of precision farming technologies. The total target market by 2050 should grow to 240 billion dollars. From this study it is clear that the introduction of precision agriculture will have an impact on the development of agribusiness.

Added value from the introduction of precision farming technologies can be estimated by increasing yields. In the Goldman Sachs study, it was calculated in dollars for each branch of precision agriculture (Table 2).

Table 2. Efficiency of investments to precision agriculture

Branches of precision agriculture	Investments, billion USD	Added value, billion USD	Increase in yield, %
Precision fertilizing	65	200	18
Precision seeding	45	145	13
Minimal soil compacting (minitractors)	35	145	13
Precision irrigation	35	115	10
Field monitoring, data management etc.	35	125	
Precision spraying	15	50	4

Summarized by authors from [11]

The most attractive markets for precision farming are those of America and Europe. Despite this, the demand for technology in other parts of the world will also increase due to the lower cost of technology and the benefits that they provide.

According to statistics, more than 80% of farmers use various elements of precision farming in the United States, and 70% in Germany. European farmers apply elements of precision farming even on 0.5 hectares, because they have the opportunity to take cheap loans for 20-30 years on the security of their plot. Funds for precision farming are returning quickly. Most of the investment pays off during the first marketing year. Nearly 90% of farms that have tried technologies related to precision farming continue to introduce its next elements.

Now there is a rather limited level of ICT implementation in the Ukrainian plant growing industry. Precise technology today covers no more than 20% of Ukrainian farmland. Not complicated technological components of precision farming systems have been distributed: Global Positioning Systems (GPS) and Global Navigation Satellite System (GNSS) navigation, mobile accessories for crop control, drones, works and controlled equipment, which are mainly used not systemically, but separately from each other.

In contrast to European agrarian industries with the possibility of introducing ICT even at the level of small enterprises, in Ukraine large agrarian holdings (PrJSC Myronivsky Hliboproduct, Svarog West Group Corporation, etc.) are leaders in this field, probably because of large financial opportunities.

As an experiment, FAO developed a regional eAGRI index, which assesses the need and readiness of countries in Europe and Central Asia to develop and implement strategies to transform their agricultural sectors by converting them to digital technologies. This index is calculated on the basis of 90 existing indicators describing the situation with the introduction of ICT in the country, with the presence of favorable conditions for the development of ICT, as well as macroeconomic indicators related to agriculture. It gives an idea of the current and irrelevant objectives of national e-agriculture strategies (such as infrastructure, rural and gender gap, business climate, government readiness to use ICT, etc.), which allows for cost-effectiveness in the process of implementing strategies and lets to identify opportunities for knowledge sharing with European and Asian countries that are industry leaders. Based on the level of importance of the agricultural sector for the national economy countries were divided into three groups (tab. 3):

1) countries with a low degree of agriculture in the economy: Belgium (overall eAGRI rating - 17th place), Denmark (7), Germany (12), Israel (15), Luxembourg (1), Malta (16) Netherlands (10), Norway (2), Sweden (5), United Kingdom (6);

2) countries with an average share of agriculture in the economy: Austria (13th place), Bulgaria (30), Croatia (29), Cyprus (27), Czech Republic (23), Estonia (3), Finland (8), France (14), Hungary (32), Ireland (11), Italy (34), Latvia (21), Lithuania (19), Poland (35), Portugal (18) Russia (38), Slovakia (25), Slovenia (26), Spain (20), Switzerland (9);

3) countries with a high share of agriculture in the economy: Albania (44th place), Armenia (41), Azerbaijan (24), Belarus (43), Bosnia and Herzegovina (48), Georgia (39), Greece (40), Iceland (4), Kazakhstan (28), Kyrgyzstan (49), Moldova (36), Montenegro, Romania (37), Serbia (42), Tajikistan (45), Macedonia (22), Turkey (31), Ukraine (47), Uzbekistan (46).

Table 3. Grouping of countries by mean values of eAGRI indices and innovativeness of economies

Group of countries	ICT introduction mean value	Availability of favorable conditions, mean value	eAGRI, mean value	ICT introduction, overall mean rating	Availability of favorable conditions, overall mean rating	eAGRI, overall mean rating	Index of innovative economies, overall mean rating
Countries with an low share of agriculture in the economy	0.926	0.743	0.834	9,8	10.4	9.1	15.7
Countries with an average share of agriculture in the economy	0.855	0.644	0.749	20.2	24.0	21.8	26.5
Countries with an high share of agriculture in the economy	0.674	0.575	0.624	38.1	33.8	36.8	35.5

Summarized by authors from [9]

The group of countries with a low share of agriculture in the economy includes developed countries with a high level of innovative activity. The more developed a country is, the higher its rating of introducing digital technologies in agriculture and innovation activity. And, despite the low share of agriculture in the economy, they use resources more efficiently and get higher yields and profits. Luxembourg, Norway and Sweden have the highest ratings.

Ukraine is among the countries with the highest share of agriculture in the economy, while it has one of the lowest eAgri and innovation activity indices. In Ukraine, there are very low rates of both ICT implementation in agriculture (47th place out of 48) and the presence of favorable conditions (43rd place out of 48).

Countries where the role of agriculture in the economy is low, and the conditions for introducing ICT are favorable, can go towards solving problems related to e-agriculture, in the framework of implementing a unified strategy for creating a digital economy, and countries where the role of agriculture is great should be taken sectoral e-agriculture strategy. Therefore, in the context of Ukrainian realities, it is advisable to focus on the development of digital technologies in agriculture, which requires the development of a separate strategy and the direction of a part of the state budget to stimulate more active development of ICT in agriculture.

So, the advanced driver nations of the innovation economy are the USA, the EU countries and Japan, that is, the more developed a country is, the more attention it pays to investing in innovative development. For Ukraine, its economy being mainly within the third and fourth technological wave, it is advisable to draw attention to the experience of these countries, in particular, energy should focus on the development of renewable energy sources and resource-saving technologies (including the possibilities of advanced processing of agricultural raw materials) and more actively use digital and nanotechnologies in the production of food raw materials and products, in particular, the capabilities of artificial intelligence.

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