ТВАРИННИЦТВО

UDC 636
DOI: https://doi.org/10.37617/2708-0617.2024.10.7-21

DIGITAL TECHNOLOGIES IN ANIMAL HUSBANDRY

Markov N.T., Assoc. prof., ncm64@mail.bg
Stoycheva S. T. E., Assoc.prof, *s_vetla@abv.bg*
Hristov M. S., Ass., m_hristov1@abv.bg
Mondeshka L. I., Ass., lora.mondeshka@abv.bg
Markov T. N., Ass. Prof. markov.tsvetan88@gmail.com
Research Institute of Mountain Stockbreeding and Agriculture, 5600 Troyan, Bulgaria
Agricultural Academy of Bulgaria
*Corresponding author (ncm64@mail.bg)

The paper evaluates the current stage of the development of innovative technologies in the agricultural sector, respectively in animal husbandry and the prospects for the digital transformation of the agricultural sector. Digital technology and various other automated systems are defined. The peculiarities and the trend in the growth of digital innovations in cattle breeding are studied, as well as the factors that impact the technologies in this sub-sector. Digital technologies, which are the basis of modern management systems and the optimization of technological processes in cattle breeding, allow to collect of timely, qualitative information necessary for making correct management decisions, optimizing resources, and significantly reducing the production cost price. A retrospective analysis shows that problem farms can be brought to digitization only if serious financial investments are made. Farmers are in keen need of practical, innovative, and efficient network technologies. Livestock farming is a conservative industry that is not integrated, but digitalization is actively being applied.

Key words: *digitalization, animal husbandry, artificial intelligence, innovation technologies*

Relevance. The digitalization of agricultural production allows obtaining the most complete information to optimize the use of resources and reduce production costs. Systems for obtaining and processing information include sensors, equipment for communication, storage, and aggregation of information, and various analytical units for optimizing the management of technological processes. Smart farms are a new trend of the agricultural market in the world, a complex of innovative technologies that allow to increase the quality of products using computer technologies (Burda, 2018, Tkachenko, 2019, Ivanov, 2019, Buklagin, 2020).

The concept of the Internet of Things (IoT), which is increasingly used in the ecological future of the planet, is built on the thesis of a permanent connection between the physical and digital worlds. This idea is already technologically possible (Borcard et al., 2011). The "things" in the Internet of Things (IoT) are constructed from a combination of different hardware specifications, communication capabilities, and quality of service that give them different IoT characteristics. Cyber-physical systems are used in many areas of industrial and agricultural production, and more recently in animal husbandry.

Smart agriculture freely uses cyber-physical systems and IoT technologies to increase productivity while continuously maintaining quality and financial return with modern means, while showing rotation and proving that the process is reversible (Sowmya, 2017).

Cyber-physical systems and the Internet of Things (IoT) are designed to free up human resources, improve the efficiency of modern human production, and help to a large extent to improve the quality of production (Deloitte, 2017).

The Internet of Things (IoT) should be considered as a single network that connects physical and virtual objects. It is possible to describe a scenario where computing devices with a unique identification are embedded in a large number of objects. Connecting to the internet allows them to collect, store, share, and analyze data, as well as control it remotely using other devices connected back to the internet. The use of the Internet of Things (IoT) is constantly expanding. Objects with built-in computing devices become recognizable and intelligent. They can take measures or propose solutions adapted to the conditions of their implementation. They also have the option to provide information about themselves and access aggregated information from other shared "smart devices". These devices can communicate with each other using wireless or wired communication channels and unique addressing schemes such as Ip v6. The goal of the Internet of Things is to provide the ability to connect objects anytime, anywhere.

The core technology for (IoT) is network sensor identification methods (RFID, QR code, etc.), communication protocols, and machine learning. They can be divided into three categories:

- Information Collection Technologies.
- Information processing technologies.
- Technologies to improve security and privacy.

The "things" in the "Internet of Things" consist of a set of different equipment specifications, communication capabilities, and quality of services, which makes I of oT heterogeneous in nature. Since "Things" can be anything from any inanimate object to any living object such as a human or animal, devices in this technology can vary in their computing power, power distribution and management, memory specifications, power consumption, and security and reliability management. This determines the need to develop a cross-layer optimization framework that can ensure effective interoperability in this heterogeneous network.

Cyber-physical systems and the Internet of Things (IoT) are designed to free up human resources, improve the efficiency of modern human production, and help to a large extent to improve the quality of production (Deloitte, 2017).

The analysis of domestic and international experience shows that the use of digital technologies is one of the important factors ensuring the growth of labour productivity, the preservation of resources, and the stability of agricultural production (Smirnov, 2018, Buklagin, 2020).

Purpose of work. To analyze the main trends and developed topics related to digital technologies in the field of cattle breeding and the prospects for the development of Cyber-Physical Systems and the Internet of Things (IoT) in agriculture.

Material and methods. The research work is based on scientific developments dedicated to the use of digital technologies for management in agriculture. As a methodological basis for conducting research, general scientific research methods, information-logical analysis of scientific and technical information, as well as research materials for the market of intelligent technologies for agricultural management were used. Descriptive and retrospective analyses were also applied. To achieve this goal, we used aggregated data for Bulgarian cattle breeding in the period 2016-2020. The information used is mainly from publications of FAO, Ministry of Agriculture, Food and Forestry, Customs Agency, Agrostatistics Department, Agrarian reports, and reports on marketing and market analyses. The paper quotes moments from the works of Bulgarian and foreign authors. Summaries are made.

Digitalization is turning agriculture into a high-tech sector where huge amounts of data are processed, coming from multiple sensors installed in the pasture, in the field, on the farm, in various agricultural machinery, from small processing plants, from weather stations, from satellites, and other systems. Analytical processing of these data sets makes it possible to obtain previously unavailable information, to find models that allow to increase in the efficiency of agricultural production management, to improve the work of agribusiness and communication with consumers. A negative trend in the development of the cattle breeding sub-sector for a long time is the stagnation in the production of raw milk and the decrease in the number of dairy cows (Kozina, 2018, Vartanova, 2018, Artemova and Shpak, 2019).

The software aims to substantiate recommendations and guidelines for specialists to improve production technologies in animal husbandry compared to the indicators achieved in recent years. They are based on modern information processing methods. Modern methods of information processing in the development of reasonable recommendations for management decision-making by agricultural specialists are based on the analysis of multiple factors affecting production efficiency, and their integration with various intelligent IT applications that process data, in real-time (Kozubenko, 2018).

Digital cattle breeding is a sub-sector of animal husbandry dealing with cattle breeding, the function of which is the introduction and integration of next-generation systems and technologies for the automation of animal care, to increase productivity and reduce costs (Ivanov, 2019. Fedorov et al., 2019).

Modern (IoT) systems, sensors, and robots that are applied in cattle breeding allow to observe each animal specifically and in detail and to predict its life cycle as effectively as possible so that it starts to profit earlier and longer than before the introduction of the technology (Petrova et al., 2020, Buklagin, 2020).

Health status, nutrition, technological solutions, movement, rest, and sleep - these are factors influencing the fertility, growth, and development of each cattle in the digital farm. They are monitored by various sensors that provide information to the farmer every minute. New digital grazing technologies have been developed. New digital grazing technologies have been developed. It is predicted that within a few years, the number of digital systems introduced in the animal breeding process will increase significantly, as well as expand their potential use (Volkov et al., 2018, Ivanov, 2019).

<u>Digital Technologies and Systems.</u> The basis of digital cattle breeding is the equipment and sensors used, their communication methods, and data processing systems. The main tasks that can be solved with their help are: monitoring the behavior of the animal, warning about its state of health, diet, life cycle., technological parameters, food, water, their dosage, control of lighting, ventilation, and temperature of the farm, statistics on all controlled indicators. The list of tasks can now be expanded by using the devices in different areas of animal husbandry. Digital technologies are software, and SaaS - solutions - web-based, and data processing (Volkov and Kolectiv, 2018, Buklagin, 2020).

Modern technologies have become the norm for most large and medium-sized enterprises in the dairy and meat industry. However, the process of using digital technologies in animal husbandry cannot be considered complete. Companies that implement such solutions at full scale, rather than at the Excel spreadsheet level, tend to be among the market leaders for processed animal products. Strong competition in the production of livestock and poultry, in meat processing, characteristic of the industry in recent years, forces all market participants to look for opportunities to reduce costs by automating managerial decision-making, effective management of purchases, sales, and inventory, and optimizing production costs. In the meat industry, digital technologies are developing most actively from processing enterprises. First of all, we are talking about the robotization of operations in factories and warehouses of finished products, and about various sensors and robots, including IoT (Belaya, 2020).

The program for digitalization of breeding and scientific research in dairy production has recently been introduced in Russia. There is a built model of a regional system for the management of farm animals. The creation of DNA passports requires the development of testing methods and systems that allow genetic differentiation of breeds, families and lines, and species of animals to be carried out with high accuracy. Research conducted over several years allowed to develop a national system for genetic identification of species, which is compatible with the systems of the countries importing breeding stock to the Russian Federation. The developed systems are characterized by high accuracy - over 99% and are the only way to control the origin of offspring obtained in Russia. An example of the role of DNA technologies in the control of hereditary diseases is the elimination of the hereditary defect "Complex spinal defect" in cattle (Ivanov, 2019, Petrova et al., 2020).

Regarding fodder and fodder additives, the main trend is not only the best fodder conversion, but also the efficient use of locally produced fodder. Milk producers have refused GMO feed, but palm oil in fodder remains. It is necessary to look for alternatives. The main substitute for palm oil in compound feed is the addition of Rupiol Sunline. This product is rapeseed processed by new pneumohydrothermal technology, enriched with rapeseed oil of high feed value and further processed with sunflower oil. In cattle breeding, the main goal of the farmer remains the full implementation of an autonomous technological chain for automated extraction, transportation, mixing, and distribution of fodder. Recently, an autonomous animal feeding system was demonstrated, consisting of maneuverable and autonomously moving feed robots Shuttle Eco and a new unique elevator for fully automatic collection of silage in the silo pit. The feeding robot finds its way using the magnets installed on the floor. Autonomous litter and manure removal systems are already in practice. Another trend is automated, early diagnosis of hoof problems. The innovative MS Korund system proactively monitors the hooves: after milking, the cows are sent for an ultrasound MS Hoof Scan. After the next milking, cows with identified abnormalities are sent to a separate room for hoof processing and treatment. Innovations in milking technology are related to improved zootechnical recording of milk productivity, prediction of individual milk yield during milking, and alternatives to traditional teats. For example, the Smartflow electronic milk meter is designed completely without cables, the data is transmitted via UHF communication. A major improvement of the new De Laval Evanza ™ milking cluster is that it integrates the milking cups into an automatic system. Changing operations equipped with Top-Flow technology and a short milk hose is very simple and saves a lot of time (Artemova and Shlak, 2019, Golokhvostova, 2019).

The sensors used, which turn ordinary "analog" cows into "digital" ones, work as software devices and in a complex with several other devices - software and hardware systems, collect and register a cloud of data. Around the world, SmaXtec automatic monitoring systems began to appear in 2016. In Russia, they have been in use for a little over a year, which is a very short time for the conservative dairy market. Currently, their application is being tested in 47 companies, including 20 leading, vertically integrated agroholdings. Every month, the SmaXtec automatic monitoring system starts to be installed by about 2-3 new factories. But, the most important thing is that on the part of large, medium, and even small farms there is an interest in the digitization of their business and an understanding of the benefits that this digitization gives them (Mitin, 2018).

Animal health and welfare monitoring. In Smart Agriculture, CFS and Internet of Things (IoT) are used to improve productivity through modern technological means and to put permanently, the best results in terms of quality, quantity, and financial returns, as well as to ensure optimal environmental processes (Sowmya, 2019). Sensors embedded in agricultural machinery, in the soil, or attached to farm animals monitor certain parameters and send data for storage and processing. This is done to optimize decision-making processes with machine learning software that can analyze large amounts of data and optimize processes in real-time.

KFS has many areas and applications in industrial manufacturing, smart grids, autonomous vehicle systems, medical monitoring, industrial control systems, robotic systems, and avionics. In recent years, there has been a growing interest in the use of CFS in animal husbandry:

Swiss firm Anemon has developed a device that can detect when a cow is ready for insemination and send a text message to inform the farmer. A body heat sensor is implanted in the cow's genitalia, which transmits the results to another sensor on the animal's collar and monitors body movements. The collar also has a SIM card so the farmer can receive SMS notifications when the cow is ready to breed.

In Sweden, the protection of animals is taken seriously. Every animal is very important; it is valuable and has its right to welfare. Therefore, it is necessary to monitor the physiological state of each animal and this is the idea of precision animal husbandry. Ear sensors are installed to measure the heart rate of the animals. By measuring the heart rate, especially if you know the parameters of the animal's normal heart rate, you can determine if it has a fever, stress, or illness before visible symptoms appear. Then the farmer can act quickly and make the right management decisions.

Health problems and diseases can reduce animal performance by up to 33%, according to a Deloitte study. The trend towards more intensive systems in animal husbandry increases productivity, but can also have adverse effects and impacts on animal health and welfare and increase the risk of rapid and widespread disease outbreaks. More animal data can be collected using ICT and IoT, such as cameras and image recognition software, wearable devices, and weight or sound monitoring. In addition, data from animal buildings can also help improve animal health, for example by monitoring climate, air quality, and ventilation.

Systems for monitoring animal environment, health, growth, behavior, reproduction, emotion and stress are based on the many animal identification technologies available to livestock producers. The electronic identification system appeared in the 1970s. However, existing laws only refer to visual, legible markings applied to animals (EU Directives 92: 102: EEC and Directive 820: 97: EC).

Radio frequency identification (RFID) can be used to identify cattle (Yongqiang, et al., 2019). These devices have an electronic number that is unique to an individual animal and links that animal to a database. Electronic ear tags, injectable transponders, and intrareticulum transponder boluses are the latest technologies for animal identification. Many types of RFID tags are used for subcutaneous placement to identify animals. These systems work with radio frequency to send data. Boluses are stored in the first two stomachs of ruminants and are considered safe for animal health. Injectable transponders can be easily inserted after parturition, while the preferred sites are different for each animal species. These devices (implants, ear tags, and bolus) have a special chip to send data to the host computer. They have some specific components in terms of data storage and evaluation. Some electronic tags have a reader that can receive and store the necessary ratings (Yucel, Taskin, 2018). Some tags work by transferring data to another storage system for another stage of evaluation. Data is sent using a data antenna to the system. From a technological point of view, tags (RFID) can be divided into two categories, depending on the frequency range of the carrier: LF (low frequency) tags operate at frequencies of 125-134.2 kHz, and HF (high frequency) tags operate at 13 .56 MHz.

Another technology that is very useful for farmers is an electronic weighing system that accurately measures and records the live weight of animals. Thus, farmers can easily and continuously monitor the growth and development of their animals. The stored information is sent to the host computer for evaluation. Animals that have passed through the system are automatically categorized by age, sex, weight, and/or other criteria that the farmer prefers.

A major risk for cattle is an outbreak of an infectious or parasitic disease. The disease can spread quickly indoors. Many diseases show specific detection signals and the farmer can look for signs of stress, clinical pictures, and various injuries. An automated system can and should alert staff or possibly other systems to locate and identify affected animals before the problem becomes widespread. Animal disease has serious economic consequences. The accurate detection time of the disease-causing process from three to five days earlier reduces the cost of treatment, reduces the real mortality, and increases the efficiency of production. The technological parameters, the quality and composition of the homeostasis of the organism, the condition of the body, and the behavior are good indicators of the health status of the animals. Careful monitoring of changes in normal behavior ensures that animal health is monitored. For this, sensors are installed on a given animal to monitor the state of health. Sensor networks consist of several small, low-cost devices and logically self-organize into ad hoc systems. The role of the sensor network is to monitor animal health parameters and collect and transmit information to other nodes in the system. The sensors that collect data such as temperature, heart rate, respiratory movements, pH, etc. receive large amounts of data to be transmitted at regular intervals. Many new sensor technologies have been developed that can be useful in assessing animal health and behavior.

The most accurate livestock applications are based on monitoring tags attached to the animal (neck, leg, or ear tags) or inside the animal (bolus). This way of modern precision breeding systems is mainly used for large farm animals such as dairy and beef cattle, camels, and horses. The economic value of each large animal justifies the cost of tagging the animal, and large animals provide sufficient space to mount sensors.

Monitoring animal welfare behavior is challenging, but advances in technological capabilities now make automated monitoring of animal behavior possible. In addition, data from animal buildings can also help improve animal health, for example by monitoring climate, air quality, and ventilation. Therefore, the inclusion of behavioral criteria is important for the overall assessment of animal condition.

Another aspect of the use and processing of large amounts of data is related to technology for identifying reproducibility Detection and insemination results vary depending on many factors, such as the number of cows, barn configuration, and thresholds in statistical data analysis methods. Detection errors range from 17% to 55% and show a high number of false positives. Both inexpensive and expensive tools and technologies are available that meet some, but not all, realistic criteria. Traditionally, reproductive potential is detected by visual observation of the dairy herd in many countries, but this procedure is particularly difficult in large dairy farms due to the short periods of observation during feeding and milking. Research reports (Halachmi et al., 2019) note that the impact on herd size, age at calving, number of lactations, and calving interval is significant, and small farms tend to be more successful than larger ones. farms. As a result of technological advances in monitoring cows using computers, it has become possible to automatically detect new reproductive opportunities. Although the costs associated with computer reproducibility are higher than with other methods, the benefits can be offset by improved precision in determining reproductive problems, and errors can lead to huge economic losses for dairy farms. Pedometers are widely used to determine the reproductive capacity of cows and heifers by measuring their physiological activity over a while. Many pedometric systems on the market can be used to diagnose problem cows and heifers in herds.

The behavior of the cows allows the farmer to assess the welfare of the animals in various environmental and stressful situations, as well as to make an objective assessment of their reproductive and health status. Continuous measurement of animal behavior parameters can help collect data for many purposes, such as detecting early signs of medical problems to alert farmers in time for individual animals in need of special care.

Animal husbandry begins in the environment in which the cow lives. Many factors influence the sensitivity of cows to environmental conditions. The latest technology (Sharofidino et al., 2020) involves the use of sensors to collect data, followed by analysis of the data for further analysis and a system of interaction and development of control systems. These technologies aim to provide farmers with adequate data to optimize the efficiency of the farming system, thereby improving overall livestock performance. There are many sensors to automate environmental management in dairy farms. Temperature and relative humidity sensors; air velocity sensors, carbon dioxide sensors, ammonia and light sensors, etc. When the ambient temperature rises above 25°C, the cow uses its energy to cool down instead of producing milk. The effect of heat stress on the physiology and performance of dairy cattle is well known. Milk yield can be reduced by about 10 percent. At the same time, poor environmental factors such as air quality can negatively affect milk production and quality. High-producing cows need optimal indoor climate comfort throughout the year to maintain high production levels. The barn environment is also important. While the thermoneutral zone for cattle varies from -5 to +25 ° C; the thermoneutral zone for humans has shifted to higher air temperature ranges.

Modern technologies help to monitor the environment in the barn, where it can measure temperature, humidity, solar radiation, and brightness using various sensors. New technological tools allow us to monitor almost every aspect of the internal environment of livestock farms. Incorporating the environmental monitoring capabilities of wireless sensor networks into mobile monitoring systems can provide convenient indoor climate control anywhere and anytime for more productive animal production. Environmental sensors are the first automation component. The second component is a computer system for monitoring and controlling the environment, and the third is maintaining the connection between these two components.

Currently, there are no standards for the exchange of data generated by sensors, which limits the use of sensors available on the market. The development of methods to transform data into usable solutions is the main objective of the project's work package.

Modeling of processes and phenomena - processing large amounts of data and complex mathematical and computer models. Digital transformation is the process of using digital technologies to create new business models. It is also an approach oriented towards scientific achievements.

CFU and the Internet of Things (IoT) provide opportunities to create repositories of value from collected data. The value of data increases when unstructured data is processed, enriched, and analyzed to create useful information. The greatest potential lies in individual animal monitoring and analysis called *precision livestock farming*, where instruments and sensors are used to continuously and automatically monitor key performance indicators of farmed animals, such as animal health, productivity, and environmental stress.

Every day, Cyber-Physical Systems (CFS) and IoT systems generate huge amounts of data. The data stream generated by different IoT systems can be in different formats. Every format has a reason. It presents information with unique attributes, megadata, structure, and schema. The integration of data from different formats increases the need for different levels of competence, and this makes the process of integrating information flows important to the practice of scientific, technical, and business data.

Existing processes for collecting, processing, and using data are designed to perform some kind of routine task (Guhr , et al., 2019). Despite the progress made in recent years, these processes are not flexible and cannot be adapted to perform combined tasks that differ significantly from the standard ones. To complete the entire application cycle from data extraction to data transformation, several workflows must be combined. This leads to the use of complex architectures and difficulties in tracking work stages, which complicates and slows down the workflow and subsequent support. Known data integration processes need to be updated and efforts focused on implementing flexible, standardized processes and methodologies, including more and more types, formats, and volumes of data, while being easy to implement and reproduce. They should cover the entire path from collection, processing, analysis, and modeling to visualization and extraction of business value.

Devices 10, collect various data from audio and video to sensor data. Their appearance has led to the appearance of the term "Big Data" (Big Data) due to the large volume and variety of formats, which are more serious than the previously known text. IoT devices allow the user to collect data at predetermined time intervals, making them suitable for time series processing and modeling. There are various aspects of information related to IoT devices, which complicates the processing process. The data collected is too contradictory due to errors that occur during collection and transmission. This data is inherently very different, both due to the huge disparity in the data flow generated by different components and the existence of different timing patterns. The usefulness of data is highly dependent on the frequency with which it is collected and how it is processed.

Intelligent animal husbandry in Bulgaria. The program for intelligent animal husbandry envisages the creation of innovative methods and tools for the intelligent and efficient development of animal husbandry with reduced human resources and a reduced impact on the environment.

Researchers and breeders will have easy and controlled online access to tools, resources, and collaboration related to high-performance computing information and communication technologies. They will be able to connect and store data, as well as have access to virtual, research ecosystems and client networks (Vasileva, 2020).

International factors predisposing to the development of digitalization in animal husbandry:

-a pan-European network of digital service centers

-EU strategy for building a European market

-proposal of the EC for the digitalization of various spheres

Yet, the "Intelligent Animal Husbandry" program must develop a scientific methodology, systems, and tools for modeling the main processes in animal husbandry, namely: breeding, feeding, milking, and cleaning in animal husbandry, monitoring the physiological state of animals, the influence of climate, environment etc. Another important objective of the program is to develop a "methodology for genetics and breeding in animal husbandry".

In total, the program includes 12 panels:

1: Robotic Milking Systems - Creation of automatic cow milking systems and use of robots in various livestock processes.

2: Robotic systems for animals and farms - automatic feeding, watering, cleaning and disinfection of premises, automatic weighing and counting of animals, etc.

3: Intelligent Systems for Genetic Advances - Genomic Evaluation Systems. Sperm sexing systems. Creating technology to produce sexed embryos.

4: Intelligent systems for monitoring and analyzing the productivity of rangelands and meadows - stationary and mobile sensor systems for sampling and monitoring soil and rangeland parameters, computer vision, and remote methods for obtaining information about the state and quality of plant matter.

5: Cyber-physical monitoring systems, including IoT devices and sensor systems to monitor the environment, health, growth, behavior, reproduction, emotions, and stress of animals, as well as GPS tagging for animal tracking and counting.

6. Cyber-physical systems for intelligent management of livestock complexes, including Internet of Things devices and sensor systems for monitoring humidity, temperature, ventilation, lighting, dust, carbon dioxide levels, and other parameters.

7: Unmanned aerial vehicles - equipped with cameras for external monitoring and counting of animals and infrared cameras for monitoring animal health (temperature control).

8. Service robots and drones for storage and/or delivery of finished products - to manage the interaction with customers during the collection and delivery of orders, which will optimize the process, increase productivity, and reduce delivery time.

9: Inventory management - animal feed and liquids, cold storage for meat and milk processing, and distribution of supplies.

10: ICT technologies in financial, economic, and reporting activities - risk assessment, databases, communications, intranet, internet of things.

11: Digital technologies in teaching, working with young talents and special target groups.

12: Smart waste management as part of the circular economy, including the use of biodegradable waste, reducing environmental pollution, and improving the energy efficiency of livestock farms (Vasileva, 2020).

Conclusions. The growing spread of digital technologies around the world offers new opportunities to successfully meet the needs of different species and categories of domestic animals, as well as a variety of information for scientific, financial, and natural resource management Farmers are in keen need of practical, innovative and efficient network technologies. Livestock is a conservative subsector that lacks integration, but digitalization is actively being used.

References

1. Artemova E., Shpak N., 2019, Digitization as a tool for innovative development of dairy farming, Vesnik Academy of Knowledge, No. 31, (2), 15-19

2. Belaya A., 2020, The end of manual control. What digital technologies are being introduced at livestock enterprises, Agroinvestor, 3, 1

3. Buklagin D., 2020, Digital technologies and control systems in livestock, Scientific Quarterly Journal Machinery and technologies in livestock, No. 4, (40), 1-8

4. Burda A.G., 2018, The feasibility of using an electronic dairy herd management system in the context of digitalization of the economy / A.G. Burda, S.A. Burda // Scientific Bulletin of YuIM., No. 3. p. 38-43.

5. Vartanova M.L., 2018, Prospects for digitalization of agriculture as a priority direction for import substitution / M.L. Vartanova, E.V. Drobot // Economic relations. – Volume 8, No. 1, p. 1-18. 1-18.

6. Volkov G.A. Automated farm management system / G.A. Volkov, K.R. Nazarova, V.T. Izikov // Scientific forum: Innovative science: collection. Art. based on materials of the XIV International. scientific-practical Conf. - Moscow, Publishing house. “MCNO”-2018- No. 5 (14), p. 25-29.

7. Manilo I.I. Automated control system for the tethered keeping of animals / I.I. Manilo, I.N. Mikolaichik, V.P. Voinkov // Agrarian Bulletin of the Urals. 2017, No. 12 (166). p. 58-64.

8. Ivanov Y., 2019, Digital livestock farming: development prospects, Quarterly journal, VNIIMZH Bulletin, No. 1, (3), 4-7

9. Golokhvostova E., 2019, Eiro Tier 2018: Livestock, Agricultural News https://agri-news.ru/zhurnal/2019/12019/eurotier-2018-zhivotnovodstvo-4.0.html

10. Kozina A.M., 2018, The use of digital technologies in milk production / A.M. Kozina, L.P. Semkiv // Bulletin of the Novgorod branch of RANEPA. 2018. Volume 8. No. 2-1 (10). p. 13-18.

11. Kozubenko I.S., 2018, Introducing digital technologies / I.S. Kozubenko // Information Bulletin of the Ministry of Agriculture of Russia - No. 7, p. 13-19.

12. Mitin V., 2018, IitWeek, No. 7, (943) https://www.itweek.ru/digitalization/article/detail.php?ID=204622

13. Petrova O., Barashkin M., Melshtein I., 2020, Digital livestock farming, New Russia, No. 8, 185-189

14. Smirnov I.G. 2019, Development of technological processes and technical means for intelligent technologies for cultivating shrub berry crops: Abstract of Thesis, Doctor of Engineering Sciences: 05.20.01. M., p. 47

15. Surovtsev V.N., 2018, Mastering digital technologies as the basis for the strategy for the development of dairy cattle breeding [Text] / Surovtsev V.N. // APK: Economics, management – No. 9. p. 108-117.

16. Tkachenko V.V., 2018, Development of a comprehensive automated information system for decision support in the management of technological processes of crop production (based on materials from the agro-industrial complex of the Krasnodar Territory) / V.V. Tkachenko, N.N. Lytnev // Bulletin of the Academy of Knowledge, No. 29 (6), p. 249-253

17. Fedorov A., Kondratyeva O., Slinko O., 2019, On the prospects for digitization of livestock farming, Mechanization, automation, and machine technologies in livestock farming, Vestnik VNIIMZH, No. 1, (33), 127-132

18. Borcard D., Gillet F., Legendre P. 2011, Numerical Ecology' with R: Springer

19. Deloitte,2017, Smart Livestock Farming Potential of Digitalization for Global Meat Supply, https://www2.deloitte.com.

20. Guhr S., Martenson J.,2019, Laser II. Data Science as a Service - Prototyping for an Enterprise Self-Service Platform for Reproducible Research: IARIA - The Fifth International Conference on Fundamentals and Advances in

Software Systems Integration - FASSI.

21. Honchar O, Shevchenko Ye, Gavry`sh O. Selekciya u krolivny`cztvi: vse avtomaty`zovano Agrobiznes s`ogodni. Gazeta pidpry`yemciv APK. 2013. 5 (252) 51s.

22. Halachmi T, Guarino M., Bewley J., and Pastell M., 2019, Smart Animal Agriculture: Application of Real-Time Sensors to Improve Animal Well-Being and Production, Annual Review of Animal Biosciences, Vol. 7: 403-425, February 2019.

23. Yongqiang C., Shaofang L., Hongmei L., Pin T. and Yilin C.,2019, Application of Intelligent Technology' in Animal Husbandry- and Aquaculture Industry, 2019 14th International Conference on Computer Science & Education (ICCSE), Toronto, ON, Canada, pp. 335-339.

24. Yucel Banu, Turgay Taskin,2018, (Eds.) Animal Husbandry and Nutrition, Intech Open 2018.

25. Jazdi N.,2014, Cyber physical systems in the context of Industry' 4.0 - Romania: IEEE International Conference on Automation, Quality and Testing, Robotics.

26. Liakos G., Busato P., Moshou D., Pearson S., Bochtis D.,2018, Machine Learning in Agriculture: A Review: Sensors, Volume 18, Issue 8-2018.

27. Molnar Ch.2020, A Guide for Making Black Box Models Explainable. Chapter 4, Interpretable Machine Learning, 2020.

28. Sanfelice R.,2016, Analysis and Design of Cyber-Physical Systems. A Hybrid Control Systems Approach, Cyber-Physical Systems: From Theory to Practice, D. Rawat, J. Rodrigues, I. Stojmenovic — CRC Press

29. Sowmya J., Shetty Ch.,2019, IoT and Data Analytics Solution for Smart Agriculture: The Rise Fog Computing in the Digital Erap — Vol. 9, IGI Global.

30. Sharofidinov F., Muthanna M.S.A., Pham V.D., Khakimov A., Muthanna A., Samouylov K.,2020, Agriculture Management Based on LoRa Edge Computing System. In: Vishnevskiy V.M., Samouylov K.E., Kozyrev D.V. (eds) Distributed Computer and Communication Networks. DCCN 2020. Lecture Notes in Computer Science, vol 12563. Springer, Cham

31. https://ru.euronews.com/next/2020/03/23/fu-16-iof-precision-farming-master

32. http://www.meridsmart.com

33. http://www.ovalert.nl

УДК 636
DOI: https://doi.org/10.37617/2708-0617.2024.10.7-21

ЦИФРОВІ ТЕХНОЛОГІЇ У ТВАРИННИЦТВІ

Markov N.T.,
Hristov M.S.,
Mondeshka L.I.,
Markov T.N.

Науково-дослідний інститут гірського скотарства та землеробства, 5600 Троян, Болгарія. Сільськогосподарська академія Болгарії
**Автор для переписки (ncm64@ mail.bg)*

У роботі оцінено поточний етап розвитку інноваційних технологій в аграрному секторі, відповідно у тваринництві та перспективи цифрової трансформації аграрного сектору. Визначаються цифрові технології та різні інші автоматизовані системи. Досліджено особливості та тенденцію зростання цифрових інновацій у тваринництві, а також фактори, що впливають на технології в цій підгалузі. Цифрові технології, які є основою сучасних систем управління та оптимізації технологічних процесів у тваринництві, дозволяють збирати своєчасну якісну інформацію, необхідну для прийняття правильних управлінських рішень, оптимізації ресурсів та значного зниження собівартості продукції. Ретроспективний аналіз показує, що проблемні господарства можна вивести на діджиталізацію лише за умови серйозних фінансових вкладень. Фермерам гостро потрібні практичні, інноваційні та ефективні мережеві технології. Тваринництво – консервативна галузь, яка не інтегрована, але цифровізація активно застосовується.

Ключові слова: *цифровізація, тваринництво, штучний інтелект, інноваційні технології*

Подяка

Към ръководството на Панел-5 на ННП “Интелигентно животновъдство“ за оказаната логистична и морална подкрепа.