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INNOVATIVE TECHNOLOGIES IN EQUINERY

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The research is devoted to a review of innovative technologies used in the world horse breeding. Innovations include ensuring a long, healthy life for horses, precision medicine, laser and PRP therapy, rehabilitation and training programs, monitoring media platforms, genetic and biotechnological methods, development of ecological and safe coatings, use of recycled materials for buildings, automated microclimate systems and waste collection, automatic feed dispensers with customized schedules, real-time feed and water consumption monitoring tools.

The most revolutionary ideas concern the development of smart technologies for horse training with monitoring of physical condition. Such developments include wearable GPS tracking devices and heart rate monitors, trackers for tracking horse movement over distances, satellite tracking technologies, saddle pads with sensors of active points on the horse's body, a horse movement analysis system, 3D imaging and motion capture tools, and mounting headsets for athletes. Much attention is paid to the safety of equestrian sports, especially children's and parasports, in connection with which protective equipment has been developed (helmets made of modern materials, pneumatic jackets and vests). An important sector of innovation in horse breeding is technologies that have a positive impact on the environment - the use of environmentally friendly materials and construction technologies in the construction of stables and sports arenas, the use of ecological bedding, manure composting systems with subsequent processing into organic fertilizers, energy-efficient design, the use of renewable energy, landscaping of horse breeding areas. It is noted that the horse breeding of the future, along with all areas of human activity, is closely related to the further development and integration of technologies.

According to the results of the research, the prospects for the development of technologies in horse breeding are outlined.

Keywords: horses, equestrian industry, equestrian sport, innovative technologies, monitoring



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Дослідження присвячені огляду інноваційних технологій, що застосовуються у світовому конярстві. Інновації стосуються забезпечення тривалого здорового життя коней, прецизійної медицини, лазерної та PRP-терапії, реабілітаційних і тренувальних програм, моніторингових медіа-платформ, генетичних та біотехнологічних методів, розробки екологічних та безпечних покриттів, застосування перероблених матеріалів для будівель, автоматизовані системи мікроклімату і прибирання відходів, автоматичні дозатори кормів із налаштованими графіками, моніторингові інструменти споживання корму та води в реальному часі.

Найбільш революційні ідеї стосуються розвитку розумних технологій тренінгу коней з моніторингом фізичного стану. До таких розробок відносяться натільні пристрої GPS-відстеження і монітори серцевого ритму, трекери відстеження пересування коней на дистанції, супутникові технології стеження, килимки під сідло з датчиками активних точок на тілі коня, систему аналізу рухів коня, інструменти 3D-зображень і зйомки рухів, гарнітури кріплення для спортсменів. Багато уваги приділяють безпеці кінного спорту, особливо дитячого та параспорту, у зв'язку з чим розроблено засоби захисту (шлеми з сучасних матеріалів, пневматичні куртки та жилети). Важливим сектором інновацій у конярстві є технології, що позитивно впливають на екологію - використання екологічно чистих матеріалів і будівельних технологій при будівництві стаєнь і спортивних манежів, застосування екологічної підстилки, системи компостування гною з подальшою переробкою в органічні добрива, енергоефективний дизайн, застосування відновлюваної енергії, озеленіння територій конярських підприємств. Зазначено, що конярство майбутнього поряд з усіма сферами діяльності людини, тісно пов'язане із подальшим розвитком та інтеграцією технологій.

За результатами досліджень окреслено перспективи розвитку технологій у конярстві.

Ключові слова: коні, кінна індустрія, кінний спорт, інноваційні технології, моніторинг.

Introduction. Ukraine is a country with ancient traditions and a rich history of horse breeding and horse breeding. Despite the current challenges caused by the war, the industry is promising. With its development, the requirements for the technology of running the industry, innovative solutions for ensuring all elements of keeping, training, protection, and monitoring the productivity of horses will also grow. The horse industry



in developed countries of the world is currently undergoing a significant transformation, new high-tech means of monitoring the health and fitness of horses are being developed, robotic technologies for keeping, training, and restoring the body of horses after physical and nervous stress are being introduced. Innovative technologies not only increase the quality and accuracy of methods, but also open up new prospects for the development of scientific thought regarding improving the sports results of horses. Therefore, innovative technologies should radically and positively change the horse industry, including in Ukraine.

Given the relevance of this issue, the purpose of the work was to study innovative technologies used in the horse industry of the world.

Materials and methods. A systematic review of literature sources was carried out by searching for publications in the databases Scopus, Web of Sciences, Google Scholar, etc., published in Ukrainian and English in recent years in accordance with the inclusion criteria. The systematization of published data was carried out with the aim of accumulating modern scientific knowledge on innovative technologies in horse breeding for further building our own methodological basis for research in this area in domestic conditions, taking into account international experience.

Research results. The countries with the largest number of horses in the world are the USA (over 10 million), China (9 million), Mexico (6.4 million), Brazil (5.5 million), Argentina (3.6 million). In total, according to FAO data (DAD-IS, FAO 2023), there are about 60 million horses of more than 200 breeds in the world. More than half of them are kept on the American continent (55.2%).

The horse breeding of Ukraine is currently represented by a horse population of about 200 thousand individuals, with about 3 thousand of breeding animals identified as pedigree (Tkachova I. V., 2024). Most of the horses are used (agricultural, rental, tourist, hobby-class horses), horses used in sports - about 20%. The leading horse breeds are the Ukrainian riding horse, thoroughbred riding horse, Ukrainian and Oryol trotter, Novooleksandrivskaya heavy-duty. Recently, riding horses of European selection have been gaining considerable popularity, which are actively used in sports.

The priority in the horse industry is to ensure a long healthy life for horses, and in this direction, innovative tools and methods of diagnostics, treatment and health prevention have developed significantly (Zhang, Y., & Liu, H., 2020). These tools allow for faster and more accurate detection of health problems in horses that were previously difficult to detect (for example, tendon damage that is not visible on X-rays). Video surveillance equipment allows the veterinarian to remotely monitor the health of the horse, which is effective in sparsely populated regions. Recently, precision medicine has been increasingly used in veterinary medicine - laser and PRP therapy (platelet-rich plasma) of tendons and joints of horses that are exposed to significant physical exertion, accelerating recovery time after strenuous training and competitions. The advantages of laser therapy are that it is non-invasive and stimulates blood circulation and metabolic activity using intense, focused light. PRP is an injection treatment that promotes healing by delivering a concentrated dose of platelet-rich plasma to the damaged area of the body. The use of platelet-rich plasma and allogeneic mesenchymal stem cells in veterinary therapy promotes the healing of tendons and ligaments, however, this sometimes triggers an immune response in the horse, destroying the added stem cells. According to studies of the last decade (Trelford C.B. et al., 2022; Deng Z. et al., 2024), the addition of the growth factor TGF- β 2 successfully blocks this immune response, with the survival of treated stem cells being 50% higher than that of untreated cell cultures. Preliminary observations suggest that in the future this therapy may be used to treat similar injuries in humans.



Innovative approaches are also being used in the treatment of musculoskeletal injuries in horses, ensuring full restoration of functionality. Therefore, hydrogels and bioactive dressings are being improved, which provide a favorable environment for wound healing, while preventing the formation of granulation tissue (Fatima A. et al., 2024). Rehabilitation also plays a crucial role for sports horses, as it helps to prevent re-injury and prolong active life (Annamiyradov K. et al., 2025). Specially designed training programs using innovative tools that take into account the individual characteristics of each horse can significantly increase its physical fitness and performance (Kurhaluk N. et al., 2023). It is also important to pay attention to the psycho-emotional state of horses, as stress and anxiety can negatively affect the recovery process. Here, innovative means of creating comfortable conditions for rapid recovery come to the rescue. In addition, an important aspect of rehabilitation is teaching owners the correct methods of caring for animals during the recovery period. This includes recommendations on diet, physical activity and regime, which allows to provide optimal conditions for recovery. Developed applications for gadgets and media platforms have brought communication between horse owners, veterinarians and trainers to another level, exchanging information and learning from each other's experiences and knowledge (Broms, L. et al., 2021; Hii C. et al., 2020). Monitoring the processes occurring with the horse (training regimen, rations and feeding schedules, medical history, pregnancy progress, etc.) in real time can be carried out more effectively and organized thanks to a mobile application on a regular smartphone or tablet. For example, the “Sleip” smartphone application uses a video of a horse in motion to track the movement of certain points of the body for further evaluation of the data by the veterinarian and trainer (Fig. 1).



Fig. 1. The Sleip smartphone application for step-by-step analysis of a horse's condition in real time (photo from the Sleip website)

Due to the high value of individual horses (outstanding sports horses, especially valuable stallions and mares, rare breeds), reproductive technologies are being developed



to increase fertility and further improve genetic selection (Palmer E. & Chavatte-Palmer P., 2020). The most important effect of new technologies is their contribution to genetic selection and genetic progress (increasing genetic value in a population from one generation to the next). Innovations in biotechnology – cell division, embryo transplantation, cloning, preservation of biological material in vitro – allow to accelerate the improvement of horses (Cabeza J. P. & Gambini A., 2023). Embryo transfer technology in equine reproduction is not very new and has been used quite successfully to reproduce the outstanding Landim horses (Alvarenga F.C. et al., 2008), but it is constantly being improved to increase survival and maintain viability during transportation. Thus, recently it has become possible to store embryos at 5°C for 12-24 hours and transport them to the transplantation site. Embryo freezing has become more common using the technique of vitrification of embryos >300 µm or dehydration of embryos >300 µm before freezing. The ability to wash oocytes from mares and fertilize them by sperm injection has revolutionized the approach of veterinarians to infertility in mares and stallions (Squires E. et al., 2020). Despite the complexity of implementation and the high cost of innovative reproductive technologies, they are a promising tool that can have a positive impact on the preservation of horse populations that are under threat of extinction and reproduce unique individuals (Turghan M. A. et al., 2022).

Regarding horse keeping technologies, the development of innovative floor coverings can be highlighted, because traditional materials - concrete, wood - have a negative effect on the joints and hooves of horses. Innovative materials provide shock absorption, hygiene, better grip (prevention of slipping), easy cleaning, and therefore - reduced veterinary costs. Indoor arenas ensure the comfort of sports horses and riders, environmental friendliness, and the ability to train in any season and weather in optimal conditions. In an indoor training room, it is possible to provide comfortable temperature, humidity, lighting, install smart microclimate systems, and cleaning (McGill S. et al., 2023). Modern climate control systems play an important role in the horse keeping system, which is especially relevant in conditions of climate change and in difficult natural and climatic regions. Automated climate control systems provide comfortable living conditions in horse facilities and equestrian facilities regardless of the external environment. They create optimal temperature and humidity indicators, improve air quality through filtration, reduce respiratory problems and heat stress, improve the comfort of horses during rest and recovery from stress in any climatic conditions. Animal husbandry systems are closely related to environmental safety issues. Environmental safety is a priority issue of the modern world, and the horse industry is no exception, although it is one of the safest for the environment (Kic P. et al., 2024). In this direction, innovative solutions include the use of environmentally friendly local, as well as recycled and recovered materials and construction technologies in the construction of horse-breeding facilities, which has a positive impact on environmental safety, as well as energy-efficient design - maximizing natural lighting and ventilation, the use of renewable energy devices (solar panels and wind generators), landscaping the territory of the horse-breeding enterprise, which has a positive impact on both the environment and the psycho-emotional state of horses and people. An interesting environmental innovation is a comfortable, well-absorbing bedding for horses made of recycled paper or hemp, which is more profitable than traditional straw. Horse manure composting systems that convert waste into highly nutritious fertilizers for the soil also require attention, which solves the problems of pasture fertilization and prevents pollution of the stable area and the environment.

Innovative horse feeding systems play a vital role in rations for horses of different purposes and workloads, maximizing bioconversion and reducing feed waste. Advanced



feeding systems are revolutionizing our approach to horse feeding, offering precision and efficiency that were previously unattainable. Innovative horse feeding systems include automatic feed dispensers with customizable schedules, real-time feed and water consumption monitoring tools, and integration with health monitoring systems for personalized feeding plans. These systems not only ensure that horses are getting the right amount of food at the right time, but also provide valuable data to veterinarians and nutritionists to optimize horse diets.

Individual balancing of horse diets is not a new process, however, in recent years, various manufacturers have offered a huge number of feed additives aimed at leveling oxidative stress, which contribute to the rapid recovery of the body, improving sports performance and health (Andriychuk A.V. et al., 2021). Such additives contain amino acids, vitamins, macro- and microelements, Omega-3 fatty acids and other elements that protect cell membranes, structural proteins, DNA and contribute to excellent health and high sports performance of horses. Recently, more and more animal nutrition products have been developed using nano-technologies. Such products, as prebiotics and probiotics, help solve problems in the digestive system of horses caused by pH instability, improve nutrient absorption and strengthen immunity. Today, the market offers a huge range of horse feed products and it is developing with the progress of scientific research into the physiology of horse nutrition and the chemical industry. In this situation, the horse owner needs to decide what exactly and in what quantities his horses need, and what can harm their health and turn out to be just an unnecessary expense. Timely hydration is of great importance in the daily routine of the stable and the comfort of the horses, and therefore the introduction of controlled drinkers is an important element of technology. An innovation in this process are non-contact ultrasonic sensors, similar to those of the Cascada Automatic Waterer, which monitor hydration using algorithms based on data collected over a long period of time, with information available via smartphone from anywhere in the world (Fig. 2). The device is attached to a stable wall, holds a 20-liter bucket and can be configured to heat the water flow to the desired temperature to prevent freezing.



Fig. 2. Cascada Automatic Waterer



A real revolution in horse training technology has been the introduction of wearable GPS tracking devices and heart rate monitors (Horsepal), which allow real-time monitoring of the horse's speed, distance and heart rate during training, and help the trainer adjust the training. The development of wearable devices (smart halters, limb sensors) has changed the level of horse health management, such devices provide real-time data on the horse's vital signs, activity level and sleep pattern (Fig. 3).

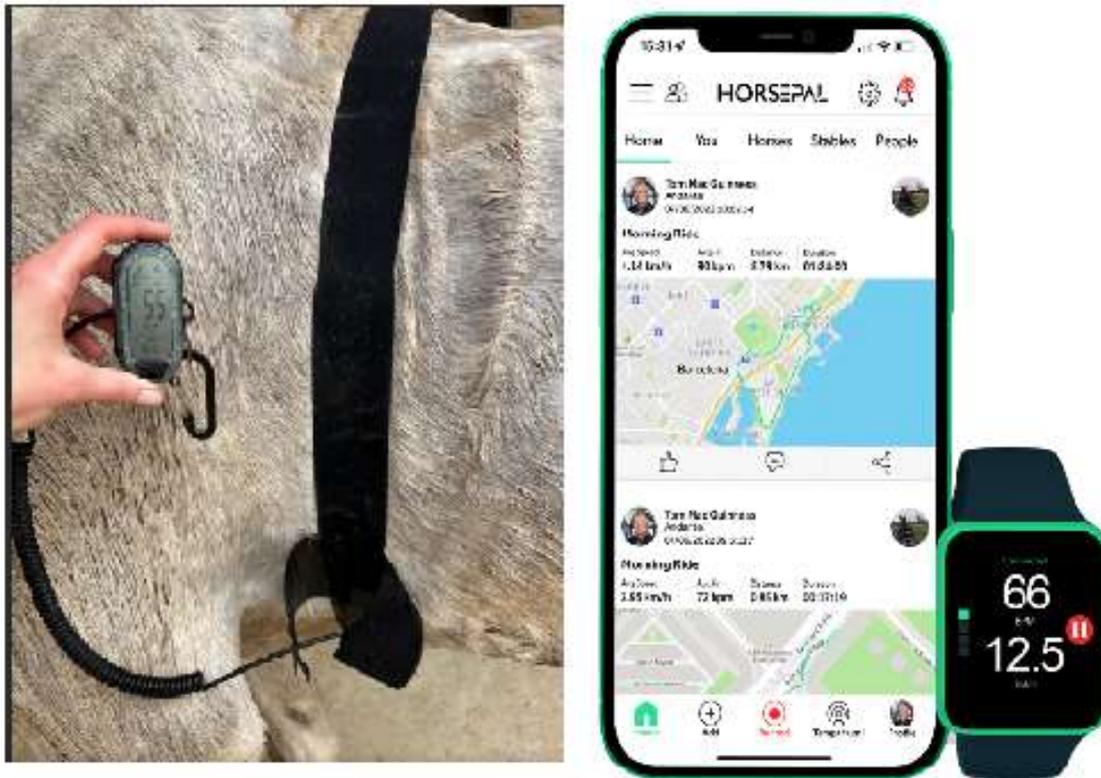


Fig. 3. GPS tracking device and heart rate monitor (Horsepal)

GPS tracking devices for distance analysis such as (EQUIMO type trackers) help to track how a horse moves over a distance on a racetrack or competition field and monitor liveliness, distance, height, angle and specific turns, etc. (Fig. 4). The tracker determines the time spent on each gait to adjust the optimal pace of movement over the distance. The recording function allows you to compare sessions to determine trends and progress. By measuring and analyzing precise changes in limb extension and joint flexion, trainers know what the horse is feeling. The value of these measurements is that they are completely unbiased and eliminate any subjectivity.

In recent years, the horse identification system has become mandatory to implant electronic chips into the horse's muscles with unique numbers, which allows for quick identification of horses. Connecting such chips to a GPS satellite navigation system makes it possible to track the movements of horses, especially when kept in herds or tracking feral populations (for example, the Przewalski's horse population in the Chernobyl Exclusion Zone).



Fig. 4. Sensor for a horse's limb

Interesting devices are saddle pads with sensors (such as Estride with 900 sensors) for monitoring saddle pressure, which measure pressure points on the horse's back during riding and jumping. Such pads control whether the saddle is properly fitted, which helps to avoid discomfort for the horse and back injuries. Thermography with a heat sensor tracks pain points due to ill-fitting equipment or excessive pressure (weight) which leads to increased blood flow and body temperature in the affected area of the horse's body. The readings from these sensors can also be useful for manufacturers of equine equipment for further adjustment and improvement (Figure 5-6).



Fig. 5. Sensors on the saddle and key points of the horse's movement (photo from the Fairfax website)



Fig. 6. Horse gait analysis mapping (photo from Fairfax Saddles Ltd)

Horse gait analysis systems (such as StrideSAFE carriers) allow for accurate assessment of horse gait, pre-purchase lameness detection, and general gait monitoring (Calle-González, N., 2024). Objectively identifying potential problems such as uneven strides, lameness, asymmetry, or gait inefficiency assists in the subjective examination of horses by veterinarians. This technology can also be used to detect hidden injuries. A horse will move in a way that minimizes discomfort, so naturally, if it is in pain, it will choose a different mode of movement. The StrideSAFE system analyzes about 3,000 readings per second and captures even the smallest changes in the horse's gait, helping to detect potential injury before the rider feels the change.

The use of 3D imaging tools makes it possible to analyze the conformation of the horse, identifying parts of the body where there has been an improvement in musculature or movement, as well as to monitor the ontogenesis of foals. In this direction, very interesting research was carried out by Giraudet C. et al. (2023), who developed a system based on underwater camera markers and cameras on the horse's body during hydrotherapy of sport horses (Fig. 7).

In addition, 3D motion capture (Mocap) systems are used to assess the biomechanics of a horse during a jump, identifying inefficiencies, stress zones and risk factors for injury. Cameras are placed around the sports field and track the movement of reflectors attached to the horse's body, accumulating data on limb movement, joint angles, and overall symmetry (Fercher, C., 2024). The Mocap device is the most accurate for measuring movement analysis and is used by athletes, but it is expensive and difficult to set up, requiring special training for the user. A more economical analogue of this device are inertial measurement unit (IMU) sensors, which are small wireless devices that measure acceleration, orientation, movements of different parts of the body, and provide information about joint angles (Parmentier J. I. M. et al., 2023). Thus, Hatrisse C. and colleagues (2022) used an inertial measurement unit located on the pasterns, hooves, and withers of trotting horses to determine gait phases on different sections of the racetrack with different track surfaces and set the load on the limbs (McGill S., 2023). In the training system of equestrian athletes, a very interesting niche is increasingly occupied



by virtual reality technologies in the form of video monitors and headsets attached to the athlete, reacting to body movements and rein pressure. The devices simulate the movements of a horse and allow the athlete to improve riding and jumping skills, orientation on the competition site or on the racetrack track where he plans to perform. Using this innovation allows the athlete to train without unnecessary strain on the horse and additional risk of injury. In addition, virtual reality systems allow people to feel like riders when it is impossible to engage in real horseback riding.

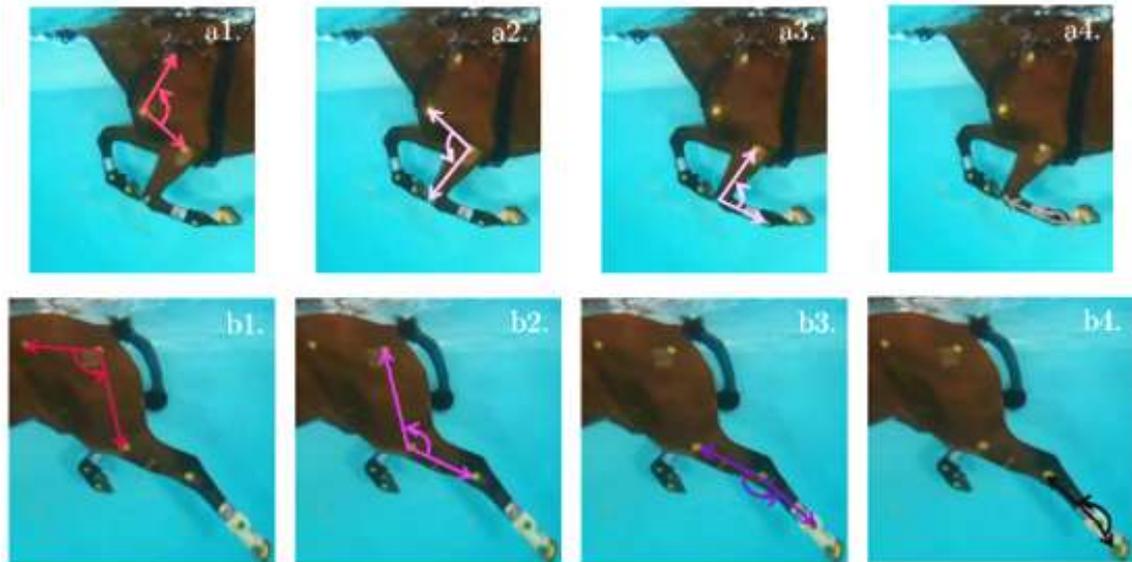


Fig. 7. Calculating the anatomical angles of a horse's limbs during hydrotherapy using 3D reconstruction (Giraudet C. et al., 2023)

An urgent problem is the safety of athletes, especially children and people with disabilities, because equestrian sports are considered one of the most dangerous sports. Therefore, various companies producing sports equipment and gear are working on creating and improving protective equipment for equestrian athletes. A good example is the Point Two USA campaign, which created innovative pneumatic jackets and vests for riders like airbags in cars (Dyer R. F. & Irizarry R. P., 2014). Riding helmets are made of modern materials (advanced polycarbonate), they combine lightness, maximum impact resistance, durability, advanced design. Such helmets have a carefully designed ventilation system, sun visors. Some models are equipped with a built-in microchip, onto which you can download data about the rider's health using the KER program, which can speed up the provision of first aid and in addition - equipped with video cameras for further analysis of the performance

In recent years, the use of unmanned aerial vehicles in economic activities and the agricultural sector in particular has developed significantly. Unmanned aerial vehicles can be very useful for filming and further studying the horse's test route, recording the course of the race (Fig. 8), as well as when overcoming obstacles, which allows you to monitor jumps from different angles and perform a detailed analysis of the jump model and the overall sports performance of the rider-horse pair.



Fig. 8. Recording of hippodrome races using a drone (image created using AI)

Management of a horse breeding enterprise is becoming increasingly efficient thanks to the introduction of satellite platforms that provide information on land use optimization, the state of the forage crop harvest, pasture health, control of horse movement during grazing, and allow you to track weather conditions for planning outdoor activities (Lupoae O.-D., 2024). Maintaining pedigree, accounting and other documentation, exchanging information between horse owners and stud inspectors, etc. on paper is a thing of the past thanks to the spread of software and mobile technologies (Johnson, M. & Carter, R., 2021). Management takes place in an automated mode in real time, which allows for rapid receipt and analysis of information.

As a result of the conducted research, it can be stated that innovative technologies introduced into the horse industry are directed in the directions presented in Table 1.

Discussion. According to the results of research, innovative technologies in horse breeding can be divided into separate blocks:

- innovative tools and diagnostic methods, means of treatment and prevention of horse health (precision medicine, modern drugs for treatment and prevention, means of protection and rehabilitation of horses);

- innovations in genetics and reproduction (genetic selection, DNA technologies, embryo transplantation, cloning);

- innovations in housing technology and environmental safety (use of recycled materials for the construction of stables and arenas, use of modern floor covering materials, introduction of renewable energy sources and waste disposal technologies);

- innovations in feeding (innovative feeds enriched with probiotics, vitamin-mineral premixes, preparations for strengthening immunity);

- digital technologies, automation and robotization of technological processes (software platforms for monitoring the condition of horses in real time, activity sensors, feeding and watering monitoring systems, robotic cleaning systems, microclimate regulation systems);

- automated management in real time.

Innovative achievements not only improve the lives of horses and the sporting achievements of riders, but also revolutionize the approach of equestrian professionals to their work. From small family farms to large competitive horse breeding enterprises, the impact of modern technologies is increasingly developing throughout the world's equestrian industry.



Table 1

Innovative technologies in horse breeding

Direction of development	Innovative technologies, means
Instruments and diagnostic methods, means of treatment and prevention of horse health	Precision medicine, modern drugs for treatment and prevention, means of protection and rehabilitation of horses
Genetics and reproduction	Genetic improvement programs, DNA technologies, embryo transfer, cloning
Comfortable life of horses, environmental safety,	Environmentally safe materials for buildings, floors, bedding
Healthy feeding, economical hydration systems	Innovative safe and nutritious feeds enriched with probiotics, vitamin and mineral premixes, preparations for strengthening immunity, controlled drinkers with moisture sensors, heart rate monitors
Digital technologies, artificial intelligence in training horses	GPS tracking devices, smart equipment for horses, trackers, satellite systems, 3D imaging and video recording tools, virtual reality technologies
Equestrian safety	Innovative equipment for riders (impact-resistant helmets with health analyzers, pneumatic jackets and vests)
Surveillance systems	Use of unmanned aerial vehicles to monitor training, movement, and horse protection
Automated management	Management of a horse breeding enterprise on satellite platforms using programs adapted to business conditions

Technologies are progressing and revolutionizing our daily lives, providing us with more information about health, finances and the world around us, while making it easier to perform tasks that may have seemed impossible a few years ago. The future of horse breeding, like any other field of human activity, is closely linked to the further integration of technologies. The development of new methods of genetic analysis, reproductive technologies, the creation of new materials and smart management systems, and the improvement of environmental sustainability allow the horse breeding industry to be in demand and competitive.

Conclusion. The modern horse industry in the world is constantly improving due to the development and implementation of innovative technologies that concern all sectors of the industry - genetics and reproduction, maintenance and feeding, training, monitoring and management. The priority in the horse industry is to ensure a long healthy life for horses, which is ensured by developments in veterinary medicine and pharmacology, genetics and biotechnology, nutrition physiology and feed production, nanotechnology and nanomaterials, and the use of artificial intelligence in monitoring systems and management of horse breeding enterprises.

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