DOI 10.32900/2312-8402-2024-131-139-148
UDC 334.732.6

CURRENT TRENDS IN INDUSTRIAL TECHNOLOGIES FOR CONSTRUCTION OF LIVESTOCK PRODUCTS PRODUCTION: INNOVATIVE CHANGES AND INTERNATIONAL EXPERIENCE

Nesterenko Vitaly, PhD in Agricultural Sciences, senior researcher
https://orcid.org/0000-0002-6853-5699
Livestock Farming Institute of NAAS, Kharkiv, Ukraine

The article summarizes the main principles, regulatory requirements, as well as innovative changes and international experience of agricultural construction for industrial animal husbandry. The author presents new technologies for the construction of facilities for industrial animal husbandry, the specifics of the construction of industrial robotic complexes and farms. The use of a rapidly erected Ruukki building based on light metal structures and a frame made of light steel thin-walled structures and the specifics of creating a microclimate in premises for industrial maintenance are represented, which makes it possible to reduce the level of capital investments in production, increase labor productivity and the profitability of animal husbandry. It has been proven that the industrialization of animal husbandry is mainly related to the volumetric planning solutions of agricultural enterprises, and the use of new volumetric planning solutions in the construction of farms and complexes, monoblock and multi-story buildings is more effective in comparison with the pavilion construction of the farm, which is characterized by: a relatively small, separate room for keeping livestock and accommodating other services; a significant building area, extensive engineering communications, a low level of mechanization, high specific labor costs and operating costs. The role of perfect sewage networks and treatment facilities in the functioning of buildings for industrial animal husbandry is presented. Special emphasis is placed on the fact that in order to introduce a more effective technology of keeping animals without tethers, standard reinforced concrete premises are often reconstructed or new easily assembled structures are built. Certain problematic aspects of the functioning of livestock complexes for the environment, in particular for water resources and the atmosphere, are also outlined. The author proposed the production of biogas from them as a promising way to solve the problems of environmental protection, obtaining alternative energy resources and integrated use of industrial animal husbandry waste. In order to simplify the operation of the farm, to comply with zoohygienic, physiological and technological standards and the requirements of industrial animal husbandry, it is recommended to introduce a round farm.

Key words: *agriculture, industrial animal husbandry, animal husbandry, technology, farm.*

СУЧАСНІ ТЕНДЕНЦІЇ У БУДІВНИЦТВІ ДЛЯ ПРОМИСЛОВИХ ТЕХНОЛОГІЙ ВИРОБНИЦТВА ПРОДУКЦІЇ ТВАРИННИЦТВА: НОВАТОРСЬКІ ЗМІНИ ТА МІЖНАРОДНИЙ ДОСВІД

Нестеренко В. В., к. арх., с. н. с., https://orcid.org/0000-0002-6853-5699
Інститут тваринництва НААН, м. Харків, Україна

У статті узагальнено основні засади, нормативні вимоги, а також новаторські зміни та міжнародний досвід агробудівництва для промислового утримання тварин. Автором подано нові технології будівництва споруд для промислового утримання тварин, специфіку будівництва виробничих роботизованих комплексів і ферм. Репрезентовано використання швидкозведеної будівлі Ruukki на основі легких металоконструкцій і каркасу з легких сталевих тонкостінних конструкцій і специфіку створення мікроклімату в приміщеннях для промислового утримання, що дає змогу знизити рівень капіталовкладень у виробництво, підвищити продуктивність праці і рентабельність тваринництва. Доведено те, що індустріалізація тваринництва переважно стосується об'ємно-планувальних рішень сільськогосподарських підприємств, а використання нових об'ємно-планувальних рішень при будівництві ферм і комплексів моноблочна та багатоповерхова забудова є більш ефективною у порівнянні з павільйонною забудовою ферми, для якої є характерними: відносно невелике, відокремлене одне від одного приміщення для утримання худоби і розміщення інших служб; значна площа забудови, розтягнутість інженерних комунікацій, низький рівень використання засобів механізації, високі питомі затрати праці й експлуатаційні витрати. Подана роль досконалих каналізаційних мереж та очисних споруд у функціонуванні будівель для промислового утримання тварин. Особливий акцент зроблено на тому, що з метою запровадження більш ефективної технології безприв'язного утримання тварин часто реконструюються стандартні залізобетонні приміщення або будуються нові легкозбірні споруди. Також окреслено певні проблемні аспекти функціонування тваринницьких комплексів для навколишнього середовища, зокрема для водних ресурсів і атмосфери. Перспективним напрямком розв'язання проблем охорони навколишнього середовища, отримання альтернативних енергоресурсів і комплексного використання відходів промислового тваринництва автором запропоноване виробництво з них біогазу. Задля спрощення експлуатації ферми, дотримання зоогігієнічних, фізіологічних і технологічних норм та вимог промислового утримання тварин рекомендоване запровадження ферми круглої форми.

Ключові слова: *агробудівництво, промислове утримання тварин, тваринництво, технологія, ферма.*

Introduction. The economic and political stability of the state and the material well-being of citizens mainly depend on the successful work of the agricultural sector. The most important factor in the level of social life of the population is the level of its food supply. In all historical times, food production has been and still is an important problem at the world level. Animal husbandry is a strategic branch of agriculture from the point of view of food security and saturation of the market with quality products. At the same time, this industry supplies industry with certain types of raw materials. The instability of the socio-economic situation, the low level of capital concentration in the

agricultural sector, the price disparity between agricultural products and industrial products and its consequences caused certain troubles in animal husbandry. That is why attention should be paid to the timely optimization of all processes in order to establish a planned development, to prevent a decrease in the quality of goods and moral obsolescence of technological equipment.

Scientists note that due to the growing demand for livestock products, it is necessary to carry out continuous development of the livestock industry (Bozhydai I. I., 2019). And it is possible only under the condition of acceleration of scientific and technical progress, which requires large-scale technological and technical re-equipment of production, improvement of its complex mechanization and automation through the use of highly efficient sets of machines and equipment. In turn, the strategic direction of the technical policy in animal husbandry consists in the comprehensive implementation of mechanization and automation of production processes with the help of systems of mutually coordinated machines and equipment with simultaneous consideration of organizational-economic, natural-climatic and technological conditions, as well as the specifics of energy supply, etc. (Hubii M.M., 2007). This period of transition from traditional systems to technologies of intensive production at certain stages of it can be one of the reasons for the so-called "rational inefficiency", which requires an appropriate period of time to overcome (Addisu Adamie B., Hansson H., 2022).

Recently, agricultural construction has become one of the most popular types of activity, which is caused by the increased interest of investors in the development of the agro-industrial complex as one of the promising areas of large-scale business, the emergence of new effective technologies in agriculture. As a result, there was a need for major repairs and reconstruction of existing livestock complexes, as well as for the construction of new agro-industrial buildings and structures. In connection with the need for faster payback of capital investments, an urgent task is, on the one hand, a significant reduction in the costs of building livestock complexes due to the use of new, environmentally safe building materials (Gedikoglu Y, Gedikoglu G, Berkin G, 2012), and on the other hand - a significant reduction in current production costs, due to a reduction in the cost of electricity, live labor and an increase in the efficiency of the use of fodder (Galama P.J., Ouweltjes W., Endres M.I. et al., 2020; Neethirajan S., 2020; Augustyn G., Mikulik J., Rumin R. and Szyba M., 2021). The concentration of livestock during the intensive production of livestock products, in turn, creates problems of increasing the ecological load on the environment and ensuring the health and productive longevity of animals. Martin G., Benoit M., Bockstaller C. et al., 2023 emphasize the need to solve them at the stage of design and implementation of new construction or reconstruction of existing livestock facilities. Gaworski M. and Boćkowski M., 2022; Li Y., Wang M., Chen X., 2022. .

The purpose of the study is to assess modern construction trends for industrial animal husbandry.

Research materials and methods. The object of the study is modern construction trends for industrial animal husbandry. The experimental research base includes the analysis of innovative changes and international experience in construction for industrial animal husbandry. The methodological basis of the research was the principles of scientificity and a comprehensive approach to the study of actual material. To systematize primary information, bibliographic and source analysis is used.

Research results. When building new animal husbandry enterprises, modern experience suggests giving preference to new highly efficient volume-planning solutions, which include: large-sized rooms with a large capacity; monobloc housings with sections intended for housing animals, fodder preparation shops, blocked with

fodder storages, milking halls and other facilities; multi-storey premises. As shown by the practice of project organizations and the experience of using new volume-planning solutions in the construction of farms and complexes, monoblock and multi-story buildings reduce the need for space by 1.5–2 times, reduce the length of engineering communications by 2.5–3 times, and also reduces the amount of construction work by 1.5–1.6 times compared to pavilion construction. All this makes it possible to achieve a significant reduction in capital investments in production, significantly increase labor productivity and the profitability of animal husbandry in general.

Recently, existing farms are being reconstructed more and more often in order to expand the production of livestock products and reduce their cost price. The basis of the reconstruction is the re-planning of the premises of the farm in order to adapt them to new organizational and technological conditions at probably lower costs. Taking into account advanced domestic and foreign experience, it is worth noting such leading options for the reconstruction of livestock enterprises as increasing the level of electromechanization of production processes without increasing capacity; introduction of industrial technologies with an increase in capacity to rational sizes; implementation of complex mechanization of production processes with a change in production direction as a result of narrower specialization (Dorosh A. M., 2011).

Modern best practice in agricultural construction suggests that all livestock complexes and large specialized farms must have perfect sewage networks and treatment facilities capable of reliably protecting the surrounding natural environment, including water bodies, from pollution. Nowadays, such methods of agricultural wastewater treatment are widely used, such as: full biological treatment according to a special scheme and use of sewage sludge for soil fertilization; separation of waste into solid and liquid fractions with subsequent use of water for irrigation, and solid sediment in the form of fertilizer; composting sewage with peat crumb organic agricultural waste in special storage facilities (compost obtained in this way is used as organic fertilizer).

The production of biogas from them is considered one of the promising directions for solving the problems of environmental protection and obtaining additional energy resources and integrated use of industrial livestock waste. It is a product of the processing of organic livestock waste with the help of methane-forming microorganisms. This gas can be used to heat water and feed. In the case of obtaining biogas without access to air, processed manure completely preserves nitrogen in organic fertilizer, and during its composting, almost half of the nitrogen is lost. The construction of an additional room for the production of biogas is a separate aspect of the best practice in construction for industrial animal husbandry (KarapuzovYe. K., 2004).

The presence of an aggressive environment inside cowsheds requires the use of fully galvanized metal structures that are resistant to the effects of ammonia, chloride and other highly active compounds. One of the most important criteria in the construction of cowsheds is to ensure optimal air exchange, which makes it possible to obtain maximum milk production. Air movement on a dairy farm should be organized so that cold air enters the housing through the side walls, falls to the floor level and, heating up, rises up, taking ammonia with it and drying the manure oil. In order to increase the efficiency of air exchange in cowsheds, innovative technologies recommend thinking through all technological solutions, including the height of the side wall, the height in the ridge, the angle of the roof, the correct design of the light aeration lantern and the dimensions of the ventilation curtains. The use of steel structures makes it possible to create an optimal microclimate inside the dairy farm thanks to an increase in the slope of the roof up to 30°. Note that this is very difficult to achieve if a concrete frame is used. Such a solution makes it possible to avoid the phenomena inherent in

buildings with a lower slope of the roof: increased humidity, the appearance of odors, the appearance of fog in winter and the risk of animals receiving heat stroke in summer. It should also be mentioned that the requirements for the export of dairy products to European countries stipulate strict restrictions on the use of porous materials in cowsheds, including concrete and brick, which contribute to the accumulation of germs and bacteria. Therefore, the use of steel structures in the construction of a dairy farm makes it possible to significantly simplify the agricultural enterprise's obtaining a product safety certificate for export to Europe.

Enclosing constructions of barns for industrial animal keeping are made in such a way as to ensure a comfortable microclimate inside the premises in order to maximize milk production and minimize the costs of operating the buildings. Due to the fact that cows emit a lot of heat, space heating is not considered a determining criterion during construction. At the same time, an important requirement for a building for industrial animal keeping is the ability of its enclosing structures to ensure the stability of the temperature and humidity regime inside the premises. For this purpose, as roofing structures of dairy farms, panels of sheet assembly are currently used, which provide minimal heating of the premises in the summer and are the optimal price solution. For additional lighting of cowsheds, light lanterns made of polycarbonate are built into the roof structure. As wall structures on the facades, sandwich panels are used, which provide high rigidity and load-bearing capacity for integrated ventilation curtains. In order to increase the durability of wall structures, panels with a special wear-resistant CSafe coating are often used. The use of this coating makes it possible to guarantee the operation of structures for 25 years in the conditions of the aggressive environment of chemical compounds of the ammonia group and sodium hydroxide. The fact that even at -30 ° C in unheated cowsheds the temperature was positive indicates the correctness of the choice of roofing and wall materials. The analysis of means of development of production of animal husbandry products in the leading countries of the world and the experience of advanced domestic farms demonstrate that the highest quality and the lowest cost of production are obtained under the condition of the introduction of modern industrial technologies: untethered keeping of cows, rearing of pigs using a free-range system, etc. The untethered keeping of cows makes it possible to use modern highly efficient means of mechanization, robotic systems, and also contributes to better organization and specialization of work. All this contributes to a sharp increase in labor productivity, a decrease in its costs, in particular, for the production of 1 t of milk to 0.6–2.0 man-hours. With untethered keeping, it is possible to use high-performance machines (mobile units designed for distributing fodder and cleaning manure; milking units mounted in special rooms, etc.), which are able to serve a significant number of animals or several livestock premises. Thanks to this, the ratio of the use of technological machines and equipment increases significantly (up to 0.7–0.9) and capital investments in means of mechanization of production processes are rapidly reduced. Currently, some farms, in order to introduce a more effective technology for keeping animals without tethering, are increasingly renovating standard reinforced concrete premises or building new prefabricated buildings, the capacity of which mainly depends on the number of livestock that will be kept in it. In general, the overall dimensions of the room for industrial animal keeping are determined in such a way that the volume of the room is at least 40 m3 per dairy cow. These rooms are equipped with boxes or combiboxes for the purpose of keeping milking herds, fences for groups of animals, group automatic feeders, scraper installations, side movable wind protection curtains, lighting and ventilation horses. There are many different technology options for tethered confinement. All year long, the animals are kept untethered on deep

bedding, and they freely go out to the walking and feeding grounds, where there are feeders, group auto-feeders and sheds intended for coarse fodder. For each cow in the premises for the industrial keeping of animals for the industrial keeping of animals, you need to have 4.5–5 m2 of floor, and in the walking and feeding area at least 10 m2 of the area with a hard surface; at the same time, for repair heifers – 3.0–3.5 and 8–10 m2, respectively. The total length of feeders is determined on the basis of 0.7–0.8 m per cow, 0.7 m for a calf and 0.6 m per repair heifer. Under such a system of maintenance, the daily rate of bedding is 1–3 kg per head. Manure is removed with a bulldozer or scraper, and fodder is distributed by mobile means. Animals are kept in boxes, small areas, separated from each other by side dividers. Boxes for resting cows have a length from 2.2 m to 2.6 m and a width from 1.1 m to 1.25 m. It is most expedient to arrange the floor of the boxes using modern polymer materials that meet sanitary and animal hygiene requirements, as well as wood , rubber and clay. In rest boxes, you can use crushed litter (the estimated daily rate of its application is 0.5 kg per head, and the frequency of application is 2-3 times a week). In this case, a beam is installed in the back of the box, which prevents the bedding from sliding into the manure passage. Sometimes, in order to create more comfortable conditions for the animals, in addition to the main boxes for rest, feed semi-boxes (combi boxes) are equipped in front of the feeders. Combined boxes are also equipped with inflators. Feed passages are provided between the feeders, the width of which is determined by the choice of the feed distribution system and means. Cows consume 2-3 component fodder mixtures prepared according to the TMR (Total Mix Ration) technology. In the case of using mobile dispensers, the fodder aisles are 3.7–5 m wide. In the aisles between the boxes, manure is removed, and animals also move along them. Passages are 2.5–3 m wide with the aim of allowing animals in resting boxes or near feeders in combi boxes to move freely along the passage (Shyshkin E. A., 2022).

Creating a microclimate in premises for industrial animal keeping is carried out using side curtains and lighting and ventilation skates. All this makes it possible to ensure natural conditions for keeping livestock, the ability to regulate air flows in the livestock premises and the supply of the appropriate amount of air per head. The high comfort of the microclimate in prefabricated buildings is indicated by the level of relative air humidity, which is 68% compared to 87% in traditional premises; the presence of ammonia is 4 mg/m3 compared to 8 mg/m3, and bacterial insemination is 2.4 thousand/m3 compared to 103.4 thousand/m3.

For pig farms and complexes, a pavilion type of construction is appropriate, when pig pens are located autonomously from each other. With such a building, it is possible to organize walks and ensure natural lighting of premises for industrial animal husbandry. Technological gaps between pig houses should be 18–20 m. Modern pig houses of the industrial type are characterized by a reinforced concrete structure (panels with a heat-insulating intermediate layer), a frame based on sandwich panels or easily assembled awning rooms. The latter options make it possible to speed up the introduction of piggery premises for industrial animal keeping into operation (in 2-3 weeks), reduce the level of construction costs and increase the efficiency of pork production. The most effective are monoblock and multi-story options for production premises. For the convenience of sanitizing and disinfecting the premises, the pigsties are divided by solid partitions into isolated sections. They are used strictly according to the principle "all busy - all free". The capacity of the sections is determined depending on the size of the technological groups, but it should exceed 60 (100) sows in sow houses, 600 weaned piglets and 1,200 (2,000) fattening pigs.

Science has established that the health of 55% of animals is based on microclimate and feeding, 20% on genetic factors, and 25% on sanitary and hygienic factors. At the same time, rules and measures for the prevention of diseases are available to every household, for example, provision of drinking water that would meet the requirements of the DSTU for animals. Studies indicate that more than 20% of drinking water samples tested do not meet the standard for sanitary and hygienic indicators, and 9-12% - for microbiological indicators. This problem is also relevant in other countries (Pan D., Chen H., Zhang N., 2023)

Keeping animals at low temperatures, high humidity, and bacterial indoor air pollution are the cause of respiratory diseases: in adult animals - in 15-18%, in young animals - 35-40%, in newborn calves kept at a temperature of 6-8° C, colostral gamma globulins in unchanged form enter the blood within 4–6 hours (instead of 8–24 hours), which does not provide colostral immunity. Hypoglycemia is often registered in newborn piglets at a temperature of 12–16°C, they stop sucking the sow, growth decreases by 8–10% for each degree of temperature decrease, and feed consumption increases by 15–20% per feeding. The increased content of ammonia, carbon dioxide, hydrogen sulfide in the air of premises for the industrial maintenance of animals causes the development of hypoxia, which leads to immunodeficiency and a decrease in the body's resistance (Chornyi M.V., 1998).

Unlike many modern construction materials, which cause the release of harmful volatile organic compounds, according to Gedikoglu Y, Gedikoglu G, Berkin G, 2012, the use of clay, volcanic tuff, modified montmorillonite clay and kliptilolite as construction materials in their natural, or chemically in a modified form, it can provide natural filtering of harmful substances through the walls to the outside, thus significantly improving the indoor microclimate for both people and animals.

Discussion. Farms for the industrial maintenance of animals can have different forms, but all of them are characterized by zoohygienic, technological and operational shortcomings. In order to simplify the operation of the farm, comply with zoohygienic, physiological and technological norms and requirements of industrial animal husbandry, modern construction experience should introduce a round-shaped farm. Work on a circular farm is carried out in the following way: before milking begins, the conveyor delivers concentrated and juicy fodder to the milking block and lets the animals of one of the sectors through the gate. After milking, the animals are released into their sector, where they eat roughage, drink water or go to pasture. In the summer, green mass can be additionally supplied to the sectors intended for walking areas with the help of mobile feeders. In this way, animals of all sectors are fed, watered and milked, only according to the schedule and with different frequency depending on their productivity, lactation time and body size. It has been proven that, under equal conditions, costs for the construction of a complex for industrial animal husbandry due to the compactness of buildings and balanced pastures are reduced by almost half, and labor productivity as a result of mechanization, technological interconnection and flow of processes, as well as the reduction of service personnel, increases by three times. At the same time, the level of milk production increases by 20%.

Undoubtedly, it is possible to increase the efficiency of animal husbandry through the comprehensive implementation of the latest innovative technological, organizational and technical solutions. Thus, according to J. Aerts, M. Kolenda, D. Piwczyński, 2022, the highest efficiency in terms of energy consumption is achieved when milking cows whose daily productivity is above 45 kg of milk, milking no more than 4 times a day on a robotic installation serving up to 56 cows. At the same time, the time for attaching the milking cups did not exceed 7.7 seconds.

Only complex mechanization, automation and robotization of production processes and operations, clear coordination of mechanization issues with production technology and organization thanks to the creation of flow technological lines are able to ensure an increase in the efficiency of agricultural production. Mechanization of processes will not only reduce the total number of workers, but also require qualified specialists to maintain machines and equipment, and animals.

Conclusions. When building new livestock enterprises, it is worth giving preference to such highly effective volume-planning solutions as:

- large-sized rooms with a large capacity;
- monobloc housings with sections intended for accommodation of animals,
- fodder preparation shops, blocked with fodder storages;
- multi-storey premises.

Options for the reconstruction of livestock enterprises to adapt them to new organizational and technological conditions at probably lower costs can be as follows:

- increasing the level of electromechanization of production processes without increasing the capacity;
- introduction of industrial technologies with an increase in capacity to rational sizes;
- implementation of complex mechanization of production processes with a change in the production direction as a result of narrower specialization.
- The total area of a one-story building is calculated based on the size of the herd according to the accepted norms.
- Equipped with a ventilation system to ensure that standard indicators of humidity and temperature are maintained

The most effective is the agricultural construction technology of Ruukki quickly assembled buildings based on light metal structures, which are designed for agricultural buildings, taking into account operation in aggressive environments, and, in addition, it makes it possible to use lightweight point foundations in construction.

In order to simplify the operation of the farm, to comply with zoohygienic, physiological and technological standards and the requirements of industrial animal husbandry, it is recommended to introduce a round farm.

References

Adamie, B. A., & Hansson, H. (2022). Rationalising inefficiency in dairy production: evidence from an over-time approach. *European Review of Agricultural Economics*, Vol. 49, Is. 2, P: 433–471, https://doi.org/10.1093/erae/jbaa034

Addisu Adamie, B., & Hansson, H. (2022). Rationalising inefficiency in dairy production: evidence from an over-time approach. *European Review of Agricultural Economics*, Vol. 49, Is. 2, P: 433–471, https://doi.org/10.1093/erae/jbaa034

Aerts, J., Kolenda, M., Piwczyński, D., Sitkowska, B., & Önder, H. (2022). Forecasting Milking Efficiency of Dairy Cows Milked in an Automatic Milking System Using the Decision Tree Technique. *Animals*, *12*(8), 1040; https://doi.org/10.3390/ani12081040DOI

Augustyn, G., Mikulik, J., Rumin, R. & Szyba M. (2021). Energy Self-Sufficient Livestock Farm as the Example of Agricultural Hybrid Off-Grid System. ***Energies***, ***14***(21), 7041; https://doi.org/10.3390/en14217041

Bozhydai, I. I. (2019). Ahropromyslovyi kompleks Ukrainy: struktura ta osnovni poniattia. [Agro-industrial complex of Ukraine: structure and basic concepts] *Ahrosvit*, 21, 107–113 (in Ukrainian).

Chornyi, M. V. (1998). Zoohihiiena: nauka i navchalna dystsyplina. [Zoology: science and academic discipline]. *Veterynarna medytsyna Ukrainy - Veterinary medicine of Ukraine.* 7, 32–33 (in Ukrainian).

Dorosh, A. M. (2011). Orhanizatsiia budivelnoho vyrobnytstva [Organization of construction trust]. Kyiv : Ahrarna osvita (in Ukrainian).

Galama, P. J., Ouweltjes, W., Endres, M. I., Sprecher, J. R., Leso L., Kuipers, M.., & Klopčič M. (2020). Review Symposium. *Symposium review:* Future of housing for dairy cattle. Journal of Dairy Science. Vol. 103, Is. 6, June 2020, Pages 5759-5772. https://doi.org/10.3168/jds.2019-17214

Gaworski, M. & Boćkowski M., (2022). Comparison of Cattle Housing Systems Based on the Criterion of Damage to Barn Equipment and Construction Errors. Animals (Basel). 12(19): 2530. https://doi.org/10.3390/ani12192530

Gedikoglu, Y., Gedikoglu, G., Berkin, G., Ceyhan, T., & Altinoz, M. A. (2012). Employing volcanic tuff minerals in interior architecture design to reduce microbial contaminants and airborne fungal carcinogens of indoor environments. *Toxicology and Industrial Health*. 28(8):708-719. doi:10.1177/0748233711422727

Heiets, V., Yurchyshyn, V., Borodina, O., Prokopa, I. (2011). Sotsioekonomichna modernizatsiia ahrarnoho sektoru Ukrainy (kontseptualni polozhennia) [Socio-economic modernization of the agricultural sector of Ukraine (conceptual provisions)]. *Ekonomika Ukrainy - Economy of Ukraine*, 12, 4–14 (in Ukrainian).

Hubii, M. M. (2007). Proektuvannia remontu y pidsylennia budivel ta sporud iz zastosuvanniam suchasnykh materialiv i tekhnolohii [Designing the repair and extension of buildings and structures using modern materials and technology]. Kharkiv : Tymchenko (in Ukrainian).

Karapuzov, Ye. K. (2004). Materialy i tekhnolohii v suchasnomu budivnytstvi. [Materials and technologies in modern construction]. Kyiv : Vyshcha shkola (in Ukrainian).

Khorunzhyi, M. Y. (2014). Zavdannia natsionalnoi ahrarnoi polityky na suchasnomu etapi [Tasks of national agrarian policy at the current stage]. *Ekonomika APK*, 2, 22–29 (in Ukrainian).

Li, Y., Wang M. , Chen, X., Cui, S., Hofstra, N., Kroeze, C., Ma d L., Xu, W. , Zhang, Q., Zhang F., Strokal, M. (2022). Multi-pollutant assessment of river pollution from livestock production worldwide. Water Research. 209. 117906. https://doi.org/10.1016/j.watres.2021.117906

Livinskyi, O. M. (2013). Konstruktsii ta tekhnolohiia budivnytstva inzhenernykh merezh ta sporud [Designs and construction technology of engineering networks and structures]. Kyiv : MP Lesia (in Ukrainian).

Lupenko, Yu. O., & Patyka, N. I. (2019). Rol innovatsii u zabezpechenni konkurentospromozhnosti Ukrainy na svitovykh rynkakh silskohospodarskoi produktsii [The role of innovation in ensuring the competitiveness of Ukraine on the world markets of agricultural products]. *Ahrosvit*, 11, 16–23 (in Ukrainian).

Martin, G., Benoit, M., Bockstaller, C., Chatzimpiros, P., Colnenne-David, C., Harchaoui, S., Hélias, A., Pépin, A., Pointereau, P., van der Wer, H. M. G., Veysset, P., Walter, N. & Nesme, T. (2023). Reducing energy consumption without compromising food security: the imperative that could transform agriculture. *Environmental Research Letters*, Vol. 18, No 8. https://doi.org/10.1088/1748-9326/ace462

Meneiliuk, O. I. (2020). Materialy ta tekhnolohii izoliatsiinykh robit v budivnytstvi [Materials and technologies of insulation works in construction.] Odesa : Vydavnytstvo FOP Bondarenko M. O. (in Ukrainian).

Neethirajan S. (2020). The role of sensors, big data and machine learning in modern animal farming. *Sensing and Bio-Sensing Research.* Vol. 29, 100367

Pan D., Chen H., Zhang N., Kong F. (2023). Do livestock environmental regulations reduce water pollution in China. *Ecological Economics.* Vol. 204, Part A, p. 107637. https://doi.org/10.1016/j.ecolecon.2022.107637

Shestakova, P. Yu., Ozhelevska, T. S. (2018). Ahrarnyi rynok Ukrainy v umovakh yevrointehratsii [The agricultural market of Ukraine in the conditions of European integration]. *Molodyi vchenyi*, 3(2), 720–722 (in Ukrainian).

Shyshkin, E. A. (2022). Innovatsiini planuvalni ta konstruktyvni rishennia suchasnykh budivel i sporud [Innovative planning and construction solutions for modern buildings and structures]. Kharkiv : KhNUMH im. O. M. Beketova. (in Ukrainian).

Sirenko, N. M. (2008). Sotsialna funktsiia innovatsiinoi modeli rozvytku ahropromyslovoho vyrobnytstva [The social function of the innovative model of the development of agro-industrial cooperation]. Ekonomika APK. № 4. 50–54 (in Ukrainian).

Topiha, B. C. (2006). Tendentsii rozvytku haluzi svynarstva v krainakh svitu ta Ukraini [Trends in the development of the pig industry in the countries of the world and Ukraine]. *Visnyk ahrarnoi nauky Prychornomoria,* 3(35), 8–14 (in Ukrainian).

Voinalovych, O.V. (2015). Bezpeka vyrobnychykh protsesiv u silskohospodarskomu vyrobnytstvi [Safety of production processes in agricultural production]. Kyiv : Vydavnychyi tsentr NUBiP Ukrainy, 2015 (in Ukrainian).

Zhvan, V. D. (2011). Zvedennia i montazh budivel i sporud [Construction and installation of buildings and structures] Kharkiv : KhNAMH (in Ukrainian).