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Prospective aspects in the robotization development of animal husbandry processes

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Robotization covers almost all the main, time-consuming and monotonous technological processes of animal husbandry – feed preparation and distribution, milking, manure cleaning, wool cutting, control, counting and packing of eggs, etc. Each of these processes is currently in a different degree of robotization. For example, all the main technological stages of milk production are already robotized so completely that further improvement of the developed automatic milking complexes is only possible. Apparently, a similar situation should develop over time in other labor-intensive, but much less or not at all robotic livestock industries. On the other hand, processes that require a creative, intelligent approach to solving technological problems of animal husbandry are still out of the field of view of developers of robotic systems. Mass vaccination of animals or veterinary control of livestock, treatment and biotechnological procedures can be mentioned among such non-robotic routine processes.

Biotechnology of animal husbandry is a promising and priority direction of development of the industry, aimed at accelerated improvement of existing and creation of new breeds and species of animals in order to maximize production. Currently, only some of the processes of animal biotechnology are partially automated – the processes of DNA technologies and only certain operations of cellular and genetic engineering, for example, cell sorting, individual micro- and electromanipulations with cells.

The article offers a conditional scheme of prospects for the development of traditional and innovative processes of animal husbandry. The first ones are the main ones (milking, feeding, manure harvesting). they are now robotic to varying degrees and have prospects for improvement to full robotization. The latter are auxiliary (veterinary, biotechnological, breeding, etc.), not yet robotic, but have significant prospects for robotization in the next 5 – 15 years due to the introduction of separate automated devices and devices.

Keywords: *robotics, prospective, process, animal husbandry, biotechnology.*

Analysis of recent studies. It should be noted that the processes that require a creative, intelligent approach to solving technological problems of animal husbandry are still falling out of the field of view of developers of robotic systems. For example, it is possible to free a person from such non-robotic routine processes as mass vaccination of animals or veterinary control (inspection) of livestock, not to mention treatment. Then a farmer or a veterinarian who is already turning into an operator of a robotic veterinary system needs to increase his intellectual level for analytical work with the data obtained by the system. Moreover, most of this work can be entrusted to the same robotic system, but the key decisions, apparently, will still have to be made by a farmer or a veterinarian. Thus, there are objective global trends in the development of unmanned robotic technologies in all areas of animal husbandry in the near foreseeable future [7, 8].

The purpose of this work was to generalize in the form of a scheme of prospects for the development of animal husbandry processes, already robotic to varying degrees, and innovative, still only developing in this direction.

Research results. Let's consider an approximate scheme of prospects for the development of animal husbandry processes, which, in our opinion, can and should be robotized in the next 5 – 15 years, Fig.1.

The directions and processes presented in the diagram are conditionally divided into traditional (milking, feeding, manure cleaning, etc.), already robotic to varying degrees, and innovative.

The former have numerous examples of successful robotic implementation and can continue to improve along this path, and therefore their prospects are brilliant. It does not make sense to consider them in more detail here. There is a large technical literature on this issue [1, 3, 4, 6].

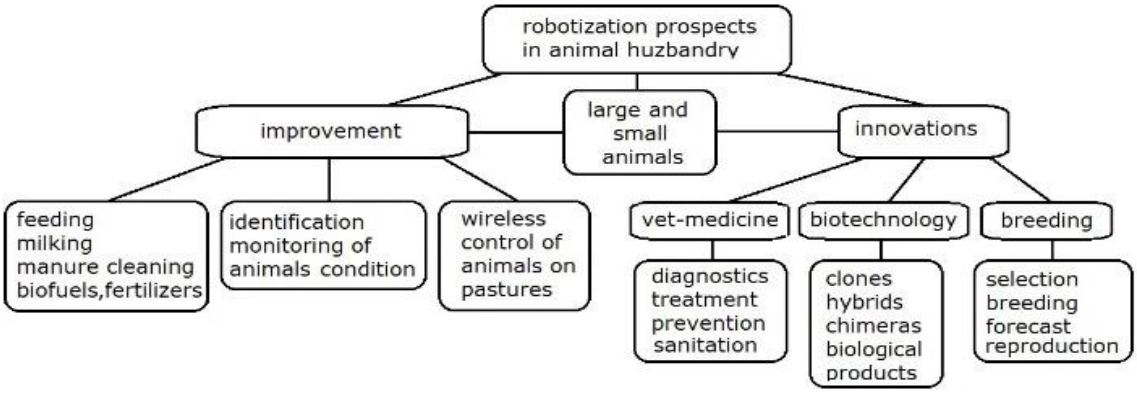

Fig. 1. The scheme of promising directions for the development of robotics in animal husbandry

The latter are still either almost not covered by automation (especially biotechnology processes), or have partially automated devices, equipment, measuring equipment, etc.

For this category of directions, based on the existing automation subsystems of some processes, there is a good opportunity to combine them into automated systems and complexes, and in the future – automatic / robotic. These are, for example, the latest robotic complexes for pastures, which also include veterinary automatic equipment that monitors the condition of animals in real time [1, 4, 9]. For example, a shepherd veterinarian robot has been successfully operated in Australia for several years, which works autonomously on remote pastures. Powered by solar panels, the robot can move around pastures and monitor the health of animals and the state of vegetation in the field. The robot will automatically detect sick and injured animals using video cameras and thermal imagers based on changes in body temperature or gait. Using the same sensors, the robot can analyze the texture of the earth and the amount of greenery needed for grazing [9], Fig.2.

Fig. 2. The world's first autonomous robot veterinarian-shepherd on a pasture

There are also separate automated systems for auxiliary processes of reproductive biotechnology of farm animals [10, 11, 12]. This promising and non-robotic direction is worth considering in more detail.

Animal husbandry biotechnology is a promising and priority direction of the industry development aimed at accelerated improvement of existing breeds, animal species, creation of new ones and obtaining maximum products from them. Many of the directions of biotechnological research in the near future can be used for practical purposes of improving farm animals. Being the newest direction in agriculture in general and in animal husbandry in particular, biotechnology uses the main achievements, methods and processes of cellular and genetic engineering, reproductive biology, cellular and molecular biophysics, biochemistry, etc. Among them:

- fertilization of eggs in vitro (outside the body);
- microsurgical operations on the cell (division of embryos, extraction-transplantation of the nucleus, electrofusion of cells, ICSI fertilization, etc.);
- artificial insemination, transplantation of embryos;
- cryopreservation of reproductive cells and embryos;
- interspecific hybridization of embryos, production of chimeras;
- cloning, obtaining transgenic animals;
- DNA technologies: sex determination in embryos, virus diagnostics, selection based on DNA markers, control of origin, early prediction of productivity, etc. And this is not a complete list.

Currently, the processes of DNA technologies are partially automated and only certain operations of cellular and genetic engineering, for example, sorting (selection) of cells, Fig. 3, separate micro- and electromanipulations with cells [11, 12].

As for the robotization of cellular biotechnology. Despite the fairly well-saturated market of medical robot surgeons, it should be noted that there are no microsurgical robots for working at the cell level, not to mention deeper, atomic-molecular, yet. Almost all micro-operations with cells – division, enucleation or transplantation of nuclei, chimerization, cloning, etc. - are carried out manually, and micro-tools are also made handmade or semi-automatic.

Fig. 3. Automated cell selection system CellCelector (ALS, Germany)

There is no automated diagnostics of the quality of cells, in particular, reproductive ones, either at the input or output stages (after biotechnological procedures) yet. It all depends on the experience and skill of a biotechnologist.

As an example, Figure 4 shows a typical automated system for performing a number of basic microsurgical operations on a cell using a micro-tool fixed in motorized holders. The movements of the micro-tool during the operation on the cell are performed by a biotechnologist using a joystick in the field of view of a light microscope.

In general, animal husbandry biotechnology is almost not provided with automated and even more so with robotic technical systems and means of implementing the above-mentioned processes. Here we see the widest field of activity for biotechnologists in alliance with robotics engineers. For example, the accumulated world experience and experimental data on the development of the latest methods and equipment for electromanipulation with living animal cells (in reproductive biotechnology) have already reached a stage where full automation of these biotechnological processes can be widely and safely implemented [10 – 13].

This is also facilitated by the fact that the main processes of the cell's vital activity, even without external influences, are of an electrical nature and are determined by electrical forces. Therefore, hardware methods of electromanipulation are relatively easily integrated into automated measuring and control biotechnological complexes, due to the fact that the information signal already has an electrical nature and it does not need to be further transformed [14 – 17].

Thus, there are good prospects for the gradual system robotization of complex cellular and genetic engineering processes associated with the purposeful transformation of biomaterial (biomacromolecules, cells, organs, tissues) for the accelerated production of animals with specified economically useful characteristics.

It should be noted that the proposed scheme, Fig. 1, remains valid for all types of animal husbandry: large, small, poultry farming, and also, in particular, beekeeping, where automation so far is reduced to the fantasies of enthusiasts, although not groundless [18].

Fig. 4. An automated system for microsurgery of the cell, including an inverted microscope, motorized micro-tool holders, micro-pumps and a video monitoring device

There are also other directions and processes that are not directly reflected in the proposed scheme on (Fig. 1), but are very important in the organization of the entire livestock industry, already automated or having the capabilities of robotics. Such are, for example, automated systems of microclimate, remote veterinary, zootechnical control and accounting of animals. There are also logistical and environmental aspects of animal husbandry that have so far been almost untouched by robotics, and even such an important one as the ethological aspect.

Conclusions. It seems most likely that the development of robotic animal husbandry systems should follow the path of intellectualization of existing technical means, as well as the creation of new ones that are still absent in modern biotechnologies and are being developed to control technological processes at a qualitatively new level in order to gradually reach automatic (robotic), unpopulated technologies in animal husbandry.

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Аннотация

Перспективные аспекты в развитии роботизации процессов животноводства

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Роботизация охватывает практически все основные, трудоемкие и однообразные технологические процессы животноводства – подготовка и раздача кормов, доение, уборка навоза, стрижка шерсти, контроль, счет и упаковка яиц и т.п. Каждый из этих процессов к настоящему времени находится в различной степени роботизации. К примеру, все основные технологические этапы получения молока уже роботизированы настолько полно, что далее возможно лишь совершенствование разработанных автоматических доильных комплексов. Видимо, аналогичная ситуация должна сложиться со временем и в других трудоемких, но значительно менее или совсем не роботизированных отраслях животноводства. С другой стороны, процессы, требующие творческого, интеллектуального подхода к решению технологических задач животноводства, пока выпадают из поля зрения разработчиков робототехнических систем. Среди таких еще не роботизированных рутинных процессов можно отметить массовую вакцинацию животных или ветеринарный контроль поголовья, лечение и биотехнологические процедуры.

Биотехнология животноводства – это перспективное и приоритетное направление развития отрасли, направленное на ускоренное совершенствование существующих и создание новых пород, видов животных с целью получения максимума продукции. В настоящее время частично автоматизированы лишь некоторые из процессов биотехнологии животных - процессы ДНК-технологий и только отдельные операции клеточной и генной инженерии, например, сортировка клеток, отдельные микро- и электроманипуляции с клетками.

В статье предложена условная схема перспектив развития традиционных и инновационных процессов животноводства. Первые являются основными (доение, кормление, уборка навоза), к

настоящему времени в разной степени роботизированы и имеют перспективы к совершенствованию до полной роботизации. Вторые являются вспомогательными (ветеринарные, биотехнологические, селекционные и др.), пока еще не роботизированы, но имеют значительные перспективы роботизации в ближайшие 5 – 15 лет благодаря внедрению отдельных автоматизированных устройств и приборов.

Ключевые слова: *робототехника, перспектива, процесс, животноводство, биотехнология.*

Анотація

Перспективні аспекти в розвитку роботизації процесів тваринництва

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Роботизація охоплює практично всі основні, трудомісткі і одноманітні технологічні процеси тваринництва – підготовка і роздача кормів, доїння, прибирання гною, стрижка вовни, контроль, рахунок і упаковка яєць і т.п. кожен з цих процесів до теперішнього часу знаходиться в різному ступені роботизації. Наприклад, всі основні технологічні етапи отримання молока вже роботизовані настільки повно, що далі можливе лише вдосконалення розроблених автоматичних доїльних комплексів. Мабуть, аналогічна ситуація повинна скластися з часом і в інших трудомістких, але значно менш або зовсім не роботизованих галузях тваринництва. З іншого боку, процеси, що вимагають творчого, інтелектуального підходу до вирішення технологічних завдань тваринництва, поки випадають з поля зору розробників робототехнічних систем. Серед таких ще не роботизованих рутинних процесів можна відзначити масову вакцинацію тварин або ветеринарний контроль поголів'я, лікування та біотехнологічні процедури.

Біотехнологія тваринництва - це перспективний і пріоритетний напрямок розвитку галузі, спрямований на прискорене вдосконалення існуючих і створення нових порід, видів тварин з метою отримання максимуму продукції. В даний час частково автоматизовані лише деякі з процесів біотехнології тварин – процеси ДНК-технологій і тільки окремі операції клітинної і генної інженерії, наприклад, сортування клітин, окремі мікро – і електроманіпуляції з клітинами.

У статті запропонована умовна схема перспектив розвитку традиційних та інноваційних процесів тваринництва. Перші є основними (доїння, годування, прибирання гною), до теперішнього часу в різному ступені роботизовані і мають перспективи до вдосконалення до повної роботизації. Другі є допоміжними (ветеринарні, біотехнологічні, селекційні та ін.), поки ще не роботизовані, але мають значні перспективи роботизації в найближчі 5 – 15 років завдяки впровадженню окремих автоматизованих пристроїв і приладів.

Ключові слова*: робототехніка, перспектива,процес, тваринництво, біотехнологія.*

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