Dairy robotic milking system

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Abstract. The article presents the results of studying the technology of robotic milking in the aspect of digitalization of dairy cattle breeding. The relevance of the topic lies in the fact that in Russia the task is to introduce the technology of "precise" animal husbandry based on digital technologies. It is noted that in our country there are successfully functioning dairy complexes, where digital technology tools, including robotics, have been introduced. The technologies for identifying animals, determining the quality of milk, controlling the robotic complex and the milking process are described. The robotic milking system is a progressive technology in terms of the use of digital technology elements: big data, the Internet of things, artificial intelligence. It is necessary to take into account the experience of these farms in order to increase the efficiency of introducing innovations.

1 Introduction

The growth of the Earth's population dictates the need for the transition of agriculture to intensive forms of production of ever larger volumes of food. According to the FAO, by 2050 more than 9 billion inhabitants of the Earth will need to be provided with food, i.e. it will be necessary to produce 60% more food products than at present. This, in turn, requires an increase in the efficiency of agricultural production [1].

Despite the fact that the pace of mastering innovations in the world has accelerated significantly, the livestock industry in Russia is in the early stages of using digital technologies, although the conditions for the formation of the digital platform "Digital Agriculture" have already been created [2]. The main goal of the digital transformation of agriculture is to create conditions to ensure a technological breakthrough in the agro-industrial complex and achieve productivity growth at “digital” agricultural enterprises [3].The importance of the accelerated development of digitalization for the agro-industrial complex of Russia is due to the fact that this will not only dramatically increase the efficiency of agricultural production, but also significantly reduce the number of workers required for the production of the required volumes of agricultural products [4].

The digitalization of animal husbandry consists, first of all, in the creation of experimental digital enterprises in animal husbandry based on intelligent automated and

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robotic biomachine complexes of a new generation. The widespread use of these technologies will lead to an increase in the quality and quantity of products by 25–30%, an increase in labor productivity by 1.5–2 times, and the preservation of animal health and productive longevity [5-7]. Centralized and local intelligent control systems for these biomachine complexes will ensure the harmonization of the interaction of biological, technological and machine objects, effective management, a reduction in production costs by 35-40% and an increase in animal productivity by 15-20% [8-9].

In our country, there are dairy farms that fit into the concept of "smart farm". These are mainly large dairy complexes, however, their number is insignificant and does not exceed 5% of the total number of farms. In such farms, certain experience has been accumulated in the field of digitalization of dairy cattle breeding, which must be taken into account when digitalizing this area. In this regard, the purpose of our research was to study and analyze the robotic milking system in terms of the use of digital technology tools.

2 Materials and methods

The studies were carried out at modern dairy complexes of the Republic of Tatarstan, where the technology of robotic milking is used (KFH "Mukhametshin Z.Z.", KFH "Akhmetov", etc.). Highly productive dairy cattle of the Holstein, Black-and-White and Kholmogory (Tatarstan type) breeds are bred in the complexes. The farms use milking robots from Lely and DeLaval. Information about the performance and milking parameters of the animals was taken from the T4C herd management program and VMS Mgmt. In the course of the research, general methods of scientific knowledge (observation, analysis, generalization), statistical methods of analysis were used.

3 Results

In the 1950s, research began in the field of automation of the milking process. In the 1970s, the concept of a device was formed that is capable of milking animals without human intervention. Scientific developments in this area were carried out by such companies as "Lely Industries N.V." (Netherlands), "Gascoigne Melotte" (Belgium), "Insentec" (Netherlands). The first milking robot (prototype) was presented by "Lely Industries N.V." in 1984. After certain improvements, the milking robot began to be used on the farm in 1989. However, the final introduction into production took place only in 1992. These were Astronaut single-box milking robots [10-11].

In the 90s, many manufacturers of milking equipment also joined the development of automatic milking systems: "DeLaval" (Sweden), "GEA Farm Technologies" (Germany), "SAC" (Denmark), "BouMatic" (USA), "Fullwood » (Great Britain), etc. Some started the process of development and production on their own, some under license from pioneer companies.

The scale of introduction of robotic milking systems is growing every year. At the end of 2020, there were more than 60 thousand such systems around the world (Figure 1).

The main number of milking robots is concentrated in Western Europe. The reason for this is, firstly, an expensive labor force, which makes investments in the automation of the milk production process more attractive, and secondly, a small number of cows from producers, when one or two milking robots are enough. The original concept of milking robots was to free farmers from the daily routine of the milking process, which they do well. However, the introduction of robotic milking systems had many advantages, which ultimately contributed to their use in large complexes with large livestock.

In Russia, the first milking robot appeared in 2007 in the Vologda region. For 15 years, their total number has reached 1000 units. The figure is not impressive, but there are objective reasons for this: the need for large investments, cheap labor, low milk productivity of cows, etc.

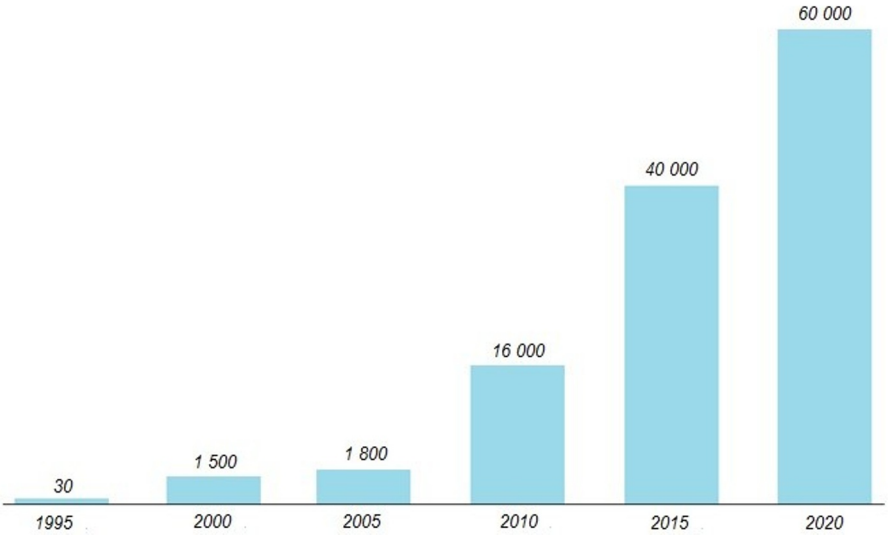

Fig. 1. Number of milking robots in the world.

In the Republic of Tatarstan, innovations in dairy cattle breeding are being introduced quite actively. The republic, among other things, occupies a leading position in terms of the pace of implementation of robotic milking systems. Their number is more than 120 units.

According to the design features, robotic milking systems are divided into single-box (Figure. 2a) (Astronaut by "Lely", VMS by "DeLaval", Merlin by "Fullwood", MR-S1TM by "BouMatic", etc.), multi-box (Figure 2b); with udder manipulator side position (Astronaut, "VMS", etc.), with rear position (MR-S1TM); with hydraulic (VMS, etc.), pneumatic (Astronaut, etc.) and electric (RDS Futureline by "S.A. Christensen & Co", etc.) manipulator drive control; with a separate udder teat cleaning cup (VMS, MR-S1TM, Galaxy Starline by "Insentec", RDS Futureline), with roller brushes (Astronaut M1one by "GEA Westfalia Surge", Merlin).

Fig. 2. Single and multi-box milking robot.

Single-box milking robots are able to serve up to 70 cows, multi-box, depending on the number of boxes (from 2 to 5), up to 160.

The concept of "precise" animal husbandry is based on the unmistakable identification, collection and storage of information about each individual. Identification allows for precise control over the animal's health, its performance indicators (milk yield, weight gain,

product quality, etc.), activity and other parameters of interest. In robotic milking technology, cow identification occurs when she enters the milking box. The control program decides whether the milking process needs to be carried out. It depends on the time that has passed since the previous milking session. Operators have the opportunity to set the minimum interval between milkings in the program. This time should be selected for a specific herd, taking into account the productivity of cows, the evenness of the herd in terms of milk yield, the number of cows in the group.

The process of animal identification, regardless of the technology of milking, keeping, consists in the fact that the individual number of the animal is read from the sensors attached to the cows (ear tags, responder on the collar or leg), when it is located next to the receiving device - scanner.

In animal husbandry, radio frequency identification technology (RFID) is actively used. It solves the whole range of production and management tasks, from accounting for livestock, control of its movement and all current indicators, to vaccination and optimization of breeding work. This significantly reduces labor costs, eliminates the possibility of errors caused by the human factor, and accelerates the processing of information even in large farms [2].

Practice shows that the use of a robotic milking system leads to an increase in the quality of milk. The reason for this is the accurate performance of all operations for preparing the udder for milking, separate milking of a separate quarter of the udder, the absence of overexposure of teat cups on the teats of the udder after the completion of lactation, the collection of substandard milk from sick animals in a separate container, washing the teat cups after milking each cow, early detection diseases of the udder on the quality of milk.

The quality of milk is, first of all, the number of somatic cells. For its determination in milking robots (additional option) built-in counters can be used. For example, in VMS ("DeLaval") milking robots, OSS counters are used (figure 3a). The counting principle is that a milk sample is taken from the VMS (1) and fed into the syringe pump (3). Coloring reagents are also supplied there (2). Further, this mixture is passed through the measuring device (4). In it, a digital camera takes a picture of the nuclei of somatic blood cells. Then the nuclei are counted. The calculation takes a matter of seconds, the result is displayed on the screen in the "Cow Status" menu of the management program.

a. OCC (DeLaval) **b. MQC (Lely)**

Fig. 3. Milk quality sensors.

The Lely MQC system (figure 3b) measures the following parameters: volume, color and conductivity of milk, milking time, milking rate from each quarter of the udder. An additional function of MQC-C determines the number of somatic cells.

All information about animals and processes recorded by various sensors is stored in the control program. These data are the basis for effective dairy herd management.

The control system of the "Lely" Astronaut milking robot is equipped with T4C software, which allows real-time display of all data about each cow on the computer screen in the form of clear and easy to read graphic information, as well as accumulation and storage of them. It implements the remote control function of the milking robot. The interaction of all units of the "DeLaval" VMS milking robot with each other and the implementation of the tasks set is carried out by a control system equipped with the VMS Management computer program. The main working panel of the program - "Monitoring of cows" - displays cows in real time, which should be paid attention in the first place. The operation of the Galaxy ASTREA 20.20 milking robot from "Insentec" is carried out using the SA-TURNUS 20.20 Farm Management program, which collects information and converts it into a form convenient for decision-making. To do this, the computer monitor in graphical and digital form displays all the necessary information about the process operation currently being performed [12].

Management programs, in general, are based on similar functionality aimed at storing and analyzing various information. One of the main tasks of specialists in a digital farm is the ability to respond correctly and in a timely manner to these programs.

4 Discussion

An analysis of research in the field of digitalization of dairy cattle shows that there is a consensus on the need to introduce digital technologies. The implementation process can be either instantaneous (full), when digitalization covers the entire production cycle, or phased (partial), in which digital solutions are introduced gradually. The volume of data, as a result of digitalization, allows analyzing and managing the production process at a qualitatively new level. It is also noted that the introduction of digital technologies will require the staff to master new digital competencies, and this issue is no less important than digitalization itself. It should be noted that this issue is also understood in the relevant ministries, which resulted in, among other things, the introduction of new disciplines into educational programs.

5 Conclusion

Increasing labor productivity, quantity and quality of livestock products at the present stage of development is closely associated with the digitalization of the industry. An example of the introduction of modern technologies in dairy cattle breeding is the use of robotic milking systems. It implements the main digital technologies: robotics, the Internet of things, big data, artificial intelligence. Despite many positive aspects, the scaling of this technology is somewhat constrained by its high cost. However, the experience of operating these systems can be used in the implementation of digital tools in dairy cattle breeding.

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