Automation of Processes in Dairy Cattle Production

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Abstract. The priority direction of modern animal husbandry is the creation of smart farms, which are managed through the use of automated systems and IT. However, not all farms use new technologies, so this article analyzes the efficiency of milk production in the conditions of the leading enterprises of the Omsk region, located in different climatic conditions, with traditional technology, and then introduced elements of a smart farm. In the course of the study in the conduct of traditional technology of milk production in large numbers were identified violations of animal identification, there was an increase in the duration of the open period and there were lower rates of purity and grade of milk. The introduction of elements of a smart farm at the same enterprises allowed to avoid errors in the identification of animals, to improve the analyzed indicators and to increase milk production.

1. Introduction

The global goal of animal husbandry is the satisfaction of world’s population needs and the constant increase of availability for animal industry products providing the safety of products and the animals’ health. Every year the consumption of animal products increases by 7%, thereby we can see the continuing need in the development of the existing technologies of livestock production [1, 2].

The production growth is due to intensification and automation of technological processes. Technical progress does not stay still and is actively implemented in all spheres of human activity, including dairy cattle breeding. The main reasons for the introduction of technical innovations in agriculture are the reduction of production costs and obtaining maximum profit [3, 4].

The main problem in the development of domestic livestock farming is the low competitiveness of livestock products on the market, which is due to the technical and technological lag in livestock raising in Russia from developed countries [5]. The development of the dairy production influences on the level of food supply in the country. The decision of this problem is the creation of production industry and sustainable development of agriculture by the use of modern scientific and physical infrastructure with the advanced management technologies [6].

The development of digital animal husbandry in the world began about thirty years ago and at present, modern technical solutions are comparable to robotics, since all technological processes are carried out without direct human participation [7, 8]. The dairy cattle breeding has reached a sufficient level of development and modern digital technologies are used along with the traditional processes of milk production in the conditions of the south of Western Siberia.

Thus, the use of modern automated technologies for the production of milk is relevant for animal husbandry in the region.

The aim of the research was to determine the efficiency of milk production when introducing modern automated herd management systems under the conditions of Omsk Region enterprises.

2. Research object and methods

The studies were conducted at the Institute of Veterinary Medicine and Biotechnology of the Omsk State Agrarian University.

The object of research was the technological processes of milk production in the leading enterprises of the Omsk Region. We selected the enterprises that have implemented the elements of a
smart farm and located in various natural and climatic zones of the Omsk Region. During the study, the main production indicators were analyzed for two periods of the enterprises' economic activities - before and after the introduction of the smart farm. Analysis of the production activities of enterprises was carried out for the period from 2000 to 2018. Automated herd management systems in the Omsk Region have been used since 2009. Thus, we identified two periods: 1 period - 2000–2009 – traditional milk production technologies; 2 period - 2010-2018 – milk production technologies with the using of a smart farm elements. The research scheme is presented in Figure 1. We also analyzed the changes in milk production indicators depending on the use of modern automated systems.

| Milk production technologies of dairy stockbreeding |
|-----------------------------------------------------|
| 10 agricultural enterprises of the Omsk region, the total number of cows - 6241 heads |

| 1 period (2000-2009) | Traditional milk production technology |
|----------------------|---------------------------------------|
| 2 period (2010-2018) | Milk production technology with the use of a smart farm elements |

- The organization of animal accounting:
  - the identification accuracy;
  - the accuracy of accounting.

- The herd reproduction:
  - the actual cows barrenness;
  - the number of inseminations per one fruitful insemination;
  - the duration of the open period.

- The milk production:
  - the milk quality;
  - the profit from the sale of milk

**Figure 1.** The scheme of the research

Livestock enterprises of the Omsk region are geographically located in different climatic zones and have a different status, so their needs are not the same. Some of the enterprises included in the research have the status of breeding reproducers or factories. In addition there are the commercial dairy complexes among them. Thereby they use the different software packages that are more suitable for specific production conditions. Breeding reproducers and factories use the software package of “Selex” Analysis and Information System for dairy cattle, but in commodity enterprises, software packages are different, for example, Data flow, Deli Master and others. The software is designed to keep primary and breeding livestock records. Nowadays in Russia, in order to ensure pedigree registration in dairy cattle breeding, automated accounting is required, which is determined by the requirements imposed on enterprises that have the status of a breeding factory or a reproducer.

### 3. Results and Discussion

There are red steppe and black pied cows for the production of milk in the enterprises of the region.

The priority direction in modern animal husbandry is a smart animal husbandry. Smart livestock is a branch of agriculture engaged in the breeding of farm animals, a feature of which is the introduction of new generation systems and technologies to automate the animal care in order to increase the number of products and reduce the cost of costs [9].

The development of the smart animal husbandry in Western Siberia is only gaining momentum and 2016-2018 years were called “years of testing”, the results of which were predicted the trend of increasing “smart” systems being introduced into production.
The automated herd management systems are based on the principles of digitizing farm production processes, which are including the monitoring of the production performance, animal health status and well-being, nutrient balance in animal diets taking into account their physiological needs [10].

Modern information technologies, sensors and robots are being introduced into stockbreeding, making it possible to monitor each animal and arrange its life cycle as efficiently as possible so that the animals start making profit as soon as possible and longer than they were before the introduction of technology.

At present, in dairy cattle breeding, three keys to success can be distinguished: reliable accounting, the use of digital technologies, and competent control and interpretation of the data obtained by a specialist.

The basis of smart livestock is the equipment and sensors, methods of their communication, data processing systems. With their help, it is possible to solve all production problems. The basic unit of the automated herd management system is the individual identification of animals in the real time conditions. Information about a particular animal goes to a specialist every minute. Specialists take into account only those parameters for which it is possible to analyze the state of health, living conditions, time of mobility. All these indicators characterize the productive qualities of animals.

In the period from 2000 to 2009 identification of animals in the enterprises of the Omsk region was provided by tagging the young in various ways, tags, collars, and brandings. The data on the origin, development and productivity of cows were systematized mechanically, and zootechnical accounting was carried out using a cow card file, as well as other established forms were filled out.

Since 2009 a transponder and two duplicate ear tags are used to identify animals after the implementation of the automated accounting in the studied enterprises. A transponder is a sophisticated modern processor used to identify and monitor animal activity. The signal from the transponder is transmitted to the collector, which controls the health and phase of the sex cycles. The transponder determines the position of the animal in the room, at the result of that in real time you can easily determine the location of the cow. Electronic identification provides registration and traceability of animals (herds) based on the unique identifiers and individual electronic passports of each animal. These passports contain the entire event history, confirming zootechnical and veterinary well-being during the life cycle of animals. The appearance of the ear tags and the structure of the animal identification code comply with the requirements of the FAO (Food and Agriculture Organization of the United Nations). The ear tag shows a bar code that matches the animal's identification number, thus mobile scanners can be used to identify animals and record events in the field conditions.

It is important to avoid mistakes when identifying animals for the organization of reliable primary and pedigree zootechnical accounting. В таблице 1 представлена структура выявленных ошибок идентификации животных в зависимости от технологии ведения первичного зоотехнического учета. Table 1 shows the structure of the identified errors of animal identification, depending on the technology of conducting primary zootechnical accounting.

| The type of error                          | 1 period (2000-2009) | 2 period (2009-2018) |
|-------------------------------------------|----------------------|----------------------|
| The proportion of detected errors, %      | 27                   | 3                    |
| Including:                                |                      |                      |
| The duplication of the individual number  | 9                    | 0                    |
| The loss of the individual number         | 13                   | 0                    |
| The destruction of the numeration order   | 2                    | 0                    |
| The incorrect record of origin            | 3                    | 3                    |

The proportion of errors in the management of zootechnical accounting, caused by identification errors in the traditional milk production technology, was at the level of 27% of the total cattle population in the studied farms. The loss of an individual number or a decrease of its quality, at which the possibility of its correct reading is lost, was the most common cause of cow identification errors. In the period from 2000 to 2009 errors due to the loss of the individual number accounted for 13%, which is by 4% more than due to duplicate numbers within the same enterprise. The incorrect record of the origin of the cows is due to the lack of reliable information about the ancestors of the cows. Violations in the assignment
of individual numbers to animals, subsequently distorted the accuracy of the production indicators’ accounting, thereby hampering the proper organization of dairy cattle breeding.

Because of the introduction of an electronic system for the animals’ identification in the enterprise conditions, there were changes in some production indicators, as well as a reduction in the number of identification errors. This way for the period from 2009 to 2018 there is a significant reduction in errors for animal identification. The proportion of detected errors was 3% of the total number of cows in the studied enterprises. After the introduction of electronic identification of animals, there were no violations in the assignment of individual numbers, which is due to the automatic exclusion of two animals with the same numbers within the same herd. The system simply does not make a mistake in assigning an individual number to an animal. When entering data into the electronic identification system, data validation is performed. Loss of the individual number to animals is also excluded. In addition, to increase the reliability of zootechnical accounting, data entry uses a calendar, international reference books of allowable values when entering details: breed, animal species, gender, disease, vaccine, research result, etc.

With automated accounting, we detected 3% of violations in the records of the origin of cows. These errors are caused by the different spelling of the names of foreign stud bulls. The same producer can be recorded differently, due to the transliteration of their names, since there is no single system for translating the names of animals of foreign origin in the country.

The obtained data let us to conclude that the introduction of an automated system for zootechnical accounting and animal identification minimizes errors. There was a decrease in the proportion of cow identification errors by 24% for the period from 2000 to 2018.

Digitalization in zootechnical accounting minimizes the number of errors during data entry, as the role model is used to regulate user access to the system's functionality. It is allowed to create new roles and edit existing ones by the system administrator.

The modern accounting system in dairy cattle breeding is not only the indicators of milk yield and fat content, it is also the core of the genetic improvement of animals, the tool of a specialist for increasing milk production and improving of technologies.

A transponder located on every farm animal not only identifies, it also transmits indicators of cow activity. The obtained information is displayed on the monitor screen in an accessible form in the type of tables and graphs. Analysis of the obtained information let you to quickly identify deviations in the behavior and state of health of the animal.

Organizing the reproduction of a herd of cows and planning milk production, it is necessary to identify cows in hunting in a timely manner and to inseminate them fruitfully. Cultural dairy cattle breeding involves the use of artificial insemination of cows. The timely identification of cows in hunting and their transfer to insemination is the most important technological link in the production of milk. Table 2 presents the indicators of the reproduction of cows in enterprises for the period from 2000 to 2018.

| Table 2. Reproductive qualities of cows |
|---------------------------------------|
| Indicators                            | 1 period (2000-2009) | 2 period (2009-2018) |
| The quantity of inseminations per one fruitful, doses | 4.1±0.7            | 2.3±0.5            |
| The actual barrenness, %              | 44.2±2.8           | 32.7±1.3           |
| The duration of the open period, days | 183.0±12.4         | 156.0±7.2          |

The analysis of the reproduction of a cows herd in the studied enterprises showed a significant positive trend after the introduction of a smart farm. The multiplicity of insemination of cows decreased, as evidenced by the number of insemination per fruitful one. On average, in enterprises of the Omsk region, before the introduction of a smart farm elements and an automated system for identifying cows in hunting, the number of insemination per fruitful was 4.1 times, which made it difficult to organize the reproduction of dairy cattle. There was the reduction in the multiplicity of insemination of one head in the studied enterprises on average to 2.3 times for the period from 2009 to 2018. Reducing the number of insemination per one fruitful can make the rational use of the reproductive function of cows and seed stocks of bulls. This reproduction indicator is mainly due to timely insemination. If the cow is properly determined in the hunt and inseminated at the optimum time, the insemination rate will be lower, that increases the efficiency of dairy cattle breeding.
The violation of reproduction leads to barrenness of the livestock, that is infertility of cows. Barren cows are unprofitable for the enterprise, since no offspring are received from them during the calendar year. In order to improve the efficiency of dairy cattle breeding, it is necessary to develop a plan of measures to reduce the actual productivity of cows and the prevention of infertility. Barrenness is caused not only by diseases of the cows, but also by technological errors in identifying cows in the hunt. Highly productive cows are characterized by a strongly pronounced dominant of lactation, which inhibits the reproductive function of the animal. Therefore, the animals with high milk production have the poor-expressed sexual hunting and, as the result, their open period is prolonged due to non-timely insemination. Thus, due to the automated system of reproduction control in the enterprises of the Omsk region, it was possible to reduce the actual barrenness to 32.7%. Skillful analysis of the received information let us to identify cows in the hunt in a timely manner and to inseminate them fruitfully. The duration of the open period is an important indicator of the reproductive qualities of cattle, since the synthesis of milk in the udder of a cow is not possible without receiving a calf from a cow. The open period is the period from calving to fruitful insemination. Figure 2 shows the trend of the open period from 2000 to 2018.

![Figure 2. The trend of the open period](image)

For the period from 2000 to 2018, the duration of the open period on average decreased by 27 days, or by 14.75%. The maximum values of the open period were noted in 2005, before the introduction of automated reproduction control systems. In 2015, the period from calving to fruitful insemination had minimal values, on average, the pregnancy in cows occurred on the 154th day of lactation.

Thus, we can conclude that the introduction of a smart farm leads to an improvement in reproduction rates in dairy cattle breeding by 52.3%.

At the same time, it is currently more cost-effective for enterprises to produce the highest quality milk. It is possible to improve the quality characteristics of the produced milk only by upgrading the milking equipment. Physical and chemical indicators of milk are the main criteria for determining its grade. The average values of milk quality indicators in the analyzed periods are presented in table 3.

| Table 3. Physical and chemical milk characteristics |
|----------------------------------------------------|
| Indicators                                         |
|                                                   |
| 1 period (2000-2009)                               |
| 2 period (2009-2018)                               |
| Acidity, °T                                        | 17.6±3.21 | 17.2±0.15 |
| Purity group                                       | 1…2      | 1        |
| Density, kg/m                                      | 1027.0±2.4 | 1028.0±2.1 |
| Mass fraction of true protein, %                   | 2.7±0.04 | 2.8±0.03 |
Studying the obtained data, we can conclude that for the second period there were changes in the physical and chemical parameters of milk in the region. The purity of the milk produced in the conditions of modernized farms improved. All the milk produced in modern automated milking parlors belongs to the first purity group, which is undoubtedly due to the optimization of the milking technology and minimal contact of the raw milk with the environment.

The mass fraction of true protein in milk depends on the feeding conditions of the cows, as well as the breed and individual characteristics, therefore the difference between the periods before automation and after is not statistically significant.

To carry out the milking process the studied enterprises are equipped by the modern milking parlors with milking units such as a parallel or herringbone. The entire milking process is automated. The modern milking parlor of the smart farm provides comfortable milking, reduced stress for animals, and improved working conditions for machine milking operators.

The milking process is displayed on the PC monitor screen in the form of a graph and the use of color indicators that show statistical information and the quantity and quality of the milk produced.

Analysis of gross milk production, depending on the grade is presented in table 4.

| The grade of milk | 1 period (2000-2009) | 2 period (2009-2018) |
|-------------------|----------------------|---------------------|
| The highest       | 42.0±4.8             | 56±4.1              |
| The first         | 36.0±4.2             | 31±3.8              |
| The second        | 22.0±3.3             | 13±3.6              |

The analysis of the grade of produced milk for the studied enterprises showed that in the period up to 2009, the share of top grade milk in gross production was 42%, and after the milking rooms were commissioned, the proportion of top grade milk was 56%, the quality of milk produced improved by 14%.

4. Conclusion
The increase of milk production is associated with the intellectualization of labor both based on promising means of automation and mechanization, and based on the organization of labor and production management using modern computer technologies.

Ensuring high growth rates of milk production and raising to a qualitatively new level of the economy of dairy cattle breeding are possible only by early transition to intensive production methods. In modern conditions of agricultural production, it is necessary to reduce the cost of human labor per unit of production. The introduction of digital technologies for smart farm, the automation of basic technological processes can reduce the load of the worker, thereby reducing the cost per unit of production.

Analysis of the economic efficiency of the use of modern herd management systems in the south of Western Siberia indicates the feasibility of modernizing domestic dairy cattle breeding. Nowadays the profitability of milk production in the studied enterprises is relatively low, since the cost of the equipment of a smart farm is quite high and pays off in a long time. Therefore, the main indicator of the effectiveness of the enterprise can be considered the specific volume of revenue from the sale of milk before the introduction of modern technologies and after, taking into account the price of selling milk.

The specific growth of profits from the sale of produced milk in the conditions of enterprises in the region amounted to +42%, and in certain production conditions, the specific profit was increased by 68%.

Thus, the introduction of modern automated herd management systems for milk production in the Omsk Region leads to an increase in key production indicators.

The result of the work of a smart farm was a reduction in the cost of fruitful insemination to 52.3% due to a reduction in the rate of insemination of cows, an increase of the young stock birthrate due to a decrease of the barrenness capacity by 34%. Due to the improvement of the quality indicators of milk and the reduction of labor costs, the use of modern technologies contributed to an increase in the specific profit from the sale of produced milk by 42...68%
In the current economic conditions, when a breed of cows was selected, a way of housing was determined, and a feeding ration was established, the role of mechanization and automation of technological processes increases in obtaining high-quality and competitive milk. Analysis of the production experience of two enterprises breeding the same breed of cattle located in different natural and climatic zones showed that the improvement of labor and the improvement of technology using modern equipment created the prerequisites for increasing the productivity of animals. This approach to the organization of dairy cattle in the conditions of the south of Western Siberia contributes to the preservation and development of relevant rural areas.

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