Automation of dairy herd management and evaluation of its economic efficiency using an information system

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Abstract. Elements and systems of automated management of the dairy herd, questions of prompt and reliable evaluation of their economic efficiency using the proposed information system are considered. The market offers various options for automated herd management, accompanied by expert assessments of technological and production effects. However, to make decisions on the economic viability of new solutions, clear algorithms and information systems are needed to convert this data into economic effects and economic efficiency assessments. Official statistics for the Russian Federation and the Southern Federal District formed the base of this study. Design calculations were performed for one of the agricultural organizations of the Krasnodar Territory. The research results were obtained using discounting methods, mathematical modeling, programming in SQL, as well as the original method of transforming non-standard cash flow by highlighting its multidirectional members. The calculations performed using the information system made it possible to evaluate the considered innovations as cost-effective, with short payback periods and high profitability. This allowed us to conclude that the automated management of the dairy herd is promising not only from the technological, but also from the economic point of view.

1. Introduction

In agriculture, as one of the most difficult sectors of the economy, there is currently a need for modern automated management systems and an objective assessment of their economic efficiency. For the adoption of economically viable decisions on the use of certain elements of automated management, a timely, prompt and reliable assessment of the economic efficiency of the proposed innovations is necessary, which is impossible without the use of information systems.

Automated management systems in dairy cattle breeding will be in demand only if they are highly cost-effective. However, the lack of clear calculation algorithms and special information systems for assessing the economic efficiency of modern automated management in livestock husbandry is hindering its wider distribution due to the difficulties encountered in the decision-making process on the viability of investing in digital technologies.

2. Literature review

Modern management of technological and technical processes is carried out, as a rule, with the usage of computers. The functioning of management systems having personal computers in their circuit is based on the principles and methods of the management theory. In the automation of management, the use of
machines, mechanisms, computers, automatic systems is focused on the labor facilitating and improving its conditions, increasing labor productivity and the efficiency of enterprises [1].

In dairy cattle breeding, automated, clearly executed, high-intensive technologies for precision management of production processes are increasingly being used [2]. In the Russian Federation, large specialized livestock farms operate on an industrial basis, where the full advantages of modern automation equipment are used. The use of electronic management systems of individual processes and integrated automation of production has been and remains one of the priority areas for the development of the agro-industrial complex, and precise livestock farming can be considered as structural subsystems of the innovative development of agriculture.

Automated accounting systems for feeds during their loading, systems for the dosed distribution of feeds, automatic weighing of animals, and systems for automatically measuring the milk productivity of animals, both group and individual, are gaining popularity. As a result of the development of liquid separation technologies in the stream, it became possible not only to take into account the amount of milk being fed, but also to automatically evaluate its quality according to many parameters.

The development of information technology has led not only to the appearance, but also to the commercial distribution of electronic management systems for the dairy herd of cattle. More and more frequently, electronic chipping to identify animals, transponders, motion and chewing activity sensors, thermal imagers, wireless local area networks, automated milking systems, automatic milk sampling and analysis during each milking from each udder part of each animal are used. The generated data should be subjected to automated processing, since a person is not able to analyze such arrays and extract useful information, in this case computer analysis technologies for big data come to the rescue. N.I. Kulikova proposed a new approach to increase the fertility of cows, based on the identification of estruation as a result of computer analysis of data obtained using a device attached to the metacarpal bone of the animal’s leg [3].

Digital technologies take management in dairy cattle breeding to a whole new level; scientists and practitioners will have to integrate data analysis and decision-making tools in the future. At present, it has to be noted that the information flows generated by the use of automated management are not fully involved in improving the production process.

There appeared systems that provide a combined overview of locomotor activity, temperature, and acidity level in the gaster of cattle, providing the monitoring from the inside, from the rumen of animals, which allows continuous measurement and processing of data on the state of their body [4]. The data is regularly transmitted to the base station antenna, which also receives information about the results of measuring the temperature and humidity in the room, all this information arrives at the server and is archived, and it can be read using a computer, tablet or smartphone. Such information support allows an automated detection of estruation in a timely manner, and is focused on reducing service and calving intervals, increasing milk productivity, improving the insemination index, timely diagnosing a decrease in the locomotor activity and diseases, viral and bacterial infections, parasitic lesions, predicting the possible onset of epizootics on early stages (aphthous fever, pasteurellosis, listeriosis, brucellosis), early detection of calving and prevention of stillborn calves, balancing and control of air temperature and humidity and prevention of animals’ heat stress.

Automation of agriculture is characterized by the inextricable connection of technical equipment and biological objects with the variable characteristics of animals, and the cyclical nature of the production [5]. Non-automated, or as it’s called, manual control of machines, aggregates and technological processes in agriculture is not effective enough.

One of the tasks of fundamental research in the field of automated management in agriculture at the present stage is to improve the methods of economic calculations of the effectiveness of its use in agriculture and the development of appropriate information systems to assess the economic efficiency of using automated management in crop production and livestock husbandry [6]. In modern conditions of increasing uncertainty and increased risks, special attention should be paid to the economic aspects of automated management in agriculture.
3. Materials and methods

Over the past 25 years, the productivity of cows has significantly increased in Russia (Figure 1).

![Figure 1. Cow productivity in Russia](image)

The regression coefficients in the paired correlation-regression model of the linear function reflect the average annual increase in the milk productivity for the corresponding periods; their values show higher growth rates of cow productivity in agricultural enterprises in comparison with other categories of farms.

The Southern Federal District (SFD) ranks third in terms of the number of cows in farms of all categories, and fourth in terms of milk production and cattle among the federal districts of Russia. In the five regions considered later in this article, in recent years a total of 94.5% of milk produced in the Southern Federal District has been obtained. A graphical representation of monthly gross milk yields shows different scales of milk production, the nature and strength of seasonal fluctuations in these regions (Figure 2).

The major seasonal fluctuations are typical for the Rostov and Volgograd regions, where a significant part of the number of cows is concentrated in private farms that are not covered by automated management, which allows regulating the seasonality of calving.

To determine the consequences of using both individual elements and whole automated management systems in dairy cattle breeding, we have developed an information system that allows us to calculate economic effects and determine the economic efficiency of measures to digitize production. During the study, discounting methods, cash flows transformations, mathematical modeling, programming in SQL were used.

The calculations were based on the materials of one of the agricultural organizations located in the northern agricultural zone of the Krasnodar Territory for the planned number of cows 1,500 units with a productivity of 6500 kg of milk per year per cow. We took into account the current and planned values of indicators of productivity, livestock, duration of the open period, incidence rates of mastitis and ketosis, culling, insemination index, consumption of sperm doses, costs of insemination, bare cost and...
price of milk, live weight of the sold young animals and rejected ones, the cost of acquiring equipment and factory supplies.

Figure 2. Seasonality of milk production in the regions of the Southern Federal District, 2018 year

4. Results and Discussion

The total economic effect from the use of automated management is formed by reducing the open period to the optimal duration, reducing the incidence of mastitis and ketosis. Automatic sampling and analysis of milk samples for the concentrations of progesterone, lactate dehydrogenase, beta-hydroxybutyrate and urea allows you to determine the individual condition of each animal, carry out timely insemination and track information about pregnancy, possible threats of mastitis and ketosis. Manufacturers of automated herd management systems, specialists in the field of animal science and veterinary medicine give possible production effects of using such systems, however, in a particular farm, information about these technological advantages should be converted into economic indicators. It is necessary to take into account many technical, technological and economic parameters to determine the effectiveness and make decisions on the implementation of the considered innovation.

The calculation of the effect of reducing the open period is based on the valuation of the additionally obtained products during the specified time, cost savings for maintaining the open cow during the expected period, and cost savings on insemination of animals, taking into account the planned decrease of the insemination index. Timely diagnosis of ketosis can reduce culling and obtain additional products; the detection of mastitis can prevent a decrease in cow productivity and maintain milk quality. The estimated value of the annual total economic effect for the studied enterprise, according to our estimates, is 28479 thousand rubles (Table 1).

Table 1. Calculation of the total economic effect using an automated herd management system, thousand rubles per year

| Production and economic effects | Reducing open period | Reducing mastitis incidence | Reducing ketosis incidence |
|---------------------------------|----------------------|----------------------------|---------------------------|
| Additional production and cost savings | 18 649 | 3 410 | 833 |
| Culling reduction | – | – | 2 888 |
| Insemination costs saving | 2 700 | – | – |
| Total amount | 21 349 | 3 410 | 3 720 |
| The structure of the economic effect, % | 74.96 | 11.97 | 13.06 |
Approximately 75% of the effect is obtained due to the additional production and cost reduction for the acquisition of sperm doses, as well as the keeping of open cows.

To calculate the effectiveness indicators of the innovation and investment project for the acquisition of electronic herd management systems, the developed information system provides for the analysis of project cash flows taking into account exchange and inflation rates. In this case, the net cash flow has a non-standard form. Since the balance of each of its members has a positive value, the internal rate of return cannot be calculated without transforming the cash flow with the allocation of multidirectional members in its composition. This allowed us to determine the approximate value of the internal rate of return of the project (Table 2).

| Investment performance indicators | Value  |
|-----------------------------------|--------|
| The average annual cumulative effect, thousand rubles | 28 479 |
| NPV, thousand rubles               | 96 092 |
| PI                                | 1.425  |
| PP, years                         | 1.285  |
| DPP, years                        | 1.732  |
| IRR, %                            | 145.8  |
| MIRR, %                           | 73.1   |

The modified internal rate of return is determined at a profitability rate on reinvestment of 50%, which corresponds to a possible level of profitability of the production and sale of milk.

In our opinion, the above-considered components of the economic effect of the use of automated dairy herd management systems need to be supplemented with potential effects of reducing the seasonality of milk production. Although the scientific publications devoted to the advantages of automated management of the dairy herd provide various options for regulating the seasonality of calving and the seasonality of milk production, there are practically no formalized presentations of procedures for calculating the economic effect of reducing the seasonality of milk production outlined by the algorithm and real examples.

A quantitative measurement of these effects can be attributed to the development prospects of proposed by us information system for evaluating the effectiveness of automated herd management.

5. Conclusion
A complex system of automated herd management with the use of electronics and touch sensors allows analyzing milk samples during milking and evaluate the health status of each animal. Information on the production and technological effects generated by this system should be converted into indicators of economic effect and economic efficiency.

Using the proposed information system improves the proficiency of calculations and facilitates their implementation, promotes the adoption of balanced decisions on investing in electronic dairy herd management systems, taking into account the changing macroeconomic parameters and technical and economic indicators that are individual for each farm. The introduction of electronic herd management systems will facilitate the transition to a qualitatively new level of dairy cattle breeding, and will allow to reduce the incidence of animals and to improve herd reproduction processes.

References
[1] Hindermann P, Nüescha S, Früha D, Rüstb A and Gygaxc L 2020 High precision real-time location estimates in a real-life barn environment using a commercial ultra wideband chip *Computers and Electronics in Agriculture* 170
[2] Burda A G, Frantsisko O Y, Baranovskaya T P, Trubilin A I and Loiko V I 2016 Grounding of the combination parameters of the agricultural and processing branches of the agricultural
enterprises by the operations research method *Journal of Applied Economic Sciences* 11 1209-1224

[3] Kulikova N I, Patieva A M, Cherechecha A A and Nimbona C 2018 A new way to increase the fertility of cows *Journal of Pharmaceutical Sciences and Research* 10 1607-1609

[4] Thomas E B, Dolecheck K A, Mar T B, Eastwood C R, Dela Rue B T and Bewley J M 2019 A decision-support tool for investment analysis of automated oestrus detection technologies in a seasonal dairy production system *Animal Production Science* 59 2280–2287

[5] Wolfger B, Jones B W, Orsel K and Bewley J M 2017 Technical note: Evaluation of an ear-attached real-time location monitoring system *Journal of Dairy Science* 100 2219–2224

[6] Baranovskaya T P, Loiko V I, Vostroknutov AY, Lutsenko Y V and Burda A G 2016 Developing a business model and a strategy map for objectives in the enterprise architecture of an agro-industrial corporation *International Journal of Applied Business and Economic Research* 14 6015-6037