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Expert system as a means for optimizing cattle diets

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Abstract. Existing expert systems for optimizing cattle diets were studied, the ISO 9126 quality model was chosen to formulate requirements and evaluate existing systems. A mathematical model for optimizing animal feed rations was developed based on the linear programming problem, which is to minimize the objective function for the ration cost with the restrictions on the indicators of overall nutritional value. The prototype of the application being developed is based on a functional model developed using the IDEF0 methodology, which defines the main functions of the system: processing user requests and providing the necessary information on animal feed and standards; creation of rations for animals according to set parameters; recalculation of a diet taking into account the changes made by the user; analysis of the diet and providing recommendations for its optimization. Methods for developing user interaction algorithms are described. To create an interface, design methods were chosen - "User-oriented design" and "Human-oriented design". When implementing the objectives of the current research, the problem of optimizing the diet of animals will be solved.

1. Introduction

Agriculture is one of the most important sectors of the economy: it accounts for 7.7% of the gross regional product. Over 50% of all income in livestock comes from cattle breeding. Livestock is the source of the most valuable food - milk and meat. For a long time in the human diet there have been milk processing products - kefir, yogurt, sour cream, butter and other dairy products. Milk contains all the necessary nutrients: fat, protein, sugar, minerals, enzymes, etc., which are easy digestible.

Currently, agriculture is moving in the direction of strengthening the knowledge-intensiveness of the products produced. Therefore, in our country it is necessary to set and consistently solve the problem of innovative development of the agro-industrial complex.

2. Literature review

Milk production targets in the Russian Federation are increasing annually, motivating producers to increase the gross volume of milk produced and milk yield per cow. However, it is reported that the production of milk and the number of cattle in Russia is annually reduced by 1.5-2% [1]. For example, according to the FSSS data, in the agricultural organizations of Udmurtia the population of cows decreased: in 2018 it was 108.9 thousand heads, which is 0.8% less than the same indicator for 2017 [2].



In addition, the data obtained from milk producers are annually checked by the FSSS and corrected. As a result of the recalculation, the official production volumes of raw milk in 2017 were lower by 3.2%, or 1 million tons, compared to published data (30.2 thousand tons) [1]. According to preliminary data of the Ministry of Agriculture of the Russian Federation, in 2018 milk production amounted to 30.6 million tons, with an average milk yield per cow of 5850 kg, but a decrease in the declared data is predicted after correction made by the FSSS.

Low rates of average milk yield per cow indicate a low level of realization of the genetic potential of cows [3, 4]. The milk production of cows depends on heredity and environmental factors, while the realization of the genetic potential of milk production depends to a large extent on the level and usefulness of feeding animals.

In the regions of the country, where there is a decrease in the number of livestock or milk production, feed consumption per 1 livestock unit does not correspond to the milk productivity of cows. This is due to improper planning and process execution of technology for forage conservation, non-compliance with the principles of rationing and feeding rations.

At present, almost all agricultural enterprises make rationing using personal computers (rationing software, Excel), but the main aspect of this ration calculation is time reduction due to group preparation without taking into account the individual characteristics of the physiological state of the cows.

Information systems and technologies enable to automate processes, increase efficiency and productivity. Existing information systems for the livestock industry do not have all the necessary functions required by specialists, or they are extremely inconvenient to use. Experts working in production point out the lack of convenient tools for working with data and automating activities.

The use of computer programs in the preparation and balancing the diets involves the replacement of the successive-approximation technique used by specialists in calculating rations “by hand” with the simplex method.

Expert systems should be considered as tools, not as ready-made solutions for the preparation the rations. The developing program “Ration and Efficiency”, unlike other computer programs for calculating rations, has a number of functions and options that allow a specialist to create both group and individual rations quickly and efficiently. The program is an automated system for calculating the diets on the basis of artificial intelligence in the form of an expert system.

The task of the expert system is to achieve the highest animal productivity under given feeding conditions. According to the set parameters, the expert system optimizes the rations of feeding animal groups, gives reasonable recommendations on the inclusion of additional components and on the adjustment of feed preparation technology [5].

3. Research methods

When creating a diet for feeding livestock, it is necessary to take into account the norms of the amount of feed used and the amount of nutrients contained in it. The food base must be formed so that the ration of livestock is composed of several components and includes a balanced diet of succulent, fibrous and concentrated feed, which must contain all the necessary nutrients. It is necessary to balance protein, essential amino acids, vitamins and minerals. The lack of micronutrients and minerals in the diet (sodium, calcium, phosphorus, etc.) is compensated by the use of special additives. With a shortage or excess of at least one element, the efficiency of nutrient utilization of the entire livestock diet deteriorates.

For the preparation of the diet, it is required to calculate the daily ration, i.e. the amount of each product P_j , on the one hand, to provide the minimum required amount of nutrients, and on the other hand, to minimize the cost of the developed diet.

In order to facilitate the implementation of the above objectives, an economic-mathematical model of the diet problem is being compiled [6]. In general, this model is as follows.

x_j ($j = 1, 2, \dots, n$) is the amount of the j -product in the daily diet. The diet uses n kinds of foods. Each product contains m essential nutrients in an amount of at least b_i ($i = 1, 2, \dots, m$) units, a_{ij} is the number

of units of the necessary nutrient B_i in a unit of the j -product. The cost c_j per unit of the j -product is known. It is necessary to make a diet of the necessary nutritional value at the minimum cost of it.

4. Research results

After studying the components of existing and current software products, it was concluded that the best way to use databases and expert systems is to develop information systems in the field of agriculture. In this regard, it was decided to develop our own data system for optimizing animal diets, with given user requirements for the program.

When developing software, there are many development methodologies. The prototype of the application being developed is based on a functional model developed using the IDEF0 methodology [7], which defines the main functions of the system: processing user requests and providing the necessary information on animal feeds and standards; creation of rations for animals according to set parameters; recalculation of a diet taking into account changes made by the user; analysis of the diet and providing recommendations for its optimization.

To implement the agreed decisions, number of tasks needs to be solved: development of a mathematical model for calculating indicators and norms; design and development of a database model; software implementation of algorithms for data access; software implementation and testing of ration calculation algorithms; development of a user interaction algorithm and a prototype of the program interface [8].

To build architecture of the system, a two-tier client-server model was chosen. The client-server technology itself provides for two independent interacting processes - a server and a client. In this case, "server" means software with a set of functions, located on a separate computer. "Client" is the main program being developed, which works with the main set of computing functions and the database.

To optimize rations of large cattle, problem formulation of the linear programming [9] is used, namely, finding the extremum of a linear objective function by formula (1) with linear constraints in the form of inequalities by formula (2).

$$F(x) = c_1x_1 + c_2x_2 + \dots + c_nx_n \rightarrow \min, \quad (1)$$

where c_i - price of i -feed, x_i - unknown amount of i -feed.

$$\begin{aligned} a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n &\leq b_1; \\ a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n &\leq b_2; \\ \dots & \\ a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n &\leq b_m, \end{aligned} \quad (2)$$

where a_{ji} is the value of the j - nutritional characteristic for the i - feed (nutritional value of the feed), b_j is the physiological daily need of the animal for the j -nutrient — proteins, fats, carbohydrates, etc. (the nutritional value by standards).

Furthermore, in this task it is necessary to take into account that the required quantity of feed cannot take a negative value, and can be limited by the user. To do this, the system must set additional restrictions on the formula:

$$0 \leq x_i \leq z_i, \quad (3)$$

where z_i - limit on maximum of i - feed.

To solve extremum problems (1) - (3), the simplex method is used. Its main advantage is the use of small amounts of storage. The disadvantage is that the method, when specifying a large number of constraints, may not find solutions, or find a local minimum, especially when studying complex samples [9].

A core element in creating a user interaction algorithm is the development of an interface. Developed on the basis of the algorithm, the program interface should create the least mental load for the user in the process of achieving the goal - drawing up a diet.

To create an interface, design methods were chosen — User-centered design and Human-centered design. Thus, the interface prototype will be built on the basis of the needs and abilities of specialists in rationing with the use of ergonomic principles in designing [10, 11].

5. Conclusion

When implementing the tasks, the problem of velocity of diet optimization will be solved. The problem of overruns of fodder in the preparation of rations is solved by better balancing nutritional indicators using unique algorithms of the expert system and the inclusion of additional components with a user-defined set of feeds. The expert system also formulates recommendations to the user on the preparation of feed and offers 3 options of rations to choose, depending on the actual production tasks (obtaining the most balanced, cheap or most cost-effective rations).

Automating the optimization of animal feed rations is the main trend in the development of livestock at the present stage. This is the main way of transition to a qualitatively new level of development, which allows not only increasing the accuracy and effectiveness of forage conservation and animal feeding processes, but also drastically reducing labor and material costs for obtaining products and thereby ensuring the transition to the sixth technological order.

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