MATHEMATICAL MODELS AND ALGORITHMS BALANCING DIET OF CATTLE IN THE DECISION SUPPORT SYSTEM

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Qualitative feeding dairy cows is an important condition for their high productivity. Therefore, preparation of a nutritionally balanced diet - it is a practical problem, which constantly have to deal with a specialist-zootechnician. Traditionally, the essence of the problem of optimizing the diet is to find a diet with minimal cost while guaranteeing the provision of the animal's needs in all nutrients. The disadvantage of this approach is overfeeding the animal, as it is assumed that the content of each nutrient in the diet component should be not less than the norm. Further, of great practical importance in the ability to specify the data structure as starting ration, i.e. Planned percentage of one or other of the diet selected to produce animal feed.

The purpose of research - development of a mathematical model and algorithm for calculating a balanced diet feeding cattle (cattle), the relevant scientific develop consumption rates in all major nutritional components.

Materials and methods of research. Initial data for calculation of the diet of dairy cows, in accordance with the procedures established in the Republic of Belarus are plenty of animal and milk yield: daily milk yield - for lactating cows or predicted milk yield per lactation - for dry cows. It is believed that the values of these two quantities, mostly daily consumption rate depends cow main nutrients (dry substance exchange energy, protein, fat, fiber, etc.). We denote the vector - required rate of daily consumption of cow j-th component of the nutrient, where M - the number taken into account when optimizing the diet of nutrients.

The results of research. Let the expert-selected N zootechnician available on the farm feed. Selected from N must create a feed ration, which must meet the needs of an animal M in the nutrient components in accordance with required standards.

For mathematical formalization requirements described for each included in the feed ration, we introduce the following notation:

a_{ij} - the content of the j-th component of the nutrient in 1 kg of i-th feed ($i = 1,...,N$);

c_i - the cost of 1 kg of i-feed;

x_i - the required daily intake of the i-th feed.

Vector $\vec{R} = (\vec{R}_1,...,\vec{R}_M) = (R_j)_{j=1,...,M}$ – vector is calculated in the content of each diet nutrient components M, and j-th vector element *Rj* is given by:

$$R_j = \sum_{i=1}^{N} a_{ij} \cdot x_i \,. \tag{1}$$

Then the relative deviation of the content in the diet of the j-th component of the daily nutritional norm of its consumption - is the difference divided by the value of the daily norm, and in vector form can be expressed as follows:

$$\vec{\delta} = \left\{ \frac{D_j - R_j}{D_j} \right\}_{j=1,...,M} . \tag{2}$$

Thus, the vector $\vec{\delta}$ - a vector of deviations from the norm nutritious diet on individual nutritional components. The more accurate nutritional diet will meet the required standards, the lower value should be the norm of the vector $\vec{\delta}$. Therefore, as the objective function is proposed to use the norm of a vector $\vec{\delta}$, defined as the weighted sum of the absolute values of its elements:

$$Z(\vec{x}) = \left\| \vec{B} \cdot \vec{\delta}^{T} \right\| = \sum_{j=1}^{M} \left| B_j \cdot \frac{\left(\sum_{i=1}^{N} a_{ij} \cdot x_i - D_j \right)}{D_j} \right|, \tag{3}$$

where $\vec{B} = (B_j)_{j=1,...,M}$, $B_j \geq 0$, $\sum_{j=1}^{M} B_j = 1$ – vector normalization coefficients whose values are proportional to the degree of importance of deviations from the normal diet of a particular nutrients. Values of the coefficients B_j determined by expert assessments.

Thus, the mathematical formulation of the optimization problem of the diet is as follows:

$$\begin{cases} X_{\min i} \le x_i \le X_{\max i}, \quad i = 1,\ldots,N; \\ \langle p_i = P_i \rangle, \quad i = 1,\ldots,N; \\ \sum_{i=1}^{N} a_{i\,\text{СВ}} \cdot x_i \ge D_{\text{СВ}}, \\ \sum_{i=1}^{N} a_{i\,\text{ОЭ}} \cdot x_i \ge D_{\text{ОЭ}}, \end{cases} \tag{4}$$

$$Z(\vec{x}) \to \min,$$

where $X_{\min i}$, $X_{\max i}$ – the initial limits on the minimum and maximum mass of the i-th feed in the daily diet, asked, if necessary, the user;

$p_i = \dfrac{a_{i\,\text{СВ}} \cdot x_i}{\sum_{i=1}^{N} a_{i\,\text{СВ}} \cdot x_i}$ либо $p_i = \dfrac{a_{i\,\text{ОЭ}} \cdot x_i}{\sum_{i=1}^{N} a_{i\,\text{ОЭ}} \cdot x_i}$ – percentage of the dry matter or the total diet metabolizable energy provided by the i-th feed (ration structure);

P_i – asked if necessary initial user restrictions on the allowed values p_i, defining the desired interest structure of diet on a dry matter basis or by exchange energy, braces "" means that this limitation is not necessarily present in the system;

indices "CB", "MA" - denote, respectively, "dry matter" and "exchange energy".

Problem (4) is a linear programming problem and can be solved by the simplex method with artificial basis. A detailed description of the algorithm for solving the problem (4) using the simplex method with artificial basis is given by the authors of this article in the paper.

The result of the solution of (4) is a diet nutritionally optimized such that the sum of deviations from the required standards for nutritional mainly takes into account nutritional components will be minimal. Ie, the diet will be as close as possible to the main content of nutrients to the required standards.

The proposed approach to the calculation of the optimal diet was used in the Belarusian State Agrarian Technical University (Minsk) when creating a computer program to support decision-making in the calculation of feed rations of dairy cows. Its practical testing in the farms of the Minsk region of Belarus has shown that at the same time optimizing the diet for 8 indicators (dry matter, the exchange energy, crude protein, crude fiber, crude fat, calcium, phosphorus, salt) is almost always achieved very exact match nutritional calculated ration with the required standards for two-three basic indicators (dry matter, the exchange energy, protein), deviations from the norm, not exceeding 1%. At the same time, in some cases, the deviation from the norm for the rest of the indicators can be large enough for calcium, phosphorous, dietary fiber, for example, abnormality can reach 10 - 15%. Therefore, as an alternative method for calculating the diet described in this paper, we propose the approach, the essence of which is to find a diet for which nutritional deviations from the norm for all the variables included lie in some permissible limits. The mathematical formulation of this approach is as follows:

$$\begin{cases} X_{\min i} \le x_i \le X_{\max i}, \quad i = 1,...,N; \\ \langle p_i = P_i \rangle, \quad i = 1,...,N; \\ 0 \le \dfrac{\sum_{i=1}^{N} a_{i\,\text{СВ}} \cdot x_i - D_{\text{СВ}}}{D_{\text{СВ}}} \le L_{\text{СВ}}, \\ 0 \le \dfrac{\sum_{i=1}^{N} a_{i\,\text{ОЭ}} \cdot x_i - D_{\text{ОЭ}}}{D_{\text{ОЭ}}} \le L_{\text{ОЭ}}, \\ \dfrac{\left|\sum_{i=1}^{N} a_{i\,j} \cdot x_i - D_j\right|}{D_j} \le L_j, \quad j = 1,...,M, \quad j \ne \text{'СВ'}, \quad j \ne \text{'ОЭ'}, \end{cases}$$

$$Z(\vec{x}) \to \min, \tag{5}$$

where L_j - margins (as a percentage) of the deviation from the norm nutritious diet for the *j*-th parameter is taken into account.

The values of L_j, like the values of the coefficients B_j (3) reflect the degree of importance of a nutritious diet overlap with the norm for the *j*-th component: the less L_j, the more accurate the match should be the norm. L_j values should be determined by methods of expert evaluation. In this paper we proposed to determine the values of L_j inversely proportional to the values of the coefficients B_j:

$$\frac{L_j}{L_{\text{СВ}}} = \frac{B_{\text{СВ}}}{B_j}, \quad j = 1,...,M, \quad j \ne \text{'СВ'}\cdot \tag{6}$$

The algorithm for calculating the next diet.

Step 1. Set the minimum acceptable value for the border deviations from the norm nutritious diet on a dry matter: 0.5%.

Step 2: According to the formula (6) are defined boundaries corresponding values of deviation from the norm nutritious diet accounted for the remaining components of the nutrient $L_j,\ j=1,...,M,\ j\neq\text{'CB'}$.

Step 3. Using the algorithm of the simplex method with artificial basis searches solving an optimization problem (5).

Step 4. If the solution is not found, then the value of the deviation boundaries of dry matter *LSV* must be increased by 0.5% and go to step 2.

The search is repeated until then, until there is a solution to the optimization problem (5).

Conclusions

The main advantage of the proposed mathematical model for calculating the diet of cows is that livestock specialist in the preparation of the diet has the ability, if necessary, to plan its desired interest rate structure based on the zootechnical requirements, available on the farm stocks of food and other conditions.

Also of note is the fact that by introducing weighting coefficients B_j and L_j take into account the importance of the match with the norm content of nutrients in the diet, ie ration balancing will be carried out with maximum accuracy for main nutrient components (exchange energy, dry substance, etc.), while the remaining components of the deviations from the norm in some limits.