

# *Methodological aspects of economico-mathematical modelling of the dairy cattle breeding development*

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**Abstract**—The paper proposes a methodological approach to determining the development directions of dairy cattle breeding, based on the application of economico-mathematical modelling. The purpose of the study is to clarify the methods of economico-mathematical modelling of dairy cattle breeding at the regional level in the conditions of providing milk processing enterprises with raw materials of their own production. In order to determine the optimal development plan for dairy cattle breeding, taking into account the peculiarities of the organization and functioning of the industry in the agricultural enterprises of the region, a targeted systematic approach, which provides for the compliance of the projected state of the object with the laws of its development, takes into account the various possibilities for the development of the object as a whole and its parts, their interconnections and structural relationships, is applied. Using the proposed models, it is possible to assess the resource support for the development of the industry and determine the economic efficiency of its development prospects in the future. Along with solving the problems of the methodology of economico-mathematical modelling of the dairy cattle breeding development based on a systematic approach, it seems possible to substantiate the development prospects of the dairy industry in the region as a whole. The solution of the practical problem, according to the proposed model provides for the calculation of the area of feed crops, taking into account the crop rotation requirements, which provide dairy cattle with feed. The model can detail and deepen the issues of the structure of livestock feeding diets, the green conveyor, etc. As a criterion of optimality, as a rule, the minimum cost of feed production is used. In modern conditions, when it is especially important to achieve an increase in milk production as a criterion of optimality in the model, it will be finding its maximum value. As part of the system under study, all agricultural enterprises producing milk for sale in significant quantities and related enterprises through the procurement system of the dairy industry are considered. If there are significant volumes of milk production in the farms of the region's population, this element can also be included in the model.

**Keywords**—*dairy cattle breeding, modelling methods, economico-mathematical modelling.*

## I. INTRODUCTION

Determining the prospects for the dairy cattle breeding development in the region for the future necessitates a

comprehensive forecasting of the development of the industry at the level of agricultural enterprises and determining the necessary proportions for the development of the dairy industry of the agroindustrial complex (AIC) for the future. The starting point of the concept of further development of dairy cattle breeding in the region is an increase in milk production to meet the needs of consumers in dairy products.

The purpose of the study is to clarify the methods of economico-mathematical modelling of dairy cattle breeding at the regional level in the conditions of providing milk processing enterprises with raw materials of their own production.

The objectives of the study correspond to the stages of the implementation of the methodological approach to modeling the industry:

- identification of methodological aspects for determining and assessing the optimal level of condition and development of dairy cattle breeding;
- substantiation of the possibilities of a systematic approach to modeling the dairy farming development in the region;
- improvement of certain aspects of the methodology of economico-mathematical modelling of the dairy cattle breeding development.

The scientific novelty of the study is to identify options for the prospective development of dairy cattle breeding in the region in a dairy cluster using economico-mathematical modelling methods.

In modern economic literature, there are various approaches to substantiating the prospects for the dairy cattle breeding development using mathematical modelling. The authors propose the construction of models of the most common mechanized technological processes in the industry, provide methods for calculating the machines and equipment used in dairy cattle breeding [1, p. 11-16], or consider one of the aspects of increasing milk production: organizational and technological [2, p. 38-703; 3, p. 212-215], managerial and personnel [4, p. 23-31].

## II. RESEARCH METHODOLOGY

A methodological approach to determining the optimal level, taking into account the peculiarities of the organization and functioning of dairy cattle breeding in the region's agricultural enterprises, is a targeted system approach, which provides for the compliance of the projected state of the object with the laws of its development, takes into account the different possibilities for the development of the object as a whole and its parts, their interconnections and structural relationships.

Depending on the purpose of the study, the same object can be considered from different points of view, that is, as an element of different systems. The key principles of target forecasting are focus and consistency, while a system refers to a separate set of interconnected elements with a focus.

A systematic approach to justifying the prospects for the dairy cattle breeding development is associated with the study of the characteristics of the industry as a system. The interaction of production and organizational subsystems, as elements of the AIC dairy subcomplex, and individual measures, as elements of these subsystems, determines the integrity of the system under consideration. The systemic properties of the object as a whole are due to the effect of the interaction of its individual elements.

Economic studies of the development prospects of dairy cattle breeding are carried out based on a systematic approach using traditional methods. One approach allows us to determine the prospects for the development of the cluster as a whole or its elements using statistical methods (factor regression, moving average smoothing, trending, etc.). In the majority of recommendations on forecasting and long-term planning for the development and placement of dairy cattle breeding as a key industry in the dairy cluster, it is proposed to carry out calculations that searches for ways to increase the production of dairy cattle based on the coordination of the goal and development trend of the industry [5, p. 43-45; 6, p. 207-211].

However, when studying the prospects for the dairy cattle breeding development, the use of mathematical modeling methods is seen as promising. The development of a system of multi-level models for the dairy cattle farming development within the AIC dairy subcomplex or in the context of modern industry clustering will solve the problems of improving the cluster structure, determining its future development directions, identifying the potential of agricultural enterprises in milk production and effective options for locating dairy enterprises based on methods economico-mathematical modelling.

Along with solving the problems of the methodology of economico-mathematical modelling of the dairy cattle breeding development based on a systematic approach, it seems possible to substantiate the development prospects of the dairy industry in the region as a whole.

As part of the system under study, all agricultural enterprises producing milk for sale in significant quantities and related enterprises through the procurement system of the dairy industry have been considered. If there are significant volumes of milk production in the farms of the region's population, this element can also be included in the model.

The economico-mathematical model of the AIC dairy subcomplex reflects the most significant interconnections and operating conditions of individual elements of the system for the production, transportation, and processing of milk.

In the model, the calculation of the options for the development of feed production for the dairy herd, as well as the levels of milk productivity, determined by the possibilities of increasing it due to genetic factors and the development of the feed base, has been carried out. The coefficients of specific consumption of the main types of resources per unit area and feed crops or land are developed using economic calculations based on equations of the linear dependence of the yield of feed crops on the level of labor costs and cash per hectare.

Calculation of feed requirements for the dairy herd is made by feed units and digestible protein. The level of feeding and the structure of the diets of cows are determined on the basis of regulatory reference data. The amount of loss of feed (by type) during transportation and storage, as well as insurance reserves of feed to create a balanced and reliable feed supplies are established on the basis of accepted regulatory indicators. When calculating the yield of feed per hectare of fodder-grain crops, the share of grain sold and seed stock are excluded. The yield of feed crops (in quintal of fodder unit) is established taking into account their actual nutritional value over the past 3 years.

The data obtained are the source for economico-mathematical problems, during the solution of which the possible options for the dairy cattle breeding development in the region are determined.

## III. RESULTS AND DISCUSSION

At the first stage, the economic statement of the problem is as follows: to determine the capabilities of agricultural enterprises in the region to increase milk production, taking into account the development of feed production. The objective function is the maximum milk production:

$$\sum (X_j * Y_{Xj}) \Rightarrow \max \quad (1)$$

$$j \in N \quad (2)$$

But it should be borne in mind that creating a sustainable feed supplies depends not only on the use of natural and economic conditions, on the level of crop yields, and other factors, but also on the structure of fodder production in agricultural enterprises in the region.

The practical solution to this problem can be reduced to various statements, both by the criterion of optimality and the preparation of initial information. Perhaps the company has established the necessary amounts of feed and has already determined the structure of the feed balance for the main elements of nutrition. At the same time, a list of crops that can be cultivated by the farm, their productivity and nutrient content in feeds is known. In this case, it is necessary to determine the optimal composition of feed crops and their structure, which would provide the necessary volumes of feed production for animal husbandry. The criterion of optimality in the model with this formulation of the problem will be the minimum size of the forage land.

In another statement of the problem, the area on which feed crops can be cultivated, as well as their list, is already determined. The initial information for the model substantiates crop yields, nutritional value of feeds, the costs of their production, and the structure of the feed balance. The optimal structure of feed crops is determined to ensure the necessary level of feed for dairy cattle breeding, which provides a minimum of costs for the production of feed in general (or certain types of feed).

In the following statement of the problem, the structure of the feed balance is optimized at the same time, in which the planned tasks for the sale of milk and other livestock products are fulfilled, as well as optimal feeding diets are determined. In doing so, the use of the minimum sown area for feed crops is achieved or there is a minimum cost of labor and funds for the production of feed. The criterion of optimality in this statement of the problem is the maximum milk production [7, p. 354-359; 8, p. 322-328].

The solution of the practical problem, according to the proposed model involves the calculation of areas of feed crops, taking into account the requirements of crop rotations that provide dairy cattle with feed. The model can detail and deepen the questions of the structure of livestock feeding diets, the green conveyor, etc. As a criterion of optimality, as a rule, the minimum cost of feed production is used. In modern conditions, when it is especially important to achieve an increase in milk production, finding its maximum value will be as a criterion of optimality in the model.

In general terms, the problem will be written at subsequent stages of the solution as follows.

The objective function is selected depending on the version of the problem statement and has the following form:

$$\sum_{j \in N} C_j X_j + \sum_{j \in NI} C_j X_j \Rightarrow \max(\min) \quad (3)$$

$$j \in N \quad j \in NI \quad (4)$$

Model limitations:

- on land use

$$\sum_{j \in N} b_{ij} X_j \leq B_i, \quad i \in M \quad (5)$$

$$j \in N \quad (6)$$

- on the use of production resources

$$\sum_{j \in N} a_{ij} X_j + \sum_{j \in NI} a_{ij} X_j \leq A_i, \quad i \in M1 \quad (7)$$

$$j \in N \quad j \in NI \quad (8)$$

- providing animals with nutrients

$$-\sum_{j \in N} v_{ij} X_j + \sum_{j \in NI} d_{ij} X_j \leq D_i, \quad i \in M2 \quad (9)$$

$$j \in N \quad j \in NI \quad (10)$$

- forming the structure of feed allowances

$$\sum_{i \in M3} d_{ij} \min X_j \leq \sum_{j \in N} v_{ij} X_j \leq \sum_{j \in NI} d_{ij} \max X_j, \quad i \in M3 \quad (11)$$

$$j \in NI \quad j \in N \quad j \in NI \quad (12)$$

- guaranteed milk production

$$-\sum_{j \in NI} X_j \leq -Q_j, \quad i \in M1 \quad (13)$$

$$j \in NI \quad (14)$$

One can include other restrictions, inter alia, specific ones that arose during the solution of a specific production problem in the model. For example, restrictions on the purchase of feed, on the introduction of new rooms for one animal, on the attraction of additional labor, the rental of equipment, etc.

The following conventions are used in the model:

$X_j$  – variable denoting cultivated area of  $j$  crop;

$X_{j1}$  – a variable indicating the volume of producing  $j1$  type of livestock products or the number of heads of  $j1$  type of animals;

$C_j$  – coefficients of the objective function reflecting the selected optimality criterion;

$i$  – index of land, production resources, nutrients, feed groups;

$j$  – index of feed crops;

$j1$  – livestock production index, animal species;

$M$  – plenty of lands;

$M1$  – many production resources;

$M2$  – many nutrients;

$M3$  – many feed groups;

$N$  – many feed crops;

$N1$  – many types of livestock products, animal species;

$b_i$  – area of  $i$  land type;

$a_{ij}$  – costs of  $i$  production resource per  $j1$  unit of crops;

$a_{ij1}$  – costs of  $i$  production resource per  $j1$  unit of the livestock industry;

$A_i$  – volume of  $i$  production resource;

$d_{ij1}$  – rate of consumption of  $i$  nutrient per 1 quintal of  $j1$  type of livestock products or 1 head of  $j1$  type of animals;

$v_{ij}$  – yield  $i$  of nutrient from unit of  $j$  crop;

$d_{ij1max}$  – maximum consumption rate of  $i$  feed group per unit of  $j$  crop;

$d_{ij1min}$  – minimum consumption rate of  $i$  feed group per unit of  $j$  crop;

$D_i$  – stock of feed on the farm;

$Y_{j1}$  – animal productivity (output of  $j1$  species per 1 head of  $j1$  animal species);

$Q_{j1}$  – guaranteed production volume of  $j1$  type of livestock products or output livestock of  $j1$  type of animals. In the model relevant for most agricultural enterprises in the region, this is, as a rule, a guaranteed volume of milk production.

The economico-mathematical model provides for the calculation of options for the development of feed production for the dairy herd, as well as levels of milk productivity, determined by the possibilities of increasing it due to genetic factors and the development of feed supplies [9, p. 106-113].

The presence in agricultural enterprises of other manufacturing sectors (except for dairy cattle breeding) can be taken into account in the model through the distribution of appropriate resources (the area of arable land, hayfields, pastures, the volume of labor resources, etc.) [10, 11].

Solving the problems of optimizing feed production using various criteria of optimality allows us to determine the reserves for reducing the cost of feed production, the possibility of increasing milk production, and identify ways to increase the economic efficiency of the functioning of dairy cattle breeding at the regional level.

Restrictions on the completeness of milk processing and on the correspondence of the volumes of its processing to the production capacities of the dairy enterprises of the region ( $F_l$ ) are necessary in the model to determine the development factors of the milk processing enterprises of the region in terms of using their own raw material resources of the region.

This restriction has the following form:

$$\sum_{j \in N_2} \sum_{l \in L} (K_j * X_j * Y_{xjl}) \leq \sum_{l \in L} F_l, \quad (15)$$

$$j \in N_2 \quad l \in L \quad (16)$$

where  $K_j$  – coefficient of marketability of milk in the  $j^{\text{th}}$  farm,

$N_2$  – numerous agricultural enterprises in the region,

$L$  – many milk processing enterprises in the region.

As a result, the model has a block structure. Agricultural enterprises act as separate blocks of the model. The connecting block of the model is the restrictions on the completeness of milk processing, the correspondence of the volumes of milk sold to the production capacities of the milk processing enterprises of the region, as well as the restrictions on the availability of certain types of resources at the regional level.

#### IV. CONCLUSIONS

The model allows us to analyze the possibilities of increasing milk production not only for each agricultural enterprise in the region, but also to assess the current state of fodder production and dairy cattle breeding at the enterprise and

regional levels, as well as to identify promising options for the dairy cattle breeding development in the region and the resources necessary for their implementation.

In the future, the methodological approaches presented in this work can be used to model industry clusters of the agricultural sector, as well as form the basis of the economico-mathematical model for the development of the agricultural sector of the region.

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