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DETERMINATION OF PRODUCTIVITY OF MILKING COWS AND EMISSIONS OF GREENHOUSE GASES FROM ORGANIC WASTE WITH DIFFERENT APPROACHES TO THE ORGANIZATION OF THE TECHNOLOGY OF THEIR FEEDING

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The analysis of approaches to reduce the consumption of fodder protein and greenhouse gas emissions from organic waste in milk production is carried out, and the need to determine these indicators for various approaches to organizing the technology of their feeding is established.

An increase in the content of difficult-to-digest protein in the diets of high-yielding cows made it possible to reduce greenhouse gas emissions per head per day by 14.12 % in CO_2 equivalent when using 1.5 kg of TEP-mix in the ration of cows. When using 1.0 kg of TEP-mix, this figure was 6.44 %. In terms of 1 kg of milk with basic fat content, these indicators are 26.72 % and 12.98 %, respectively.

A multicriteria analysis of milk production with different approaches to organizing the technology of feeding dairy cows and, in particular, when using the additive TEP-mix with a protected protein showed a significant advantage of research option No. 1 (1.5 kg of TEP-mix). For it, the objective function according to the considered criteria is the smallest and amounts to 0.039 in comparison with the idealized variant. At the same time, the target function of the control variant (without TEP-mix) is 2.67 times worse, and for the experimental variant No. 2 (1.0 kg of TEP-mix) this indicator is 2.12.

The use of TEP-mix in feeding cows provided an increase in their milk productivity, milk fat and protein content and, as a result, the profitability of milk production.

The studies have found that the use of the proposed approaches to the organization of the technology of feeding cows provides an increase in their productivity, a decrease in the cost of feed protein and an improvement in environmental protection. According to the authors, this is due to an increase in the content of difficult-to-digest protein in the diets of high-yielding cows

Keywords: tethered housing, dairy cows, milk productivity, greenhouse gases, multicriteria analysis

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1. Introduction

With the growth of the population on the planet, the demand for food – bread, milk, meat, etc. consequently, the need for grain, as a source of protein and energy feed for farm animals, also increases. In such circumstances, there is a need to develop methods to improve the efficiency of the use of feed protein and energy in the body of ruminants. Rationing of rations for feeding cattle only by the content of crude protein, without taking into account its degradability, leads to overconsumption of fodder protein. This leads to metabolic disorders, the formation of excess ammonia, excreted from the body by urine.

One of the ways to reduce the consumption of protein in grain crops in feeding cattle is to take into account the digestibility of protein when developing rations. This will help to better meet the needs of animals, increase their productivity and reduce the cost of production.

Environmental protection is an urgent problem of the world ecology. One of the reasons was greenhouse gases, which are directly related to climate change on the planet. It is the responsibility of each country to provide annual reports on accounting and control of hazardous emissions [1].

The problem of the greenhouse effect is largely due to the development of industry and food production, as well as an irresponsible attitude towards natural resources. Not only industrial production is causing environmental degradation, agriculture, in particular animal husbandry, is also a threat to the environment due to the waste products of cattle.

The main environmental problems arising from the activities of industrial-type livestock farms are the increase in the level of environmental pollution due to greenhouse gas emissions [2–4], which is about 18 %, or almost a fifth of anthropogenic greenhouse gas emissions [4]. Considering that the production of dairy products is 3–4 times more profitable than in other livestock production systems [5], the rate of increase in production volumes will grow from year to year.

Thus, the need for these studies is to study various approaches to organizing the technology of feeding cows for their productivity and the level of greenhouse gas emissions. This will reduce the loss of feed protein per unit of milk production and improve the environment.

2. Literature review and problem statement

One of the main conditions for the realization of the productive potential of animals is the improvement of the feeding system based on the use of highly effective methods of balancing rations. Reducing the deficiency of nutrients and minerals in them will significantly reduce the cost and increase the efficiency of livestock production.

The work [6] analyzes the current state of development of the dairy cattle breeding industry, which provides the population with irreplaceable food products and is a supplier of raw materials for the dairy industry. The necessity of reviving dairy cattle breeding in Ukraine is proved and the ways of strengthening the position in the world market are suggested. But for this, it is necessary not only to increase the number of cows, but also to feed them with high-quality feed with a sufficient amount of nutrients.

The protein that is broken down in the felling is a source of nitrogen for microorganisms, which use it to synthesize amino acids and their own protein. At high milk productivity, the synthesis of milk protein from amino acids of microorganisms is only 40–50 % [7], the rest should be provided with dietary protein, which is not hydrolyzed in the felling. It is basically impossible to achieve this by the selection of feed. Therefore, to protect the protein from degradation in the rumen, feed, especially high-protein feed, is processed by various physical and chemical methods.

In modern ruminant feeding systems, protein requirements are determined not based on the amount of crude and digestible protein in the diet, but on the amount of protein that is broken down in the small intestine. This indicator is defined as the sum of protein degradable and non-degradable in the felling. A new approach to providing protein nutrition for highly productive ruminants is based on providing the body with readily soluble nitrogen compounds of feed protein and non-protein sources of nitrogen, which provides proteolysis of microorganism protein and feed protein [8]. The authors note that bacteria require approximately 1.31 kg of available rumen nitrogen to produce 1 kg of bacterial protein. This data is consistent with the 2001 NRC.

Studies [9] of a long-term experiment (12 weeks) have shown that a deficiency of metabolizable protein leads to a decrease in milk productivity and the content of milk protein. However, the use of protected amino acids helped to maintain performance at near calculated levels. At the same time, the authors have not made economic calculations of the use of amino acid supplements.

When studying the effect of the concentration and degradability of fodder protein with the introduction of protected methionine into the diets of lactating dairy cows, an increase in the consumption of dry matter by 0.7–1.1 kg/day was noted. In this regard, the milk productivity increased by 1.8 kg/day, and the milk fat yield by 0.06 kg/day [10].

There have also been studies on the use of protected proteins and fats in the feeding of dairy cows [11]. Compared to the control, in the experimental groups with protected protein, a higher consumption of dry matter of feed was observed and, accordingly, an increase in milk productivity by 16.5 and 21.0 %. At the same time, despite the increase in the cost of the diet, the profit in these groups was also higher. But it should be borne in mind that the experiment used cows with a low, as for countries with developed animal husbandry, daily productivity – at the level of 9–13 kg of milk.

Livestock produces greenhouse gases such as methane, carbon dioxide and nitrous oxide [12]. Major emissions include intestinal CH_4 from animals, C_{H4} and N_2O from pus during long-term storage and when applied to fields. This also includes N_2O as a result of nitrification and denitrification processes in the soil on which fodder crops are grown.

After analyzing the current state and structure of greenhouse gas emissions in agriculture [13], it was concluded that the main source of emissions of methane and nitrous oxide is animal husbandry. According to the author's data, the emission of CH_4 and N_2O is 85.06 and 55.52 kg/head of cattle/year, respectively. However, this is generalized data without allocation to content systems.

To reduce greenhouse gas emissions into the atmosphere, numerous studies are being carried out in the field of cow feeding around the world. For example, [14] it is proposed to replace the system of keeping and feeding in the detachments with a pasture one. At the same time, in [7], it is proposed to use protected amino acids in feeding dairy cows at different periods of lactation. According to their research, this allows not only to increase the productivity of cows, but also to reduce greenhouse gas emissions. However, the authors do not provide economic calculations for their proposals.

Research has been carried out to reduce the emission of greenhouse gases in the frequency of ammonia CH_4 by replacing barley with oats in the feed mixture. This substitution has no negative consequences for animal body weight, productivity, or energy balance [15].

The possibility of regulating emissions through breeding and genetics is also being considered. Although the results have not yet been validated in a sufficient number of populations and different breeds, studies demonstrate the presence of additive genetic variation in traits that can be used in breeding programs to improve milk production [16]. However, it would be desirable to supplement these studies with data on the determination of actual emissions obtained, for example, with the help of respiration chambers.

When studying the influence of Holstein-Friesian cow lines and the feeding system on greenhouse gas emissions, it was found that cows with a higher level of productivity emit 1 kg of milk solids more greenhouse gases. [17]. At the same time, the authors note that the decrease in emissions by 9 % in milk production was due to a decrease in the share of dry cows (from 35 % to 18 %) in the herd. That is, when determining the total amount of greenhouse gas emissions on a farm, unproductive cows should also be taken into account, and calculations should be made not per unit of production, but per livestock.

In general, the share of greenhouse gas emissions associated with livestock is up to 7.1 gigatons of carbon dioxide annually, which is 14.5 % of all emissions. The main sources of emissions are as follows: production and processing of feed (45 % of the total), digestion by cows (39 %) and manure decomposition (10 %). The rest are represented by the processing and transportation of animal products [18].

In connection with the above, it became necessary to study the influence of different approaches to organizing the technology of feeding cows on their productivity and the level of greenhouse gas emissions from organic waste during milk production. After the analysis, propose measures to reduce this impact.

3. The aim and objectives of research

The aim of researchis to establish the productivity of dairy cows and greenhouse gas emissions from organic waste with different approaches to organizing the technology of their feeding. This will increase the productivity of dairy cows and reduce greenhouse gas emissions.

To achieve the aim, the following objectives were set:

– to study different approaches to organizing the technology of feeding cows for their productivity;

– to determine the levels of greenhouse gas emissions from organic waste in milk production;

– to conduct a multicriteria analysis of the impact of different approaches to organizing cow feeding technology on the level of greenhouse gas emissions from by-products.

4. Materials and methods of research

4. 1. Methodology for studying the influence of various approaches to organizing the technology of feeding cows on their productivity

The object of research is the milk production of dairy cows. Experimental groups were formed by the method of analogue pairs based on the breed, milk productivity, lactation phase, live weight [19, 20].

The studies were carried out in different seasons of the year on highly productive dairy cows of the Ukrainian black-and-white dairy breed on a tied-up farm.

A study to determine the possibilities of reducing the negative impact of the microclimate in winter on the manifestation of signs of animal productivity through the use of a protein feed additive with a protected protein TEP-mix (LLC "Arnika FID", Ukraine). A scientific and economic experiment was carried out in the conditions of the State Enterprise "Gontarivka" Kharkiv region on 3 groups of cows, 8 heads each. Were formed three groups of cows control and two experimental. As part of the diet of the 1st experimental group, 1.5 kg of the energy-protein protein supplement TEP-mix was used, and the 2nd experimental group – 1.0 kg of the same additive instead of a part of the compound feed.

The duration of the experiment was 235 days.

Conditions of detention, microclimate parameters, feeding and drinking regimes in all groups were the same.

The diets of all tested animals for all limited organic and mineral nutrients were balanced according to the current detailed feeding norms [21], taking into account the chemical composition and nutritional value of the feed.

During the experiment, the following factors were taken into account:

– actual chemical composition and nutritional value of the feed;

– actual feed intake by performing control feedings every 10 days;

– level of milk productivity of cows – by carrying out control milking followed by taking average milk samples to determine its quality.

Milk was analyzed according to its chemical composition, nutritional value and energy value. Determination of physical and technological properties: mass fraction of true (tru) protein, fat (Fat), lactose (Lac), dry matter (Solids), dry skimmed milk residue (SNF), total protein was carried out according to DSTU 8396:2015 Cow's milk. Determination of the mass fraction of fat, protein, lactose, dry matter – by infrared spectrometry (express method), freezing point (FPD) according to DSTU 7671:2014 Cow's milk. Determination of the freezing point by conductometric method (express method) – on a Bentley Combi 150 device (Bentley, USA). Nutritional and energy values are based on nutrient content and caloric factors. The content of somatic cells in milk – instrumental DSTU 7672:2014 Cow's milk. Determination of the number of somatic cells – by flow cytometry (express method) on a Bentley Somacaunt 150 device (Bentley, USA).

Milk samples from each cow were taken using a sample, in proportion to milk yield in accordance with the requirements of DSTU ISO 707: 2002 Milk and dairy products. Sampling guidelines (ISO 707: 1997, IDT). Samples arrived at the laboratory using canned Broad Spectrum Mikrotabs from D&F Control Systems, Inc. (USA).

4. 2. Methodology for studying the levels of greenhouse gas emissions from by-products in milk production

The experimental part of the work was carried out on the basis of the SE "Gontarivka", in the department of feeding, physiology of nutrition of farm animals and fodder production and the laboratory of technologies in cattle breeding of the Institute of Animal Breeding of the NAAS (Kharkov, Ukraine).

The object of research is greenhouse gas emissions from a dairy farm with a tied dairy cow.

Estimation of greenhouse gas emissions due to the removal, storage and use of by-products (organic waste) in milk production was carried out on the basis of the approaches set out in the "Guidelines for National Greenhouse Gas Inventories" [22].

For this purpose, feed samples were taken to determine crude protein, crude fat, crude fiber and nitrogen-free extractives. Samples of organic waste were taken with subsequent determination of nitrogen, phosphorus, potassium, moisture, organic matter in the control and experimental groups. Based on the data obtained, methane emissions, direct N_2O emissions and indirect N_2O emissions were determined.

The value of the CH_4 emission factors from the collection, storage and use of organic waste was determined by the equation:

$$EF_i = (VS_i \cdot 365) \cdot \left[B_{oi} \cdot 0{,}67\ \text{kg/m}^3 \cdot \sum_{s.k} \frac{MSF_{s.k}}{100} \cdot MS_{isk} \right], \quad (1)$$

EF_i – coefficient of annual methane emissions for a given category i of livestock, kg CH_4/animal*year;

VS_i – daily release of volatile solid for a given category of livestock and, kg CP/animal*year;

365 – basis for calculating the annual production, days/year;

B_{oi} – the maximum methane-producing capacity for cattle manure of the category and m^3/kg of VS_i released;

0.67 – conversion factor of m^3 CH_4 into kilograms of CH_4;

$MSF_{s.k}$ – methane conversion factor for each system s for cleaning, storing and using manure in the climatic region k, %;

MS_{isk} – proportion of manure processed using the system s for cleaning, storing and using manure in climatic region k, depending on the category of livestock, has no dimension;

The value of direct emissions of N_2O as a result of harvesting, storage and use of manure was determined by the equation:

$$N_2O_{D(\min)} = \left[\sum_s \left[\sum_i (N_i \cdot Nex_i \cdot MS_{i.s}) \right] \times \atop \times EF_{3s} \right] \cdot \frac{44}{28}; \quad (2)$$

$N_2O_{D(\min)}$ – direct N_2O emissions as a result of harvesting, storage and use of manure in the country, kg N_2O/year;

N_i – the number of heads of the type/category of cattle i in the country;

Nex_i – average annual nitrogen excretion per head of livestock of the type/category of cattle i in the count-ry, kg N/animal*year;

$MS_{i.s}$ – share of total average annual nitrogen excretion for each livestock species/category i, managed under system s;

$EF_{3s.}$ – emission factor for direct N_2O emissions from the system for the collection, storage and use of manure s in the country, kg N_2O – N/kg in the system s;

s – system for cleaning, storing and using manure;

i – type/category of livestock;

44/28 – emission conversion factor (N_2O – N) (min).

The value of indirect N_2O emissions associated with the evaporation of nitrogen as a result of harvesting, storage and use of manure was determined by the equation:

$$N_2O_{G(\min)} = (N_{\text{volatility MMS}} \cdot EF_4) \cdot \frac{44}{28}, \quad (3)$$

$N_2O_{G(\min)}$–N_2O, associated with nitrogen evaporation as a result of harvesting, storage and use of manure in the country, kg N_2O/year;

EF_4 – emission factor for N_2O emissions from atmospheric nitrogen deposition on soil and water surfaces, kg N_2O – N/kg, NH_3-N+NO_x-N evaporated, default value is 0.01 kg N_2O–N/NH_3-N+NO_x evaporated.

The value of indirect N_2O emissions as a result of leaching during the harvesting, storage and use of manure was determined by the equation:

$$N_2O_{i(\min)} = (N_{\text{erosion-MMS}} \cdot EF_5) \cdot \frac{44}{28}, \quad (4)$$

$N_2O_{L(\min)}$ – indirect N_2O emissions as a result of leaching and runoff during cleaning, storage and use of manure in a given country N_2O/year;

$N_2O_{L(\min)}$ – the amount of nitrogen lost from the system for the removal, storage and use of organic waste, kg N/year,

EF_5 – emission factor for N_2O emissions as a result of nitrogen leaching from the runoff, kg N_2O – N/kg leached and leached nitrogen (by default it is 0.0075 kg N_2O – N/kg leached and leached nitrogen).

4. 3. Methodology for assessing different approaches to organizing the technology of feeding dairy cows

Multi-criteria analysis was carried out by the method of assessing the integral criterion of distance to the target using the approach of folding all criteria to one N using normalization [23].

For a comparative assessment of a complex indicator based on the method of multicriteria analysis, the relative distance $N(C_k)$ was found for each alternative solution by the expression:

$$N(C_k) = \frac{\sum_{i=1}^{n} u_{ij}^{norm} - \sum_{i=1}^{n} u_{i_0}^{norm}}{\sum_{i=1}^{n} u_{i_0}^{norm}}, \quad (5)$$

where $N(C_k)$ – effectiveness of each of the studied options in comparison with the idealized one;

u_{ij}^{norm} – normalized j-th indicator of the studied option;

$u_{i_0}^{norm}$ – normalized 0-th indicator of the idealized variant;

n – the number of evaluated criteria.

By means of statistical processing, an assessment of the correlations between the studied indicators was carried out, and the degree of influence of the main characteristics of the microclimate and weather conditions on the effective characteristics obtained with such technological parameters was established [23].

5. Results of the study of different approaches to organizing the technology of feeding dairy cows

5. 1. Study of various approaches to organizing the technology of feeding cows for their productivity

In order to study the influence of various approaches to organizing the technology of feeding cows on their productivity through the use of an energy-protein supplement with a protected protein TEP-mix, studies were carried out on highly productive cows. The results are presented in the Table 1.

The use of TEP-mix in the rations of feeding cows made it possible to increase the content of protected protein by 41.4 % in experimental group I and by 26.4 % in experimental group II, with almost the same crude protein content. This contributed to an increase in milk productivity of natural milk and milk of basic fat content (by 117.2 and 7.5 %, respectively), protein content in milk (by 5.2 and 3.5 %). Despite the rise in the price of the daily ration, the profit from the sale of daily milk yield was also higher in the experimental groups (by 19.2 % and 8.0 %, respectively).

Table 1

Data for determining the productivity of dairy cows with different approaches to organizing the technology of their feeding, ($M \pm m$), (n=8)

Indicators	Designation	Group		
		Control	Experimental I	Experimental II
Duration of the experiment, days	D	235	235	235
Total nutritional value of feed, MJ	TNV	223.9	228.8	227.2
Crude protein, g	CP	3216	3295	3248
Digestible protein, g	DP	2499	2281	2342
Protected protein, g	PP	717	1014	906
The amount of milk with basic fat content, kg/head/day	MFC	30.35	35.57	32.63
Protein, %	P	2.87	3.04	2.97
Greenhouse gas emissions in CO_2 equivalent, kg/head/day	GGE	0.0417799	0.0358812	0.0390877
The cost of the diet for 1 head/day, UAH	CD	87.03	95.23	92.50
Revenue from the sale of milk, UAH/head/day	RM	153.0	174.0	163.8
Profit from the sale of milk, UAH/head/day	PM	66.0	78.7	71.3

5. 2. Determination of greenhouse gas emissions from by-products in milk production

On the basis of the data on the mass particles of crude protein, crude fat, crude fiber and extractive nitrogen-free substances in the feed, the gross energy consumed by the animals at the complex was determined. Based on these data, methane emissions, direct and indirect N_2O emissions were estimated. The results are presented in the Table 2.

Table 2

Greenhouse gas emissions from milk production in the control and experimental groups

Greenhouse gas emissions per day from a cow per 1 kg of milk with a basis fat content	CH_4 emissions, kg	N_2O emissions from organic waste, kg		GHG emissions together in CO_2 equivalent, kg
		N_2O direct emissions	N_2O indirect due to weathering	
Control group	0.000784	0.00007597	0.00000569654	0.0417799
Experimental group I	0.000680	0.00006481	0.00000486055	0.0358812
Experimental group II	0.0007389	0.00007071	0.00000529859	0.0390877

It was found that, on average, 0.0417799 kg of greenhouse gases in CO_2 equivalent per day were emitted during the study period of organic products of cows in the control group. From the animals of the I experimental group, 0.0358812 kg were released, and the II experimental group released 0.0390877 kg of greenhouse gases in CO_2 equivalent per day.

Studies have shown that greenhouse gas emissions per head per day decreased by 14.12 % in CO_2 equivalent when using 1.5 kg of TEP-mix in the ration of cows. At the same time, when using 1.0 kg of TEP-mix, greenhouse gas emissions per head per day decreased by 6.44 %.

In terms of 1 kg of milk of basic fat content, these indicators were 0.001376603, kg 0.001008749 kg (–26.72 % to control) and 0.001197907 kg (–12.98 % to control), respectively.

5. 3. Multi-criteria analysis of the impact of various approaches to organizing cow feeding technology on the level of greenhouse gas emissions

The normalized performance indicators u_{ik} for the basic and new options and the goal function $N(C_k)$, calculated according to (5), are given in Table 3.

Table 3

Normalized indicators for determining the productivity of dairy cows with different approaches to organizing the technology of their feeding

Indicators	Designation	Group		
		Control	Experimental I	Experimental II
Duration of the experiment, days	D	1	1.021	1,015
Total nutritional value of feed, MJ	TNV	1	1.074	1,01
Crude protein, g	CP	1.095	1	1,027
Digestible protein, g	DP	1.414	1	1,119
Protected protein, g	PP	1.172	1	1,090
The amount of milk with basic fat content, kg/head/day	MFC	1.051	1	1,024
Protein, %	P	1.164	1	1,089
Greenhouse gas emissions in CO_2 equivalent, kg/head/day	GGE	1	1.094	1,063
The cost of the diet for 1 head/day, UAH	CD	1.37	1	1,062
Revenue from the sale of milk, UAH/head/day	RM	1.192	1	1,104
ΣU_k		11,458	10.189	10.603
$N(C_k)$		0,1041	0.039	0.0492

Multi-criteria analysis of milk production with different approaches to the organization of feeding technology for dairy cows and, in particular, when using the additive TEP-mix with a protected protein showed a significant advantage of the experimental variant No. 1 (1.5 kg of TEP-mix). For it, the objective function according to the studied criteria is the smallest and amounts to 0.039 in comparison with the idealized variant. The target function of the control variant (without TEP-mix) is 2.67 times worse, and for the experimental variant No. 2 (1.0 kg of TEP-mix) this indicator is 2.12.

6. Discussion of the results of the study of different approaches to organizing the technology of feeding dairy cows

One of the advantages and novelty of the research carried out is the possibility of increasing the productivity of high-yielding cows through the use of an energy protein supplement with a protected protein TEP-mix. Its use in the diets of cows on average over the period of the experiment contributed to an increase in the average daily milk productivity in experimental group I by 2.9 kg (11.2 %), and in experimental group II – 1.7 kg (6.6 %). There was also an increase in the content of milk fat by 0.13 % and 0.03 % and milk protein by 0.17 % and 0.10 %, respectively (Table 1). This, in turn, contributed to an increase in the profit from the sale of the obtained milk.

As can be seen from the data in the Table 2, the use of an energy-protein supplement with a protected protein TEP-mix allowed to increase the content of difficult-to-digest protein in the diets of cows. This contributed to a decrease in greenhouse gas emissions on average over the period of the experiment by 14.12 % in the experimental group I, and in the II – by 6.44 % in comparison with the control. In terms of 1 kg of milk with basic fat content, these indicators were 26.72 % and 12.98 %, respectively.

Multi-criteria analysis showed that the productivity of lactating cows with different approaches to the organization of their feeding technology and, in particular, the use of a TEP-mix supplement with a protected protein provides a significant advantage of the experimental options. So, for the first experimental group, the target function according to the studied criteria is less and is 0.039, while the target function of the second experimental group and the baseline variant were 1.26 and 2.67 times worse, respectively. At the same time, the second experimental group prevailed 2.12 times in the control group (Table 3).

The results obtained, indicating an increase in cow productivity and a decrease in greenhouse gas emissions, can be explained by the peculiarities of the digestive tract of ruminants with a 4-chamber stomach. To ensure the digestibility of feed, the stomach constantly contains from 4 to 10 kg of bacterial biomass. The conditions maintained by the microflora in the rumen facilitate the digestion of not only fiber, but most of all nutritional components of feed – fats, proteins, free sugars and starch.

Despite the large volume of the gastrointestinal tract, even large cows cannot consume and process more than 25 kg of dry matter of the diet. To increase the productivity of animals, it is necessary to influence the processes of the ratio of the intake of the split and non-split part of it with feed. In this case, the non-cleavable part should be well digested in the abomasum and intestines and serves as an effective material for the synthesis of products.

The use of protected protein in the feeding of high-yielding cows improves the digestibility of nutrients and their absorption, reduces the formation of ammonia and, accordingly, its release into the atmosphere.

The following pattern can be stated – an increase in the productivity of dairy cows and a decrease in greenhouse gas emissions. According to the authors, this is due to an increase in the content of difficult-to-digest protein in the diets of high-yielding cows. However, there are certain limitations, namely to establish a critical value of increasing the content of the supplement with protected protein in the diets of high yielding cows, when the cost of milk production will increase.

Further research can be aimed at determining the effectiveness of increasing the content of difficult-to-digest protein in the diets of high-yielding cows, taking into account regional conditions.

7. Conclusions

1. The use of the protein additive TEP-mix in feeding cows with tied housing provided an increase in the milk productivity of natural milk and milk of basic fat content (by 117.2 and 7.5 %, respectively), the protein content in milk (by 5.2 and 3.5 abs. %) and, as a consequence, the profitability of milk production.

2. Studies have shown that greenhouse gas emissions per head per day decreased by 14.12 % in CO_2 equivalent when using 1.5 kg of TEP-mix in the ration of cows. When using 1.0 kg of TEP-mix, greenhouse gas emissions per head per day decreased by 6.44 %. In terms of 1 kg of milk of basic fat content, these indicators are 26.72 % and 12.98 %, respectively.

3. Multi-criteria analysis of milk production with different approaches to the organization of feeding technology for dairy cows and, in particular, when using the additive TEP-mix with a protected protein showed a significant advantage of the experimental variant No. 1 (1.5 kg of TEP-mix). For it, the objective function according to the criteria under consideration is the smallest and amounts to 0.039, in comparison with the idealized variant. At the same time, the target function of the control variant (without TEP-mix) is 2.67 times worse, and for the experimental variant No. 2 (1.0 kg of TEP-mix) this indicator is 2.12.

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