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Energy Balance in the Body of Dairy Cattle as the Criterion of the Optimal Level of Feeding

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ABSTRACT

The algorithm for estimating energy balance in the body as a criterion for the optimality of animals feeding has been developed and tested in the conditions of a modern complex of large-group, non-tethered keeping of highly productive dairy cattle and its free access to the feed table in accordance with accepted feeding standards. Its essence lies in the fact that, based on the results of using a full-feed mix, the intake of net energy of lactation with the feed mixture was calculated by the formula: $NElact_1 = NEyield + NEmaint_1$, where $NElact_1$ – net energy of lactation received with the consumed food, MJ; NEyield - energy value of daily milk yield in net energy, MJ; $NEmaint_1$ - net energy of maintenance received with the consumed food. In parallel with this, the need of dairy cattle in net energy of lactation was determined by the formula $NElact_2 = NEmaint_2 + NEyield$, where $NEmaint_2 = 0,4 \times W^{0.75}$. The ratio $NElact_1 / NElact_2$ equal to one corresponds to a zero balance, less than one to a negative balance, and more than one to a positive balance. The difference between $NElact_1$ and $NElact_2$ reflects the value of the balance in +/- NE_{MJ}.

Keywords: Energy Balance, Lactation, , Milk Yield, , Maintenance, , body

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INTRODUCTION

The objective assessment of feed nutritional value and the justification of the conditions for realizing the potential of its productive effect, which ensures an increase in the volume and efficiency of the production of livestock products, estimated by the dry matter of feed on the unit of output, is the theoretical basis for the rationed feeding of farm animals. Moreover, the acuteness of the problem of improving the methods for assessing the nutritional value of feeds, as an equivalent to the potential for their productive effect, increases with the development of the livestock sector, its transfer to an industrial basis associated with a significant increase in animal productivity, stricter conditions for their keeping and intensity of use. All this makes special demands on the level and usefulness of feeding animals, differentiated, taking into account their production purpose, productivity and physiological condition.

This problem is especially acute in dairy cattle breeding [1]. During the historical period, beginning with the "hay equivalents" of A. Thaer, and completing by the second half of the twentieth century, experimental studies in the field of dairy cattle feeding were closely related to the development of objective methods, an integrated assessment of the potential for productive effect of feed. As a result of these studies, by the beginning of the 1950s, four systems for assessing the nutritional value of feed and rationing of livestock feeding were formed and found wide practical use. This is the amount of digestible nutrients (ADN) - in the US; starch equivalents - in the FRG; Scandinavian fodder units - in the Scandinavian countries and oatmeal feed unit - in the former USSR [2-6].

Each of these methods, corresponding to the level of development of science and world experience, in the field of animal feeding, for the period of their creation, served as a theoretical basis for their further development. Moreover, the improvement of these methods, today, amounts to:

- the content of the metabolizable energy in the feed;
- determination of the net energy needs of animals and the efficiency of the use of feed energy to meet these needs [7-9].

In accordance with this, at the basis of modern systems for assessing the nutritional energy of fodder and the norms of feeding animals, on the one hand, the data on feed digestibility and the efficiency of the use of metabolizable energy (ME), and on the other side, the physiological need of animals for net energy (NE, MJ) for maintenance, lactation and fat deposition were laid, and since the energy value of individual feeds for dairy cattle is determined mainly in the digestible energy, so in all cases the principle of recalculating the content of ME into net energy for each of these functions in the body is laid in the formation of all modern systems for assessing the nutritional energy of fodder and the norms of the energy feeding of dairy cattle [10].

At the same time, the generalization of numerous experimental studies indicates that the evaluation of the energy value of rations for dairy cattle in the DE, and its productivity in the NE do not adequately reflect the energy needs of dairy cattle and the contentment degree of this needs, in relation to specific production conditions. The resulting error in assessing the energy supply of high-yield dairy cattle significantly increases in the context of its large-group, non-tethered keeping and free access to the feed table.

The reason for this error is due to the fact that the energy value of the diet, determined by simply summing up the DE content in feeds included in these rations, does not take into account that the effectiveness of using the DE, consumed feed, or the content of ME in the ration is the result of the interaction of feed in the composition of the feed mixture and the animal that consumed it.

In order to give an objective assessment of the nutritional energy of the ration for dairy cattle during the lactation period, corresponding to its potential productive effect, the given daily feed should be evaluated not in the DE, but in the form of the energy in which daily milk yield is estimated. That is, in net energy of lactation (NElact), the value of which is the result of the functioning of the biosystem "consumed food → the animal's body → products", and if you take into account that the value of NElact = NEyield + NEmaint, then it adequately reflects the productive effect of the ration only in those cases when the level of DE intake with consumed feed and the features of energy metabolism in the productive cattle ensure a zero energy balance. In all other situations, both with positive and negative energy balance, the value of NElact does not adequately reflect the nutritional energy of the diet and the degree of the energy supply of dairy cattle: with the negative balance of energy its value is overestimated and with a positive one it is underestimated [1].

Proceeding from the above, the problem of improving existing and developing new methods for optimizing the energy supply of highly productive dairy cattle is of undoubted relevance and practical importance, especially in the conditions of industrial complexes with large-group, non-tethered keeping and free access to the feed table.

The aim of the research was the development and approbation of a method for assessing the energy supply of highly productive dairy cattle in terms of the nature and value of the energy balance in the animal's body.

MATERIALS AND METHODS OF RESEARCH

The experimental data given in the article are part of the complex studies, carried out jointly with LLC "APC-Invest" (Belgorod), which devoted to the development and introduction of feed programs for the high-yielding Holstein livestock of import selective breeding to production.

The results of these studies were obtained in the conditions of the modern industrial complex of large-group, non-tethered keeping of highly productive dairy cattle, the main herd of which consist of the Holstein cattle of the American selective breeding numbering 2300 animals.

The object of research was the technological group of cows numbering 222 heads, which was on average in the group for 168 ± 2.62 days of milking, of which 186 cows for 159 ± 2.34 days of milking on the current second lactation and 37 cows for 218 days of milking on the first lactation. Including 105 cows - on 81 ± 2.6 days of pregnancy on the second lactation and 31 cows - on 102 ± 3.76 days of pregnancy on the first lactation, respectively.

The average daily productivity as a whole in the technological group was 30.56 ± 0.51 kg, of which 31.59 ± 0.59 and 27.42 ± 0.73 kg of milk for the second and first lactation, respectively (Table 1).

Table 1 . Technological group of cows selected as the object of research

Characteristics of animals	Heads	Days of milking	Days of pregnancy	Current lactation number	Service period	Number of inseminations	Daily milk yield, kg	Milk yield for the current lactation, kg
All livestock	222	168±2.62	53±3.13	1.83±0.02	60±3.16	2.0±0.05	31.5±0.44	4571±74
Cows on the 2nd lactation, of which	184	159±2.34	46.4±3.2	2.00	51.3±3.62	1.99±0.06	32.25±0.5	4545±84
calvers	105	170±3.1	81±2.6	2.00	89.4±2.87	1.67±0.07	31.59±0.59	4876±106
infertile	79	143±2.88	0	2.00	0	2.43±0.08	33.32±0.85	4117±120
Cows on the 1st lactation, of which	37	218±5.6	86±7	1.00	107±8.9	2.11±0.09	27.75±0.71	4698±150
calvers	31	230±3.35	102±3.76	1.00	178±58	2.06±0.1	27.42±0.73	4935±130
infertile	6	160±15.3	0	1.00	0	2.33±0.21	29.5±2.27	3427±342

As can be seen from the data given in Table 1, the technological group of cows, located in the milk production section and selected as an object for research, consists of cows that are mainly on the second lactation and coming from the herd's breeding section. The fresh cows come from the maternity ward (transit group) into the breeding and milking section on days 14-21 after calving and are kept here for 65 to 80 days of milking. After successful insemination or the peak of lactation, but no later than 90-120 days of milking, the cows, according to the flow and rhythm of production adopted at the complex, enter the milk production section and the technological group corresponding to their daily productivity and the physiological state, by the days of milking and the periods of pregnancy.

The subject of research. Assessment of the nature and value of the +/- NE balance of energy in the body as a criterion adequately reflecting the energy value of the feed mix and the satisfaction degree of the energy needs of dairy cattle using this feed mixture, in the conditions of large-group, non-tethered keeping and free access to the fodder table.

To solve the task, a group of 24 calvers was formed as part of a technological group, which was selected as an object for research, with the aim of organizing fixed observations to assess the nature and value of the energy balance in the cows, depending on the feeding conditions and individual characteristics of the animals.

The cows selected for the research were on the second lactation, and in all controlled parameters (daily milk yield, lactation days, duration of the service period and quantity of insemination) were analogous to all the calvers on the second lactation included in the technological group (Table 2).

Table 2 . Characteristics of cows selected for conducting fixed observations

Indicators	Whole group of selected cows (N = 24)	including the subgroup	
		first n=12	second n =12
Current lactation, days	192±13	154±9	211±14
Terms of pregnancy, days	77.1± 0.96	78.1± 1.5	77± 1.24
Service period, days	114 ± 12	74 ± 8.2	135 ± 13.8
Number of inseminations	2.12 ± 0.26	1.25 ± 0.25	2.56 ± 0.26
Daily milk yield, kg	32.2±1.5	38.25±1.45	29.19±1.01
Milk yield for the current lactation, kg	5079±231	5890±223	4999±172
Average daily milk yield at milking days, kg	26.45±1.2	38.25±1.45	23.69±0.81

Cows selected for research, as can be seen from the data in Table 2, were divided into two subgroups, each with 12 heads, differing in those controlled parameters that reflect the degree of the composition homogeneity of the technological groups during their formation, and, in particular, it is 154 ± 9 and 211 ± 14 days of milking for the current lactation; 38.25 ± 1.45 and 23.69 ± 0.81 kg - the average daily milk yield at the milking days of the current lactation, with practically the same periods of pregnancy - 78.1 ± 1.5 and 77 ± 1.24 days for the cows of the first and second subgroups, respectively. This fully corresponds to the intra-group differences in these indicators for the cows of the technological group as a whole.

In the accounting period of the experiment, the cows of the technological group, including cows selected for conducting fixed observations, received a full-feed mixture designed for an average productivity of 35 kg of milk (Table 3).

Table 3 . Composition and energy value of the full-feed mixture used in feeding cows of the technological group, kg/on head per day*

Composition of daily feed	kg	DM, kg	DE, MJ	Crude protein, g	Crude fiber, g	Crude fat, g	Nitrogen-free extractives, g	Sugar, g	Starch, g
Legume-cereal hay	1.50	1.40	10.90	70.40	536.00	17.10	14.20	152.00	53.10
green mass of corn, 2nd seeding tim	6.00	1.38	1.34	126.00	330.00	36.00	742.50	180.00	22.80
Haylage of perennial grasses	11.00	4.93	45.80	527.30	1419.00	123.20	2513.30	394.20	107.80
Cereal-legume silage	10.00	3.67	33.80	282.60	1152.40	110.10	1886.40	165.20	254.20
Corn grai	3.35	2.97	41.60	309.20	50.30	112.20	2460.60	91.50	1846.90
PVMFA, for high-yielding**	2.68	2.44	28.90	897.80	356.40	145.50	753.30	206.40	38.60
Barley grain	3.62	3.19	39.40	380.30	146.50	38.40	29.41.40	166.80	1554.30
Sunflower cake	1.74	1.67	20.80	538.60	371.40	220.40	517.40	111.00	45.50
Belkoff-M	2.01	1.86	28.40	803.20	136.10	151.40	770.60	201.40	28.50
Total***	42.27	23.85	272.50	3935.30	4498.30	1206.0	13299.0	16668.0	3961.70

*The presented full-feed mix was balanced by 27 indicators, including 12 mineral components and 4 vitamins (carotene, vitamins A, D and E); **PVMFA - protein-vitamin-mineral feed additive “Belgorodskaya”, manufacturer of LLC “APC-Invest”, Belgorod; ***The composition of the feed mixture also included: a natural forage chalk of the MMJP brand and the fodder complex “Fungitox”.

The full-feed mixture, the composition of which is given in Table 3, for energy value, or for the content of DE and concentration of digestible energy (CDE) MJ / kg DM, including the content and concentration of crude protein, fat and fiber, based on the accepted feeding standards, fully complies with the needs of dairy cattle with a daily productivity of 33 - 35 kg of milk. The lack of easily hydrolysed carbohydrates in this feed mixture is compensated by including in its composition green mass and grain of corn, barley grain, PVMFA "Belgorodskaya" and Belkoff-M. The use of this feed mixture for the technological group of cows with an average norm of 23.85 kg of DM / head per day, provided an average productivity for a livestock of 222 cows equal to 31.5 ± 0.44 kg of milk with 4 % fat content, including 84 infertile cows (on 145 ± 2.9 days of lactation) - 32.96 ± 0.81 kg of milk. However, the indicators of the achieved value of daily milk yield and its energy value, corresponding to the energy value of a given diet and estimated by the content of the DE and NElact, still does not adequately reflect the energy supply of dairy cattle. An objective assessment of the energy supply of dairy cattle can be obtained only on the basis of the nature and value of the energy balance in the body with a fixed level of productivity and the physiological state of dairy cattle.

Determination of the energy balance in the body of cows selected for research was carried out according to the following algorithm:

- daily consumption of the dry matter of full-feed mix with the known concentration of digestible energy (DE MJ / kg DM), by means of control measurements and construction of production functions describing the level of daily consumption of DM depending on daily milk yield and DE concentration for fixed values of live weight within 500-720 kg [1];
- metabolizable energy (ME) which is the difference between DE and energy losses with intestinal gases and urine. The experimental data published in the literature are somewhat contradictory. On the one hand, there is an opinion that allows to accept the content of ME in modern diets equal to 81% of DE [7, 12]. On the other hand, to calculate its content by raw nutrients, using the appropriate equations for individual fodder groups [13]. Or, under production conditions, when working on a large number of productive livestock, it is possible to admit the equality between the dietary content of the DE and ME [14];
- metabolizable energy used for milk biosynthesis (MElact) was determined based on the energy value of daily milk yield (NEyield), using the formula: MElact = NEyield / C, where NEyield = 0.389 × % of fat + 0.229 × % of protein + 0.804 [14], C - coefficient value, reflecting the efficiency of MElact use for milk biosynthesis, equal to 0.58 - 0.63, depending on the level of productivity and physiological state of the animal [1];
- metabolizable energy, used to maintenance the vital processes, that comes with the consumed feed is determined by the difference: MEmaint1 = ME – Melact;
- net energy used to maintenance the vital processes, supplied with the consumed feed, is determined based on the MEmaint1 and the efficiency of its use - C, equal to 0.71: NEmaint1 = MEmaint1 × C;
- net energy of lactation, coming from consumed fodder, is the sum of the net energy of milk yield and net energy for maintenance the vital processes that came with the consumed fodder: NElact1 = NEyield + NEmaint1;
- the need for dairy cattle in net energy of lactation (NElact2), which depends on the daily milk yield and its energy value, the days of milking after the last calving and the physiological state of the animal, is the sum of the net energy of milk yield (NEyield) and the need for net energy of maintainance: $NElact_2 = NEmaint_2 + NEyield$. At the same time, the need for the net energy of maintenance is determined by the formula: $NEmaint_2 = 0{,}4 \times W^{0.75}$, where $W^{0.75}$ - exchange mass, which corresponds to the body weight of the animal in degree of 0.75 kg [15];
- the value +/-NE of energy balance in the body of dairy cattle is determined by the difference between NElact1, supplied with the consumed fodder, and the need for dairy cattle in NElact2: +/-NE = NElact1 - Nelact2.

If the ratio of $NElact_1$, supplied with the consumed fodder, to the needs of dairy cattle in $NElact_2$ is less than one, then the energy balance will be (negative) -NE, MJ. If this ratio is greater than one, the energy balance acquires a positive value +NE, MJ.

Negative balance of energy for fresh cows in the first 30-60 days of lactation or the process of "milking from the body" is considered the norm, and the amount of "milking from the body" value depends, on the one hand, on the genetic potential of the animal productivity, and on the other hand, on the degree of satisfaction of the animal's energy needs.

The loss of one kilogram of mobilized body weight reserve, with a negative energy balance, is equivalent to 22-25 MJ of ME, the efficiency of using which for milk synthesis is on average 80%, which provides obtaining of 5-5.5 kg of 4% milk [5].

RESULTS OF STUDY

An assessment of the nature and value of the energy balance in dairy cattle body was carried out on 24 cows with a second calving selected for fixed observations and divided by the daily productivity into two subgroups, the characteristics of which are given in Table 2. Being in the technological group containing 222 heads and having free access to the feed table, on which a full-feed mix was served in accordance with the daily rate, an average of 42.27 kg per head, containing 23.85 kg of DM and 272.5 MJ of DE, due to their individual characteristics, and, in particular, different live weight and daily productivity, the cows consumed a different amount of dry matter, and hence had a different level of the digestive energy intake (Table 4).

Table 4 . The value of the energy balance in the body of dairy cattle, depending on the content in the consumed feed mixture of DE and NE in daily milk yield, MJ

Indicators	Whole group of selected cows (N=24)	including the subgroup	
		first n=12	second n=12
Service period, days	114 ± 12	74 ± 8.2	135 ± 13.8
Days of milking for the current lactation	192±13	154±9	211±14
Days of pregnancy	77.1± 0.96	78.1± 1.5	77± 1.24
Daily intake of DM, kg	21.3±0.21	22.13±0.2	20.88±0.14
Intake of DE, MJ	243±2.37	252.3±2.28	238.1±1.6
Daily milk yield, kg	32.2±1.51	38.25±1.45	29.12±1.03
Net energy of daily milk yield, NEyield, MJ	104.3±4.9	123±4.7	94.57±23.29
$MElact_1$, received with ration and calculated by NEyield, MJ	171±8.03	203.1± 7.7	155.05± 5.4
$MEmaint_1$, received with ration, MJ	71.1±8.03	49.1±5.4	82.09±3.63
Net energy of maintenance, $NEmaint_1$, received with ration, MJ	50.48±5.59	34.87±3.84	58.29±2.58
Need for the net energy of maintenance, $NEmaint_2$, MJ	45.80±1.04	52.14±1.0	45.50±1.24
Net energy of lactation, $NElact_1$, supplied by ration, MJ	154.84±1.1	158.00±0.85	152.80±1.01
Need for the net energy of lactation, $NElact_2$, for the achieved milk yield, MJ	150.10±4.9	175.14±4.7	140.07±3.3
Energy balance in the body of dairy cattle, +/-NE, MJ	(+) 4.74 ±3.9	(-)17.14±3.84	(+) 12.73±2.58
The ratio of the balance value in cows of subgroups to the whole group, %	100.00	27.65	268.00

As can be seen from the data given in Table 4, with an average daily milk yield for the whole group of selected cows equal to 32.2 ± 1.51 kg and its energy value of 104.3 ± 4.9 MJ of NEyield, the level of consumption of feed mix was 21.3 ± 0.21 kg, and the intake of the DE was 243 ± 2.37 MJ, or 10,3% less than the average for the technological group.

At the same time, the cows of the first subgroup, where the daily productivity and its energy value were at the level of 38.25 ± 1.45 kg and 123 ± 4.7 MJ NEyield, respectively, the consumption of DM and intake with consumed food of the DE were on the average within 22.13 ± 0.2 kg and 252.3 ± 2.28 MJ, respectively, which is 3.7% higher in energy intake compared to the average for the entire group of experimental cows, but 7.53% less than the average for the technological group.

Significantly less productivity and energy value of daily milk yield, equal to 29.12 ± 1.03 kg and 94.57 ± 23.29 MJ NEyield, corresponded to a relatively low consumption of DM and digestive energy, equal to 20.88 ± 0.14 kg and 238.1 ± 1.6 MJ DE, which is 13.46 % less compared to the same value for the technological group of cows, and 2.06 % less compared to with a group of cows selected for the experiment.

An assessment of the nature and value of the energy balance in the body of the calvers, selected for the experiment, indicates that the energy value of the feed mixture, estimated by the DE content in the average portion on head per day and the CDE of 11.42 MJ / kg DM, does not provide the energy demand of the first subgroup of cows, the daily milk yield of which was 31.3% higher in comparison with the average productivity of cows in the second subgroup. The relatively low daily milk yield of cows in the second subgroup is primarily due to the fact that during the first 100 days of milking, according to the current lactation, they were kept at the energy level of feeding, which does not ensure the required intensity of their milking, as evidenced by the duration of the service period equal to 135 ± 13.8 days. As a result, with such a daily milk yield of 29.12 ± 1.03 kg on 211 ± 14 day of milking, the nature of metabolism in the body tended to focus on the deposition of energy reserves in the animal's body (Table 5).

Table 5. Nature and value of the energy balance in the body of calvers, depending on the daily milk yield, days of milking and pregnancy duration

Indicators	Whole group of selected cows (N=24)	including the subgroup	
		first n=12	second n=12
Days of milking for the current lactation	192±13	154±9	211±14
Days of pregnancy	77.1± 0.96	78.1± 1.5	77± 1.24
Daily intake of DM, kg	21.3±0.21	22.13±0.2	20.88±0.14
Intake of DE with consumed feed, MJ	243±2.37	252.3±2.28	238.1±1.6
Net energy of lactation, $NElact_1$, supplied by ration, MJ	154.84±1.1	158.00±0.85	152.80±1.01
Need for the net energy of lactation, $NElact_2$, for the achieved milk yield, MJ	150.10±4.9	175.14±4.7	140.07±3.3
Energy balance in the body of dairy cattle, +/-NE, MJ	(+) 4.74 ±3.9	(-)17.14±3.84	(+) 12.73±2.58
Daily change in body weight, +/- kg	(+)0.137±0.014	(-) 0.422± 0.15	(+) 0.416±0.042
Daily milk yield, kg	32.2±1.51	38.25±1.45	29.12±1.03
including obtained from the energy reserves of the body, kg	0	2.64 ± 0.76	0
Net energy of daily milk yield, NEyield, MJ	104.3±4.9	123±4.7	94.57±23.29
including obtained from body reserves, MJ	0	8.55 ± 0.33	0
% of daily milk yield	0	6.95	0

Based on the data given in Table 5, if we do not take into account the results of the assessment of the energy balance in the body of cows selected for research, we can conclude that the energy value of a daily portion of a full-feed mixture containing 272.5 MJ DE with CDE = 11.42 MJ / kg DM, and calculated for the average productivity for a group of cows equal to 32 with an advance of 35 kg of milk, ensures the achievement of daily milk yield in the whole group of 32.2 ± 1.51 kg, including the first subgroup - 38.25 ± 1.45 kg of milk. At the same time, low productivity in the second subgroup of cows at the level of 29.12 ± 1.03 kg with a positive balance of energy, which provides an increase in body weight in the range 0.416 ± 0.042 kg / day, is associated not with the feed mix used, but with past feedings in the first 100 days of lactation, when the low energy value of diets reflected not only on the intensity of cows' milking, but also on their reproductive function: the duration of the service period increased to 135 ± 13.8 days. In contrast to the second subgroup, in the first subgroup of cows the nature and negative value of the energy balance in their bodies at 154 ± 9 day of lactation and 78.1 ± 1.5 day of pregnancy testifies to the acute need of normalizing the energy supply of dairy cattle carried out by raising in the used fodder mixture of CDE from 11.42 to 12.5 MJ / kg of DM, which stabilizes the daily milk yield in the range of 40-42 kg, with an increasing tendency to obtain a positive energy balance. In this case, the cows of the second subgroup should be transferred to the technological group for cows with similar daily productivity, pregnancy, value and nature of the energy balance in the body.

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