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Substrate energy use by calves for weight gain

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Abstract

Efficiency of the use of metabolizable energy of diets for calves with the increased level of energy nutritional value by 5.0 % (MEC is equal to 9.6 MJ/kg) promoted the increase of energy deposition and weight gain synthesis by 10.04 %, weight gain energy by 19.50 %, the efficiency of the use of metabolizable energy for weight gain by 3.81 %.

Keywords: calves, energy deposition and weight gain synthesis, metabolite, rumen digestion

1. Introduction

In recent years, in countries with well-developed animal husbandry it has become necessary to improve the theory and practice of rationing food of cattle on the basis of modern scientific advances in the assessment of the nutritional value of feed and rations, and it has become necessary to have a physiological control of the adequacy of feeding [1].

Good nutrition of cattle must meet two basic requirements: it should be adequate for the physiology and biochemistry of cattle and should be economical in the production of livestock products. The development of analytical and physiological research methods and computer technologies have made it possible to justify in theory and apply the new principles of assessment and planning of food rations for ruminants. Based on the data of a detailed chemical analysis of the feed, its digestibility and animals' needs in energy and plastic substances, diets are evaluated on a range of substrates and metabolites which are necessary for sustaining life and producing milk and meat. These substrates-metabolites are primarily volatile and higher fatty acids, amino acids and glucose.

Most of the substrates are produced in the gastrointestinal tract; it is the initial and most important step of metabolism and absorption of ration nutrients.

The fact that ruminants have a rumen, where practically all feed components are digested by microbes, makes fundamental differences in the processes of digestion and absorption of both ration nutrients and metabolites produced there [2-9].

Depending on the filling of metabolizable energy with different substances, the efficiency of its use for a certain type of product may be different, and thus there is a change in the productive areas of its use. It was Kellner who showed the difference in the efficiency of the use of various nutrients for fat deposition (Table 1).

Table 1. Energy deposition and efficiency of using net nutrients for cattle [3]

Nutrients	Deposited energy, kJ/g	Efficiency of deposition, %
Starch	9.9	59
Protein	9.3	49
Fat	22.7	63
Saccharose	7.5	50
Cellulose	10.0	68

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Historical background of the suggested principles can be found in the works of Blaxter K. L., Arstrong D. C., Rook J. A., Holter J. B. [4, 7, 8]. These studies were performed to determine the efficiency of the metabolizable energy use depending on its filling with various substances as a result of infusion of VFA and various mixtures in the rumen of lactation cows (Table 2).

Table 2. Use of VFA energy for fat deposition in sheep, % [4]

VFA	Efficiency of use, %
Acetic acid	32.9
Propionic acid	56.3
Butyric acid	61.9

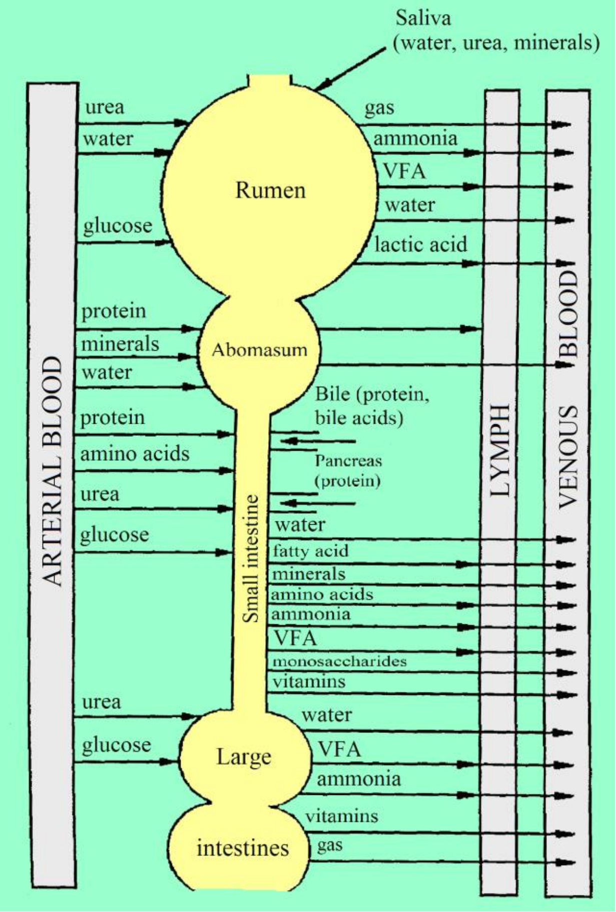

Figure 1. Diagram of absorption and excretion in the gastrointestinal tract of ruminants

However, these studies have not been applied. Existing systems also suggest the possibility of creating a specific structure of the metabolizable energy in nutrients, especially protein, mainly on the basis of optimal nutrient ratios in the diet for more complete fermentation in the rumen, by introducing different regulatory ratios of diet nutrients (the ratio of sugar and protein, the ratio of fiber and sum total of sugar and starch). The needs of the productive organs in certain substrates are not taken into account. It is problematic to take into account these requirements in terms of digestible crude nutrients because the correlation is established between the multifactorial variables. It is possible to determine the exact correlation only if we take into account the contained substances [1].

Therefore, adequate nutrition of ruminants and physiologically correct assessment of the nutritional value of feed rations need additional knowledge about the quantitative transformation of the main components of any particular feed in different parts of the digestive tract. Thus, you must know the true digestibility of nutrients of any particular feed. Moreover, the lack of information about the recycling of a number of components and metabolites prevents us from determining the true digestibility and absorption from the digestive tract (Figure 1) [2].

Previous studies established the possibility of determining the number and ratio of substrates used in energy metabolism [5]. For example, as for lactating cows, over 50 % of the metabolizable energy of their diets can be used in the energy processes and, ultimately, can be lost as heat. Maintaining the energy balance in the body of ruminants is the most important task, especially at low levels of feeding. At this level of feeding all the feed substrates available for the digestion of food are used for energy. Reserve and structural elements of tissues and organs are used for energy needs in case of starving [6]. Therefore, the study of the principles of substrate energy use is necessary in each particular case to define the actual need in substrates, which determines the efficiency of their use for implementing biosynthesis and physiological functions.

The determination of the influence of the energy supply of the diet of young cattle aged 7-12 months on the efficiency of energy use in the organism.

2. Material and Methods

To achieve this goal a physiological experiment lasting for 30 days was carried out in the "Science-practical center of the National Academy of Sciences of Belarus on Animal Husbandry". Three groups of young cattle of the Belarusian black-motley breed, containing 4 heads each, were formed.

Standards for nutrient and energy needs were determined for receiving 1000 g of productivity. The ruminants of the first control group received basic diet (BD) according to the norms of Agricultural Sciences (1985) [10]. The rations of the second and third experimental groups had the content of metabolizable energy increased by 5 and 10 %, respectively, with the help of including of dry fat supplements containing 30.14 MJ of metabolizable energy per 1 kg into the diet.

The chemical composition of feed rations was analysed in the laboratory of biochemical analyses of the "Science-practical center of the National Academy of Sciences of Belarus on Animal Husbandry". The gross energy (GE) of feed was determined by direct colorimetric method in the laboratory of nutrition and physiology of nutrition of cattle with the help of the calorimeter C 2000 Control IKA-WERKE.

The total substrate energy was determined by conventional methods on the basis of the energy of digestible nutrients excluding energy loss with methane and thermal fermentation [12, 13]. It characterizes the energy of the digested nutrients or the energy of the absorbed nutrients [14]. In the process of determination of the metabolizable energy it is possible to exclude only methane loss, but the amount of "the total energy of substrates which are available for absorption" corresponds to the energy equivalent of the digested substrates more accurately.

The amount of the total energy of substrates which are available for the absorption is the starting point for calculating the number of the main groups of substrates, which are produced in the rumen (VFA) and the small intestine (HFA, amino acids (AA), glucose), and are absorbed.

The amount of feed consumed was also studied in the research. The daily calculation of the given feed and its remaining part before morning feeding was analysed for this purpose.

Nutrient digestibility of the feed was determined on the basis of the following formula: the consumption of nutrients minus excretion of metabolic products. The index of digestibility was calculated.

The results are processed with the help of the method of variation statistics, taking into account the reliability criterion according to Student [11].

3.Results and Discussion

Feed consumption is a crucial step in the complex process of regulation of energy metabolism in the animal organism. [15, p. 35].

As for the total nutritional value of the average daily diet of experimental animals, it contained 52-56 % of concentrated feed (Table 3).

Table 3. Food ration of young cattle

Index	**Unit of measurement**	**Group**		
		I	**II**	**III**
Corn silage	kg	16.3	15.7	15.2
Mixed fodder	kg	4.0	4.0	4.0
Profat	kg	-	0.1	0.3
The diet contained:				
metabolizable energy	MJ	79.91	83.46	84.37
dry matter	g	7456	7661	7597
crude protein	g	685	640	655
degradable protein	g	473	365	341
digestible protein	g	474	441	454
crude fat	g	260	364	473
crude fiber	g	1425	1395	1346
starch	g	1507	1507	1507
sugars	g	137	138	121
calcium	g	43.9	58	70,5
phosphorus	g	27.3	26.7	28.4

Table 4. The list of substrates available for absorption, g

Index	Group		
	I	II	III
The amount of amino acids	413.3	396.9	410.8
The amount of HFA	186.9	322.8	445.0
Acetate	1585.4	1667.3	1731.4
Propionate	726.4	736.8	746.4
Butyrate and others	410.2	423.1	432.1
Glucose	4818.6	4724.3	4482.4

Table 5. Use of energy by the cattle, MJ

Index	Group		
	I	II	III
Metabolizable energy	79.91±1.71	83.46±1.19	84.37±2.14
The energy of heat	60.69±0.84	60.50±0.52	62.28±2.49
Weight gain energy	19.22±0.83	22.96±0.95 *	22.09±0.66
Basal metabolism energy	24.95±0.69	24.40±0.97	25.04±0.41
Maintenance energy	36.68±1.02	35.89±1.43	36.83±0.61
Excess maintenance energy	43.23±0.86	47.57±0.45 *	47.55±1.13 *
Efficiency of using the ME for weight gain, %	44.46	48.27	46.46
Metabolize GE, %	57.91	58.63	58.91

Note: * – $P<0.05$

The experimental animals received 7.5-7.7 kg of dry matter. In terms of 100 kg of live weight, it accounted for 2.4-2.5 kg. Crude fiber content varied from 177.2 to 191.1 g per 1 kg of dry matter.

The concentration of digestible carbohydrates in the dry matter of the diet in the first control group was 22.1 %, in the second group 21.5 % and in the third group 21.4 %, which is within acceptable limits [16].

The ratio of easily hydrolyzable carbohydrates and protein was the highest in the experimental diets: 3.59-3.73:1, whereas the diet of the first control group contained 3.47 g of nonstructural carbohydrates per 1 g of digestible protein. The norm, according to N. B. Kurilov and A.Y. Masloboev, is not less than 2.3:1 [17].

Modern systems of the feeding of ruminants, based on metabolizable energy needs, allow to predict the level of productivity with high accuracy, but at the same time, they focus only on the realization of the productive potential of animals. This results in the increase of the efficiency of the feed usage, but at the same time, the negative influence on the product quality, health condition and the period of productive usage is observed. More attention has recently been given to these problems, attempts to improve the systems of animal feeding with the help of the control of biochemical reactions in the stomach, small and large intestine of ruminants, as well as at the level of tissue metabolism, have been done [19].

New methods of evaluating the nutritional value of the rations – quantitative data on the substrates produced in the gastrointestinal tract as a result of digestion were used. Depending on the content of essential nutrients in the rations, the following indices change: the quantity and the ratio of the production of acetate, propionate and butyrate in the rumen, the amount of intestinal digestion and the absorption of higher fatty acids, amino acids and glucose from the intestine (Table 4).

When the animals of the first control group received their ration having the energy level according to the norms of Agricultural Sciences, the digestion of nutrients took place mainly in the rumen which accounted for 68 % of the total amount of all digestible nutrients, while only 32 % took place in the intestine. As a result of the rumen digestion 48.5 MJ of energy was contained in VFA in the following ratio: acetic acid 64.6 %, propionic acid 24.0 %, butyric acid and other acids 11.4 %. The contribution of VFA to the exchange fund of the organism was the following: acetate 19.5 %, propionate 8.9 %, butyrate and others 5.0 % available for the substrate absorption. In the intestine the following amount was formed: 59.2 % of glucose, 5.1 % of amino acids, 2.3 % of higher fatty acids.

When the energy nutrition was increased by 5 % in the ration of the young cattle of the second experimental group, 68 % of all digestible energy was digested in the rumen and 32 % was digested in the intestine. The total energy of VFA was equal to 50.3 MJ, and the ratio and the weight quantity were the following: acetic acid 65.3 % (1667.3 g), propionic acid 23.4 % (736.8 g), butyric acid and other acids 11.3 % (423.1 g). In the intestine the following amount was formed: 4724.3 g of glucose, 396.9 g of amino acids and 322.8 g of higher fatty acids.

When the nutritional value was increased by 10 % in the ration of the cattle of the third experimental group, 69 % of all digestible energy was digested in the rumen, and 31 % was digested in the intestine. The total energy of VFA was equal to 51.5 MJ and the ratio was the following: acetic acid 65.8 %, propionic acid 23.0 %, butyric acid and other acids 11.2 %. The contribution of VFA to the fund of available substrates was the following: acetate 21.0 % (1731.4 g), propionate 9.1 % (746.4 g), butyrate and others – 5.2 % (432.1 g). In the intestine the following amount was formed: 54.4 % of glucose, 5.0 % of amino acids, and 5.4 % of higher fatty acids.

The efficiency of using the energy value of the ration is shown in Table 5.

There were certain differences in the nature of the use of the ME by the young cattle of the compared groups. In particular, with the increase of the energy level of the diet by 5 % at the concentration of metabolizable energy (MEC) equal to 9.6 MJ, the cattle spent more energy on the deposition of the product and its synthesis. As for the second group, this indicator was higher by 4.34 MJ ($P < 0.05$), or 10.04 %. With further increase of the energy level of the diet by 10 % at MEC equal to 9.9 MJ, excess maintenance energy expenditure remained at the level of the second group exceeding the first control group by 4.32 MJ ($P < 0.05$), or 10.0 %. Excess maintenance energy accounts for 54.1 % of metabolizable energy in the first group, 57 % in the second group and 56.4 % in the third group.

Excess maintenance energy consists of the production energy (44.5-48.3 %) and the energy spent on its synthesis (55.5-51.7 %).

The amount of metabolizable energy in the diets was considered as to the sum of the energy expenditure of the animal and the energy deposition. Consequently, the metabolizable energy of the diets can be represented in more detail, being divided into the energy part and the productive part. One of the objective indicators of the final results received in the process of growing and fattening of calves is the accumulation of the energy in the weight gain and in the body as a whole, due to the deposition of protein, fat, and of carbohydrates in small amounts.

Significant differences between the experimental groups were observed in weight gain energy of calves. There was a clear pattern noticed: with the increase of the energy level of the diet by 5 %, weight gain energy increased by 3.74 MJ ($P < 0.05$), or 19.5 %. Further increase of the energy level of the diet by 10 % resulted in the increase of weight gain energy by 2.87 MJ (14.9 %) (in comparison with the first control group). The weight gain energy of the calves from the experimental groups was equal to 24.0-27.5 % of metabolizable energy.

The energy for maintaining bodily functions mainly depends on bodyweight of the animal [18] and varies between 59.1-60.4 % of the heat production and more than 43.0 % of the metabolizable energy. In the experimental groups, with the increase of the energy level of the diet by 5 % at MEC equal to 9.6 MJ, the maintenance energy decreased by 0.79 MJ, or 2.2 %, while the production energy increased. The calves in the third group had the level of the maintenance energy equal to the first control group.

The heat energy of tissue metabolism is represented by the energy released from the body of the animal in the form of heat to perform physiological functions and the synthesis of weight gain. It is equal to 72.5 % in the second group, 73.8 % in the third group and 76.0 % in the first control group. The calves from the third experimental group expended more energy on heat production than the other animals and exceeded the control group by 1.59 MJ, or 2.6 %.

Despite the differences in live weight of calves, the level of metabolizable energy and productivity, energy expenditure, the heat production of tissue metabolism is proportional of consumed dry matter – 8.14 MJ/kg (in the first control group), 7.90 MJ/kg (in the second group), 8.20 MJ/kg (in the third group). This energy expenditure is inevitable as it is connected with the provision of basic physiological functions and biosynthesis of the components of weight gain of animals.

The increase of the energy level of the diet by 5 % reduced the expenditure of basal metabolism energy by 0.6 MJ, or 2.2 %. The calves from the third experimental group spent basal metabolism energy in the same way as the animals from the first control group. The difference between the experimental groups was not significant.

With the increase of the energy nutrition by 5 % at MEC equal to 9.6 MJ, the indicator of the productive use of the metabolizable energy for weight gain increased by 3.81 percentage points ($P < 0.05$). The calves from the third experimental group used the metabolizable energy for weight gain at 2.00 percentage points better than the calves from the first control group.

4. Conclusion

The efficiency of the use of metabolizable energy of diets for calves having increased nutritional value by 5 % (MEC is equal to 9.6 MJ/kg) and the following ratio of metabolites: 34.4 (VFA): 3.9 (HFA): 4.8 (AA): 57.1 (glucose), promoted the increase of energy deposition and weight gain synthesis by 10.04 % ($P < 0,05$), weight gain energy – by 19.50 % ($P < 0,05$), efficiency of the use of metabolizable energy for weight gain – by 3.81 % ($P < 0,05$). The ratio of VFA in this case was the following: acetic acid – 65.3 %, propionic acid – 23.4 %, butyric acid – 11.3 %.

Compliance with Ethics Requirements. Authors declare that they respect the journal’s ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards.

References

1. Нормирование питания жвачных животных на принципах субстратной обеспеченности метаболизма / Е. Л. Харитонов, Б. Д. Кальницкий // Актуальные проблемы биологии в животноводстве : III конф. – Боровск, 2001. – С. 10-19.
2. Результаты и задачи изучения процессов пищеварения при разработке систем оценки и нормирования питания жвачных животных / А. М. Материкин [и др.] // Актуальные проблемы биологии в животноводстве : II конфер. – Боровск, 1997. – С. 49-59.
3. Kellner., 1904. Цитировано no Werner A. and Franke E. R., 1953. In: K, Nehring and A. Werner (Eds.) Untersuchungen uber den Starkewert verschiedener Futtermittel. Wiss. Abh. Dt. Acad. Landw. – Wiss. Berlin, Deutscer Bauernvergal, 1, 335.
4. Arstrong D. C., Blaxter K. L., 1957. Brit. J. Nutr., 11, 413.
5. Обеспеченность субстратами энергетических процессов у коров при различных уровнях кормления и продуктивности / В. И. Агафонов [и др.] // Тр. ВНИИФБиП с.-х. ж-х. – 1999. – Т. 38. – С. 375-384.
6. Агафонов, В. И. Нормирование энергии у жвачных животных по принципу субстратной обеспеченности метаболизма / В. И. Агафонов // Актуальные проблемы биологии в животноводстве : материалы II Междунар. конф. Боровск. – 1995. – С. 97-103.
7. Rook J. A., Balch C. C., Jonson V. W. Brit. J. Nutr. – 1965. – N 19. – S. 93-99.
8. Holter J. B., Jones L. A. et al. J. Dairy Sci. – 1972. – N 55. – S. 1757-1762.
9. Sporndly R. Aspects on ration formulation based on substrate system || Norveg. Y.
10. Нормы и рационы кормления сельскохозяйственных животных : справ. пособие / под ред. А. П. Калашникова, Н. И. Клейменова. – М. : Агропромиздат, 1985. – 352 с.
11. Рокицкий, П. Ф. Биологическая статистика / П. Ф. Рокицкий. – Изд. 3-е, исправл. – Мн. : Вышэйшая школа, 1973. – 320 с.
12. Изучение обмена энергии и энергетического питания у сельскохозяйственных животных : метод. указ. – Боровск, 1986. – 58 с.
13. Обсуждение проекта Советской системы энергетического питания жвачных животных : материалы заседания комиссии ОНК от 22 февраля 1989 года и координационного совещания от 2 марта 1989 г. – Боровск, 1989. – 55 с.

14. Агафонов, В. И. Оценка энергетической питательности кормов / В. И. Агафонов, В. Б. Решетов // Материалы координационного совещания 17 июня 1999 г. – Боровск, 1999. – С. 74-80.
15. Физиология кормления жвачных животных : учебно-методическое пособие / Н. С. Мотузко [и др.]. – Витебск : УО ВГАВМ, 2007. – 205 с.
16. Мещеров, Р. Энергетическое питание высокоудойных коров / Р. Мещеров, А. Серянкин, Ш. Мещеров // Животноводство России. – 2008. – № 9. – С. 49-50.
17. Курилов, Н. В. Роль углеводов и использование питательных веществ / Н. В. Курилов, А. Я. Маслобоев // Животноводство. – 1964. – № 10. – С. 26-28.
18. Свиридова, Т. М. Закономерности переваримости питательных веществ и обмена энергии у молодняка крупного рогатого скота в зависимости от кормового и возрастного факторов / Т. М. Свиридова, Б. А. Джуламанов, А. П. Зиленский // Вестник мясного скотоводства : Всерос. науч.-исслед. ин-т мясн. скотоводства. – Оренбург, 2003. – Вып. 56. – С. 427-432.
19. Лазаренко, В. П. Метаболические параметры энергетического обмена в середине лактации у коров черно-пестрой породы : автореф. дисс. … к-та биол. наук / Лазаренко В.П. – Боровск, 1997. – 28