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Metabolic diseases in cattle

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SUMMARY
The main trend in the development of dairy farming in the Russian Federation suggests maximising milk yield and reducing milk net cost. The economic effectiveness of industrial dairy farming is largely determined by adequate feeding, as well as effective system of measures to ensure animal health and prevent infectious and non-infectious mass diseases. The main reason for the premature retirement of highly productive cows is based on the factors typical of the intensive technologies used in dairy cattle breeding, which lead to the occurrence of metabolic diseases. It is established that the intensity of metabolism is directly linked to the high productivity of cows. With a highly concentrated, mainly silage-based type of feeding, an imbalance of nutrients is often recorded, in particular as regards the sugar/protein ratio, leading to deep metabolic disorders and the development of immunodeficiency states. Metabolic disorders in highly productive cows occur as a result of unbalanced diets as far as protein, carbohydrates, vitamins and minerals are concerned. Acidosis, ruminitis and hepatosis are recorded in disordered cows and heifers. The service period exceeds 100 days in 70–75% of cows. Hepatosis and immunodeficiency states are often found in calves born to cows with signs of deep metabolic disorders. Metabolic disorders often remain unnoticed and become apparent only when pronounced pathological changes occur resulting in decreased productivity and ability to reproduce resistant young animals, as well as culling of animals. Metabolic diseases were recorded in 30–70% of cows examined in large dairy farms. The average lifetime productivity of high-yielding cows is (2.1 ± 0.15) lactations in Russia. The results of epidemiological investigations and laboratory testing of sera samples showed that emulsion inactivated vaccines administered to immunodeficient cattle induce higher titres of virus-specific antibodies than those in animals vaccinated with adsorbed vaccines.

Keywords: review, cattle, metabolic diseases, metabolic disorders, fiber, acidosis, liver dystrophy, biogeochemical zones, metabolic immunodeficiency, hypomicroelementoses, rumen, high-concentration feeding, emulsion inactivated antiviral vaccines, biogeochemical provinces

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Метаболические заболевания крупного рогатого скота

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РЕЗЮМЕ
Основная тенденция развития молочного животноводства в Российской Федерации предусматривает увеличение продуктивности коров молочных пород и снижение себестоимости молока. Экономическая эффективность промышленного молочного животноводства во многом определяется полноценным кормлением, эффективной системой мероприятий по обеспечению здоровья животных и профилактике инфекционных и массовых незаразных болезней. Главной причиной преждевременного выбытия высокопродуктивных коров являются факторы, присущие используемым в молочном скотоводстве интенсивным технологиям, приводящим к возникновению метаболических заболеваний. Установлено, что интенсивность обмена веществ имеет прямую

связь с высокой продуктивностью животных. При высококонцентратном, в основном силосно-концентратном, типе кормления часто регистрируется дисбаланс питательных веществ, особенно по сахаро-протеиновому отношению, что приводит к возникновению глубоких нарушений обмена веществ и развитию иммунодефицитных состояний. Метаболические нарушения у высокопродуктивных коров возникают на фоне рационов, несбалансированных по белку, углеводам, витаминам и минеральным веществам. У больных коров и нетелей регистрируются ацидоз, руминит и гепатоз. У 70–75% коров сервис-период превышает 100 дней. У телят, полученных от коров с признаками глубоких нарушений обмена веществ, часто регистрируется гепатоз и иммунодефицитное состояние. Нарушения обмена веществ часто остаются незамеченными и становятся очевидными лишь при ярко выраженных патологических изменениях, которые приводят к снижению продуктивности и способности воспроизведения резистентного молодняка, выбраковке животных. При обследовании коров в крупных молочных животноводческих хозяйствах метаболические заболевания были зарегистрированы у 30–70% животных. В России средняя продолжительность хозяйственного использования высокопродуктивных коров составляет (2,1 ± 0,15) лактаций. Как показали результаты эпизоотологических расследований и данные лабораторных исследований проб сывороток крови, при иммунизации крупного рогатого скота с иммунодефицитным состоянием эмульсионные инактивированные вакцины индуцируют в организме образование вирусспецифических антител в более высоких титрах, чем у животных, привитых сорбированными препаратами.

Ключевые слова: обзор, крупный рогатый скот, метаболические заболевания, нарушения обмена веществ, клетчатка, ацидоз, дистрофия печени, биогеохимические зоны, метаболический иммунодефицит, гипомикроэлементозы, рубец, высококонцентратное кормление, эмульсионные инактивированные противовирусные вакцины, биогеохимические провинции

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The profitability of industrial dairy farming is ensured by three main factors: genetic potential, well-balanced feeding and freedom from infectious (including transboundary) and non-infectious mass diseases. The genetic potential of highly productive cows can be realized due to intensity of metabolic processes and rigorous neurohumoral regulation. The problem of metabolic disorders is particularly significant in modern industrial livestock production and resulting from one-sided selectional breeding aimed at productivity only [1–4]. Feeding diets are balanced in terms of all nutrients, the sugar-protein ratio and digestible protein content (100–110 g per feed unit) are strictly observed [3, 5–8]. Livestock performance improvement is one of the main factors contributing to a decrease in resistance level and resulting in a higher susceptibility of animals to infections.

The evolutionarily developed process of bovine digestion is aimed at digesting a large amount of fiber-based coarse feed needed for reproduction of cellulolytic bacteria that play an essential role in ruminal digestion [5, 9, 10]. To obtain high milk yields, a high-concentrate type of cow feeding is used. In many farms, the amount of coarse feed fed to cattle is 2.1–3.0 times lower than recommended. As a rule, there is a low content of easily digestible carbohydrates in such diets, leading to the sugar/protein imbalance [4–6, 11]. The poor-quality concentrated feed, even in large quantities, does not ensure synthesis of sufficient amounts of glucose.

In case of concentrate feeding, grain starch is utilized by the ruminal amylolytic bacteria for the synthesis of volatile fatty acids, including the basic lactic acid. At optimal ratios, lactic acid is processed by the rumen microflora into propionic acid, which serves as the main source for the synthesis of glucose and glycogen in the liver. With an excess of protein in the diet and a lack of carbohydrates, a large quantity of ammonia is produced in the rumen inhibiting the propionic acid synthesis [7, 8].

Acidification of the rumen contents (pH 5.5) leads to a significant excess of volatile fatty acids in blood and occurrence of metabolic acidosis, being the main pathogenetic mechanism of liver and kidney dystrophy, as well as other pathological disorders [4, 8, 10–22]. The transition of animals to concentrate feed leads to a shift in the rumen microflora [4, 5, 15, 23]. Feeding excessive amounts of concentrates inhibits the activity of ruminal microorganisms, which subsequently leads to liver fatty infiltration [1, 11, 24]. Rumen acidosis increases the reproduction of amylolytic and lactic acid bacteria, resulting in the suppression of the growth of propionic acid and cellulolytic microorganisms [12, 13, 25]. The highly concentrated type of feeding used, nutrient imbalance, stress, hypodynamia, lack of insolation are the basis for deep metabolic disorders and development of immunodeficiency states [3, 9, 11–13, 17, 21, 26].

The intensity of metabolism is directly linked to livestock productivity. Thus, a deficit of nutrient and plastic substances is continuously recorded in highly productive cows, which is compensated by the decomposition of substances in the organism. The energy demand of cows increases threefold during pregnancy and milk biosynthesis

in the first 2–3 weeks after calving [3, 4, 27]. These cows are able to transform the diet metabolic energy and feed nutrients into milk with a high coefficient, the costs of producing a unit of milk are low, the animals show high intensity metabolism, which leads to a decrease in their immunobiological status even with minor violations in feeding and maintenance. These animals have significantly reduced the ability to adapt to changing environmental conditions and protect themselves from various environmental effects [1, 6, 11, 13, 17, 23, 28, 29]. Therefore, the health of highly productive animals directly depends on the amount of trace elements within the body [4].

Metabolic disorders are the main pathogenetic mechanism of rumen metabolic acidosis and metabolic immunodeficiency in high-yielding cows that experience energy stress [12, 14, 17–21, 29, 30]. It is believed that one of the reasons for the development of metabolic acidosis is a lack of sugars in cows' diets. It was found that metabolic disorders in pregnant cows adversely affect the fetus in-utero development and the quality of colostrum. Dystrophy of the liver, kidneys, spleen and lymph nodes was observed in calves born to cows with signs of metabolic disorders [25, 31]. The observed increased activity of the enzymes most specific for liver cells (aspartate aminotransferase and alanine aminotransferase) occurred due to predominant catabolic processes in this organ as a result of dystrophic changes in its tissue [1, 7, 9–11, 24]. The results of an epizootological study of livestock farms indicate that metabolic disorders are constantly recorded in highly productive cows. The peak of such disorders occurs in animals in the first months after calving, and they vary for different breeds [9–12].

Unbalanced feeding most often affects cows of high-yielding breeds (Holstein-Friesian, etc.), that have an accelerated metabolism and a fine neurohumoral system. The reason for the fact that highly productive cattle are more likely to suffer from metabolic disorders than animals with average productivity is related to biological factors and depends on the rapid conversion of food energy into milk. This mechanism of milk synthesis requires high-quality feed, proper maintenance conditions and constant zootechnical control. The abundance of concentrates causes ruminal digestive disorders (hyperkeratosis and mucosis), liver dystrophy and loss of ovarian functions, as well as obesity and decreased productivity [3, 22, 24].

Newly calved heifers who are in demand of energy for milk synthesis and continuing growth are at risk. If there is a lack of easily digestible carbohydrates, the level of volatile fatty acids elevates in the rumen, while the concentration of butyric acid increases and the content of acetic and propionic acids decreases. If there is a lack of energy, there is little glucose and propionic acid in the animal's blood, which leads to ketogenic processes and hypoglycemia [27], which is often diagnosed with a predominantly concentrated type of feeding and the introduction of acidic feed into the diet of cows [6, 7, 14–16, 22, 32].

Liver dystrophy in highly productive cows is one of the most dangerous diseases, and, along with chronic microelementosis, it causes death [3, 7, 8, 12, 15, 22, 33]. In case of deficient or decreased supply of vital micro- and macronutrients with feed, chronic complex hypomicroelementosis manifested by a decrease in all types of productivity and leading to the development of secondary immunodeficiencies occurs in animals [12, 22, 33]. Animals with the deficiency or excess of such elements as cobalt, copper, zinc, calcium, demonstrate slowed rumination, loss or perversion of appetite, thickening of joints. If there is a lack of alkaline elements (calcium, sodium, magnesium, etc.) and an excessive content of acidic elements (chlorine, phosphorus, sulfur, etc.) in the feed, the acid-base balance of the blood shifts towards acidosis, which reduces the reserve alkalinity of the blood and general resistance [11, 16, 33].

The researchers of the Altai State Agrarian University studied characteristics of clinical and biochemical manifestations of metabolic disorders in highly productive cows in the biogeochemical province of their region. It was found that the soils in this area are deficient in iodine, cobalt, manganese, copper, zinc and molybdenum. The results of the conducted studies showed that metabolic diseases were detected in 30% of the examined animals, while metabolic disorders were recorded not only in cows, but also in calves born to them [33]. These deviations are especially acute in biochemical provinces, where there is a significant imbalance in the content of macro-and microelements in the 'soil–plant (feed)' chain [29, 33]. According to the results of long-term clinical observations and biochemical studies conducted in the farms of the Leningrad Oblast, metabolic disorders (metabolic diseases) are registered in 62% of cows with a milk yield of 25–35 kg per day in the first 2–3 months of lactation after calving [34].

The deficient content of mineral substances (copper, zinc, cobalt) in agricultural soils is the primary link of etiopathogenesis in the biogeocenotic chain and serves a leading factor in the development of mineral metabolism disorders in livestock animals. Microelementoses of alimentary origin are registered in the final link of the biogeocenosis chain at the 'mother – offspring' level, which leads to the development of an immunosuppressive state and secondary immunodeficiency [2, 4].

During epidemiological investigations conducted in specialized livestock farms for industrial milk production in different Subjects of the Russian Federation, it was found that the main cause of death of newborn calves was diarrhea, most often induced by rotavirus, coronavirus and bovine viral diarrhea virus. There were cases of two or three of these pathogens circulating in the same livestock population. It was documentarily confirmed that cows in late stage of pregnancy and heifers were vaccinated against these diseases in the surveyed farms. It is known that during the intrauterine fetus development there is no passive (transplacental) maternal antibody transfer, so the calf is born being unprotected from pathogens, and when it gets into a new environment, it does not have cellular and humoral specific protection. The only means of protecting a newborn calf is colostrum obtained from the immune dam [23, 32].

Metabolic disorders and immunodeficiencies in cows are one of the main reasons for the low effectiveness of vaccination for infectious disease prevention, which leads to premature retirement of animals [22, 32]. For determination of the reasons for the low effectiveness of vaccines used in the field, blood samples were taken from vaccinated cows and heifers 10–15 days prior to calving, and from 2–5-day-old calves born from immunized animals. Along with this, colostrum samples were taken on day 1–3 after calving.

The obtained study results served as the basis for the development of new means of specific prevention of viral diseases in immunodeficient cattle. Inactivated emulsion mono-, bi- and polyvalent vaccines against rotavirus and coronavirus infections, viral diarrhea, parainfluenza-3 and infectious bovine rhinotracheitis were developed at the FGBI "ARRIAH" for the immunization of animals with signs of metabolic immunodeficiency.

A number of production tests conducted in large industrial dairy complexes in 16 Subjects of the Russian Federation showed that the developed emulsion inactivated vaccines induce the formation of rotavirus-, coronavirus-, and viral diarrhea virus – specific antibodies in highly productive cows with signs of metabolic immunodeficiency. Antibodies to these pathogens were detected in cow colostrum at the titers of (11.3 ± 0.8–12.6 ± 0.9) $\log_2$. Antibodies to rotavirus, coronavirus and viral diarrhea causative agent at the titers of (8.5 ± 0.6–9.7 ± 0.8) $\log_2$ were detected in the sera of 3–7-day-old calves who, in a timely manner, received colostrum from cows immunized with an emulsion vaccine [32]. Emulsion vaccines are suitable for vaccination of newborn calves with colostral immunity. The use of emulsion inactivated vaccines against parainfluenza-3, infectious rhinotracheitis, coronavirus infection and bovine viral diarrhea in different combinations allowed to reduce the incidence rate in young animals and retirement level by 30–50% and 15–25%, respectively. The results of epidemiological investigations and laboratory testing of sera samples were the basis for the recommendation to use emulsion vaccines for immunization of immunodeficient cattle [9].

CONCLUSION

The results of epizootological investigations conducted for large-scale livestock farms specializing in milk production indicate that the average service life of highly productive cows with a milk yield of more than 6 thousand kg of milk does not comprise more than three lactations. An excess of concentrated feed, along with a shortage of sugar and coarse feed, leads to digestive and metabolic disorders and accumulation of toxic substances [3]. Intensive metabolic disorders constitute the main pathogenetic mechanism of metabolic diseases that lead to acidosis, liver dystrophy and metabolic immunodeficiency [3, 9, 10, 12, 13, 34]. Pregnant cows with impaired metabolic processes give birth to calves with dystrophy of liver, kidneys, spleen and lymph nodes. Diseases caused by opportunistic microorganisms are often identified in animals with signs of metabolic immunodeficiency. It has been shown that emulsion inactivated vaccines induce virus-specific antibodies in highly productive cows with signs of metabolic disorders in higher titers than those in animals vaccinated with adsorbed vaccines, which can be explained by the peculiarities of immunogenesis when using these vaccines.

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