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FACTORS DETERMINING THE ELEVATED BLOOD CHOLESTEROL LEVEL IN DAIRY COWS DURING FIRST MONTHS OF POSTPARTUM

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ABSTRACT. The aim of the review is to systematize data on factors that can cause an increase in cholesterol in the blood of healthy cows during the first months of lactation, in particular, during the formation of ovulatory reproductive cycles, before fertilization and in the first months of pregnancy. Variations in blood cholesterol after calving directly reflect the current rate of its use for the production of lipid components of milk. Other factors contributing to an increase in blood cholesterol in animals during the first months of lactation are its release from adipocytes of adipose tissue, activation of lipo- or gluconeogenesis processes, as well as increased absorption of lipid components of the feed and the use of certain metabolic intermediates (acetate) for the synthesis of endogenous cholesterol. An increase in the level of cholesterol in the blood of cows during this period, the first months after calving, may also be associated with the manifestation of functional abnormalities in animals, for example, with liver dysfunction. The determination of cholesterol in the blood of healthy cows in the first month after calving provides valuable information on the level of milk productivity, the state of energy reserves, and also characterizes the conditions in the body for accelerated resumption of ovulatory cycles, successful fertilization and the development of pregnancy in a shorter postpartum period. High levels of cholesterol in the blood of cows in the first months after calving can be used as one of the prognostic markers of increasing the efficiency of their fertilization during this period. Today, the exact range of changes in the level of individual lipids in cows of different breeds and with different milk productivity in first months of the postpartum period is not sufficiently represented. It is important to disclose detailed mechanisms that determine fluctuations in cholesterol levels in cows, depending on the stage of the reproductive cycle.

Key words: cows, lactation, blood cholesterol, ovulatory cycles, fertility

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Introduction

Cholesterol is an important sterol for animals. Cholesterol participates in many processes and is necessary for the normal functioning of cells and the structural integrity of their membranes. It presents in small quantity in the milk, and is an essential component of the milk of all mammals. The level of cholesterol in the blood of females of different species depends on the stage of the reproductive cycle and achieving a certain level is important for the normal passage of separate stages (Vasilenko, 2016).

Most researchers note that in normal conditions of feeding and maintenance, the level of cholesterol in the blood of healthy cows is characterized by a decrease during pregnancy and a noticeable increase in the first months of lactation (Puppione et al., 1980; Kweon et al., 1986; Pysera, Opałka, 2000; Filipejová, Kovaáćik, 2009; Jożwik et al., 2012; Kessler et al., 2014; Kupinska et al., 2015; Chalmen et al., 2016; Folnožić et al., 2016; Garcia et al., 2017). Usually, elevated levels of cholesterol in the postpartum period are associated with its increased use for milk production (Piccione et al., 2011). Differences of the concentration of cholesterol in the blood and the amplitude of its variations in cows of different breeds before calving and in the postpartum period may be due to hereditary features of the use of this metabolite in the organism (Petrera et al., 2015).

Today, little is known about the physiological norm of changes in cholesterol levels of cows during lactation and at other stages of the reproductive cycle, which is important both for the interpretation of the results obtained and for the early diagnosis of deviations in animal organism.

The purpose of this review is to summarize the latest data on factors that may contribute to an increase of the level of cholesterol in cows during first months of lactation, during the recovery of ovulatory cycles, fertilization and initial stages of pregnancy.

Total cholesterol in cows during lactation

Redistribution of substrates under hormonal control is the main characteristic of metabolic adaptation to lactation. The lactation period of cows is increased to 9-12 months or more as a result of intensive selection by the level of milk in the process of prolonged domestication of these animals. As a rule, cows should be fertilized in the second or third month after calving (at the peak of lactation). Approximately 75% of the duration of pregnancy (7 months) coincides with lactation period. The high level of milk productivity in modern cows causes an increased metabolic load on the organism and may adversely affect their health and reproduction. In turn, animal health is directly related to the body's ability to maintain homeostasis - a complex dynamic system that preserves the required or necessary stability of the body's metabolic and regulatory functions at each stage of the lactation and reproductive cycle.

Lactation of cows is accompanied by complex metabolic alterations that can directly affect cholesterol metabolism and its blood levels. It is necessary to take into account the fact that cholesterol is practically absent in the food of herbivorous mammals. The level of cholesterol in cows is determined by its *de novo* synthesis in the liver, features of transportation in the blood, processes of catabolism and use in tissues, excretion from the body through the formation of neutral steroids and bile acids.

It was found that plasma total cholesterol positively correlates with the energy balance in cows on the beginning of lactation (Reist et al., 2002; Kida, 2002). The cholesterol metabolism in these animals can be affected by energy and nutrient deficiencies depending on the lactation period (Gross et al., 2015)., The elevated levels of cholesterol in cows from parturition up to 30 days postpartum may indicate the presence of high energy reserves (Pradhah et al., 2008). At the same time, during the first weeks of lactation, cows often show a negative energy balance. Low levels of cholesterol in this period may indicate a poor adaptation of their organism to increased energy needs. The synthesis of milk fat during early lactation is determined by the reserves of fat that accumulates in the body of ruminants in the last months of pregnancy. The release of cholesterol from adipose tissue is an alternative mechanism that helps increase its level in cow blood during this period.

The milk yield and stages of lactation in dairy cows has significant effect on serum cholesterol (Kweon et al., 1986). A positive correlation has been noted between serum cholesterol and milk yield in early (Puppione et al., 1980; Jorritsma et al., 2003) or late lactation (Puppione et al., 1980). Significant changes in blood lipid levels of mammals during postpartum and lactation consistent with the findings that these stages of the reproductive cycle are most energy dependent (Gittleman, Thomoson, 1988). It is believed that a higher level of cholesterol in the blood of ruminants during lactation is a physiological adjustment of its cost for milk production (Ashmawy, 2015). The optimally high level of cholesterol in the blood of cows at the peak of lactation is also may be associated with an increase in the amount of glandular tissue in the mammary gland, since cholesterol is actively involved in the renewal lipids of membranes of glandular cells (Volnin et al., 2015).

Lactation of cows is usually accompanied by an increase in feed intake and, consequently by elevated assimilation of lipid components what may have a direct effect on their level in the blood. The level of lipids is also dependent on the activity of regulators, such as thyroid hormones, whose influence on blood lipids is well known. Variations of serum cholesterol in ruminants may correlate with the activity of the thyroid gland (Gueorguieva, Gueorguiev, 1997; Nazifi et al., 2002). Thyroid hormones have a direct effect on lipid metabolism, stimulating the process of releasing fats from adipose tissue (Eshratkhah et al., 2010). The net effect of thyroid hormones on the metabolism of cholesterol is associated with an increased rate of its catabolism in the liver and thus to a decrease in its level in the blood (Barttley, 1989). A decrease in thyroid hormones was found in cows with ketosis. These animals also have a lower level of cholesterol compared with its concentration in healthy cows in the postpartum period (Djokoviĉ et al., 2010; Nogalski et al., 2012).

Effect of feeding on blood cholesterol in dairy cows

Typical diets for cows generally contain from 2 to 5% fat. Fat supplements in the diet of dairy cows almost always increase the level of blood cholesterol, and this increase is independent of the use of the type of fat supplements. Differences in sources of dietary fat could cause differences in the level of circulating cholesterol among studies (Park et al., 1983; Talavera et al., 1985; Grummer, Carroll, 1988; Highshoe et al., 1991; Wehrman et al., 1991; Hawkins et al. 1995; Lammoglia et al. 1996; 1997; Thomas et al., 1997; Pechova et al., 2006). The cholesterol level may also depend on the duration of use of fat supplements in the diet.

Acetate and fatty acids supplied to the animal feed can also be used for the synthesis of cholesterol. Unlike monogastric animals, acetate is used instead of glucose to cover the energy needs of the cows. It covers about 30% of these needs. Such an evolutionary adaptation of ruminants is due to the presence of fore stomach (rumen), in which the fermentation of fodder and the formation of short chain (volatile) fatty acids take place. Acetate is one of the products of the normal digestive process in ruminants. It is known that in the rumen of cows up to 4 kg of acetate is formed per day (Aliyev, 1980).

It was shown that the inclusion of an aqueous solution of potassium salt of acetic acid (20% solution) in the high protein diet for cows with low cholesterol on 60-90 days after calving raises the level of cholesterol in the blood (Vasilenko, Roschevsky, 2008). Consequently, an increase in the blood cholesterol level may be associated not only with the activation of lipogenesis and gluconeogenesis, but also with an increase in the consumption or formation of intermediate products that may be used to synthesize cholesterol.

Blood cholesterol as a predictor of fertility in cows

It is established, that high concentrations of plasma cholesterol were associated with a shorter interval from calving to fertilization (Ruegg et al., 1992; Westwood et al., 2002; Reist et al., 2003), and with greater probabilities of fertilization and successful pregnancy by days 150 of lactation (Westwood et al., 2002). These data are consistent with results obtained by other researchers (Guedon et al. 1999; Veena et al., 2015). Westwood et al (2002) found that estrous signs were more likely detected at first postpartum ovulation among cows with higher dry matter intakes, increasing plasma cholesterol concentrations and the ratio of glucose to beta-hydroxyl butyrate.

Elevated levels of cholesterol in cows during first three months of lactation may be used as a prognostic indicator of their subsequent fertility. There is a significant relationship between the cholesterol concentration in cows during the estrous cycle, the likelihood of fertilization, and the development of pregnancy (Francisco et al., 2003; Vasilenko, Roschevsky, 2008). Low cholesterol concentration characterizes the health and energy status of cows-donors, has a direct impact on the maturation of follicles and oocytes, which contributes to disruption of the ovulation process and reduction in the number of viable embryos (Balakrishnan et al., 1993). Total cholesterol concentrations in heifers and cows are correlated positively with numbers of recoverable embryos from superovulated animals (Kweon et al., 1987; Pradhan et al., 2008). Similar results were received in other studies (Bader et al., 2005).

It is believed that high levels of total cholesterol in cycling cows may reflect increased production of steroid hormones (Dutta et al., 1988). Elevated cholesterol levels in cows before fertilization has a direct impact on progesterone production and thus may affect the preservation and subsequent development of pregnancy (Ryan et al., 1992; Lammoglia et al., 1996; McNamara et al., 2003). The level of cholesterol also can have a regulatory effect on the synthesis of steroid hormones in the ovaries (Rabiee et al., 1999).

Low concentrations of cholesterol and albumin were detected in animals with fatty infiltration of the liver after limited feed intake (Mostaghni, Aakari, 1996) and large weight loss after calving (Ruegg et al. 1992; Yamada et al. 1994). Low serum cholesterol levels were detected in cows with endometritis or other postpartum disorders (Sepulveda-Varas et al., 2015).

Today, the mechanisms by which cholesterol can affect the resumption of normal estrous cycles and the fertilization of dairy cows have not yet been disclosed. However, it is well known that a high level of repeated insemination and anestrus in cows is associated with noticeable decrease of cholesterol level (Kumar, Sharma, 1993; Francisco et al., 2003; Vasilenko, Roschevsky, 2008; Widayati et al., 2018).

Conclusion and Recommendations

This review emphasizes the need for research to identify the relationship between the level of cholesterol in the blood of cows, the effectiveness of their reproduction or the possible manifestation of postpartum disorders. An increase in the level of cholesterol in the blood of cows in first months after calving may be due to a high level of milk production and the additional inclusion of fats in the diet, or the manifestation of functional deviations in animals during this period. For example, liver dysfunction can affect the interpretation of results on cholesterol in the blood. The determination of elevated concentrations of cholesterol in the blood of healthy cows in first month after calving gives valuable information about level of milk production in these animals, normalization of the energy balance, and also characterizes the conditions in the organism for accelerated resumption of ovulatory cycles, fertilization and the development of pregnancy in a shorter postpartum period.

Normal lactation and the reproductive cycle as a whole in cows are accompanied by complex metabolic adaptations that can directly affect cholesterol metabolism and its blood levels. Despite more detailed studies of changes in cholesterol concentration in cows during lactation, fertilization or pregnancy, many questions remain unanswered, such as the specificity of cholesterol metabolism and the significance of its noticeable fluctuations for these physiological states. Today, the exact range of changes in the level of individual lipids in cows of different breeds and with different milk productivity in first months of the postpartum period is not sufficiently represented. It is important to disclose the mechanisms that determine the fluctuations in cholesterol levels in cows depending on the stage of the reproductive cycle.

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Conflict of Interest Declaration

The author declares that she has no conflict of interest

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Факторы, определяющие высокий уровень холестерина в крови коров в первые месяцы после отёла

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Цель работы – систематизация данных о факторах, которые могут обуславливать повышение уровня холестерина в крови здоровых коров в течение первых месяцев лактации, в частности, в период формирования овуляторных половых циклов, перед оплодотворением и на первых месяцах стельности. Вариации содержания холестерина в крови после отёла непосредственно отражают текущие темпы его использования для производства липидных компонентов молока. Другими факторами, способствующими повышению уровня холестерина в крови животных в первые месяцы лактации, являются его высвобождение из адипоцитов жировой ткани, активация процессов липо- или глюконеогенеза а также увеличенное усвоение липидных компонентов корма и использование определённых интермедиатов метаболических процессов (ацетата) для синтеза эндогенного холестерина. Повышение уровня холестерина в крови коров в первые месяцы после отёла может быть также связано с проявлением функциональных отклонений у животных, например, с дисфункцией печени. Определение холестерина в крови здоровых коров в первый месяц после отёла даёт ценную информацию об уровне молочной продуктивности, состоянии энергетических резервов, а также характеризует условия в организме для ускоренного возобновления овуляторных циклов, успешного оплодотворения и развития беременности в более короткий послеродовой период. Высокий уровень холестерина в крови коров в первые месяцы после отела может быть использован в качестве одного из прогностических маркеров повышения эффективности их оплодотворения в этот период. В настоящее время точный диапазон изменений уровня отдельных липидов у коров разных пород и с разной молочной продуктивностью в первые месяцы послеродового периода представлен недостаточно. Важно раскрыть детальные механизмы, которые определяют колебания уровня холестерина у коров в зависимости от стадии репродуктивного цикла.

Ключевые слова: коровы, лактация, холестерин крови, овуляторные циклы, оплодотворение

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