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Review articles

Alimentary infertility in female cattle: Part II – the effect of macronutrients on reproductive function (Overview)

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Abstract. Macronutrients are direct participants in the most important biochemical processes, and their deficiency or excess leads to metabolic disorders, which, in turn, is a direct cause of infertility. Thus, an excess of energy leads to diseases of the uterus and ovaries, violations and inferiority of sexual cycles, reduced fertility, abortions, difficult births, and litter retention. Energy deficit causes a delay in the onset of puberty, formation of persistent corpora lutea and cysts of follicles, violation of the rhythm of the sexual cycle and the process of ovulation, low fertility, embryonic mortality, abortions, and postpartum pathologies. An excess of protein causes changes in the hormonal balance and sexual cycle, deterioration of oocyte maturation and embryo development, disruption of intrauterine development and the occurrence of abortions, increased frequency of gynecological diseases, disruption of the course of childbirth and the postpartum period, and the birth of offspring with reduced resistance. Instead, protein deficiency leads to alimentary infantilism in heifers, delay in their sexual and physiological maturity, reduction in the mass of the ovaries, pituitary gland, adrenal glands, and thyroid gland, disruption of the rhythm of sexual cycles, a weak manifestation of estrus and desire, low fertility, resorption of embryos, reduced survival of embryos and abortions, premature births, prolongation of the process of uterine involution, decrease in weight, viability and immunity of neonatal calves. Violation of carbohydrate metabolism is associated with changes in the amount and nature of estrous mucus, inferiority of the sexual cycle, reduced fertility, disruption of intrauterine and neonatal development, metabolism, contractile function of the uterus, and restoration of ovarian activity after calving. Due to a violation of fat metabolism, there is a decrease in the level of reproductive hormones (progesterone, prostaglandins), the growth of follicles and eggs, fertilization, an increase in the number of abortions, and embryonic mortality. Therefore, control of the intake of the necessary macronutrient contents – proteins, carbohydrates, and fats - contributes to proper metabolism and, accordingly, the correct functioning of the reproductive function, and therefore a preventive measure of alimentary infertility.

Keywords: cows; heifers; sterility; necessary feed substances

Аліментарна неплідність самок великої рогатої худоби: ІІ – вплив макронутрієнтів на функцію відтворення (літературний огляд)

Анотація. Макронутрієнти виступають у ролі безпосередніх учасників найважливіших біохімічних процесів, а їх дефіцит чи надлишок зумовлює порушення обміну речовин порушення, що, у свою чергу, є безпосередньою причиною неплідності. Так, надлишок енергії призводить до захворювання матки та яєчників, порушення та неповноцінності статевих циклів, зниження заплідненості, абортів, важких родів, затримання посліду. Дефіцит енергії обумовлює затримку настання статевої зрілості, утворення персистентних жовтих тіл та кіст фолікулів, порушення ритму статевого циклу та процесу овуляції, низьку заплідненість, ембріональну смертність та аборти, післяродові патології. За надлишку протеїну відбуваються зміни гормонального балансу та статевої циклічності, погіршення дозрівання ооцитів та розвитку ембріонів, порушення внутрішньоутробного розвитку та виникнення абортів, почастішання гінекологічних захворювань, порушення перебігу родів та післяродового періоду, народження приплоду зі зниженою резистентністю. Натомість дефіцит протеїну веде до аліментарного інфантилізму у теличок, затримання їх статевої та фізіологічної зрілості, зменшення маси яєчників, гіпофізу, наднирників та щитоподібної залози, порушення ритму статевих циклів, слабкого прояву тічки та охоти, низької заплідненості, резорбції зародків, зниження виживаності ембріонів та абортів, передчасних родів, подовження процесу інволюції матки, зниження маси, життєздатності та імунітету неонатальних телят. Порушення обміну вуглеводів пов'язане із змінами кількості та характеру тічкового слизу, неповноцінністю статевої циклічності, зниженням фертильності, порушенням внутрішньоутробного та неонатального розвитку, обміну речовин, скорочувальної функції матки, відновлення активності яєчників після отелення. За порушення жирового обміну відбувається зниження рівня репродуктивних гормонів (прогестерону, простагландинів), росту фолікулів та яйцеклітин, заплідненості, збільшення кількості абортів та ембріональні смертності. Отже, контроль надходження до організму необхідної кількості макронутрієнтів – білків, вуглеводів та жирів – сприяє належному метаболізму і, відповідно, правильному функціонуванню репродуктивної функції, а отже й превентивним заходом аліментарної неплідності.

Ключові слова: корови; телиці; порушення репродуктивної здатності; поживні речовини корму

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Introduction

The normal functioning of living organisms, including the reproductive system, is possible only by receiving nutrients from food – biologically significant elements necessary to support life. In English, this term is translated as «nutrients.» There are five main groups of nutrients, which can be combined into two classes – macronutrients and micronutrients. The daily need for macronutrients (proteins, fats, and carbohydrates) is calculated equal to from tens to hundred grams. In contrast, micronutrients (vitamins and minerals) in the daily diet are contained in the amount from milligrams to grams.

However, the difference between these two classes of nutrients is not only in this but also in the fact that the functions they perform in the body are also significantly different. Macronutrients serve as a building material for cells (proteins), are converted into energy (carbohydrates), and perform the function of a depot for storing its reserves (fats). They act as direct participants in the most important biochemical processes. Instead, micronutrients take part in the body's vital activity mostly indirectly.

Therefore, the direct causes of infertility are metabolic disorders caused by the deficiency or excess of macro- and micronutrients (Sonderegger & Schurch, 1977; Francos et al., 1980; Klug et al., 1989; Murphy et al., 1991; Wright et al., 1992; Rhodes et al., 1995; Hegazy et al., 1997; Butler, 2000).

The role of macronutrients in the reproduction of cattle

The role of macronutrients in the manifestation of reproductive function can be related to the deficient or excessive intake of energy and protein and disturbance of both carbohydrate and fat metabolism (Table).

Energy

Among dietary influences, energy balance is probably the essential factor associated with impaired animal reproductive function (Randel, 1990; Ibtisham et al., 2018). All physiological processes accompanied by chemical and biological reactions are related to the energy transformation into living organisms. Energy is the primary nutrient required for feeding dairy cattle, and insufficient energy intake harms their reproductive performance (Nigussie, 2018).

Nevertheless, the mechanism of the influence of feeding on reproductive function has yet to be sufficiently studied because the data available in the literature on the effect of the feeding level on milk and reproductive functions are not devoid of contradictions. Some authors (Armstrong & Beever, 1969) believe that abundant feeding beyond average norms has a positive effect on metabolism, milk productivity, and reproductive function; according to others (Sonderegger & Schurch, 1977; Bonomi, 1979; Pandey & Parai, 1988), abundant feeding beyond average norms causes obesity, high milk yields negatively affect the energy balance, hormonal status and fertility of cows, lengthening the interval from childbirth to the first stage of the disorder sexual cycle (Jordan et al., 1983).

Short & Adams (1988) prioritized the metabolic use of available energy in ruminants by ranking each physiological state in order of importance as follows: 1) basal metabolism, 2) activity, 3) growth, 4) energy stores, 5) pregnancy, 6) lactation, 7) additional energy stores, 8) estrus cycles and the onset of pregnancy, and 9) excess energy stores (Ryan et al., 1992). Based on this list of metabolic priorities for energy, reproductive function is impaired as available energy is directed to meeting minimum energy stores and milk production. Energy restriction during late pregnancy increases the duration of postpartum anestrus (Bellows et al., 1982) and reduces the frequency of subsequent pregnancies. The effects of insufficient energy intake during late pregnancy cannot be reversed by increasing energy intake after delivery (Scaramuzzi & Martin, 2008).

The metabolic energy reserves at the time of calving significantly impact potential complications during or immediately after calving. A negative energy balance can begin before parturition due to decreased feed intake. During the first three weeks of lactation, harmful energy balance delays early ovulation and recovery of reproductive function after parturition. It provides a vital forage link to low fertility in lactating dairy cows. A negative energy balance can adversely affect the egg released after ovulation and reduce the frequency of conception after insemination. Cows with a negative energy balance have long periods of ovulation. Postpartum anxiety and infertility are aggravated by the loss of body condition in the early postpartum period, associated with a negative energy balance (Nigussie, 2018). In addition, it affects milk production and reproductive capacity during the subsequent lactation. When a cow is exhausted, milk productivity decreases due to a lack of nutrients in the stage of the first half of lactation, an increase in the number of cases of certain metabolic diseases (ketosis, displacement of the rumen, etc.), a delay in returning to heat after calving.

One of the most common causes of infertility in cows is a lack of energy concerning the animal's needs or the so-called negative energy balance. Most animals enter the stage of negative energy balance in the first half of lactation because they cannot consume the energy necessary for milk production. Therefore, cows mobilize the body's energy reserves (fat) during this period and, consequently, lose live weight. A negative energy balance can last from two to ten weeks from the start of lactation, depending on the level of milk production. During the following lactation periods, the cow's energy balance is positive. Energy consumption exceeds the needs of milk production, and some energy is used to replenish the body's reserves depleted during the first half of lactation.

In animals with a negative energy balance (the cow loses weight), the frequency of fertilization is significantly lower compared to animals with a positive energy balance (the cow gains live weight). Studies have shown that the greater the negative energy balance, the longer the interval until the first ovulation and the higher the probability of hidden sexual desire. There was detected no evidence that high-producing cows have a lower reproductive capacity, but it is clear that cows with a negative energy balance have low fertility regardless of their performance (Kilmer, 1986; Ibtisham et al., 2018; Mischenko et al., 2021).

Taking into the account complex interaction energy metabolism with other factors, an energy deficit is the leading cause of anestrus in the postpartum period (Mwaanga & Janowski, 2000). A healthy organism can overcome limited periods of starvation by using its resources (nutrients), the size of which depends on the previous stage of accumulation. In the context of prolonged famine, these nutrient reserves eventually deplete, prompting the body to progressively restrict individual functions. As the existence of any organism in nature is tied to the preservation of a particular species, these restrictions initially impact reproductive functions, and metabolic processes operate in an «economy mode» (Koshovyj, 2004).

High milk productivity and high reproductive capacity of cows are mutually determined by the need to provide them with adequate nutrition both before and after calving. In this connection, a scheme of permissible changes in the body weight of cows in the early period of lactation is proposed. Reducing the body weight of cows to 35 kg within the first 70 days after calving is considered beneficial. However, individual characteristics of cows vary; some may expend significantly more energy reserves for milk production, making them «problematic» in terms of reproduction (Gnojevyj, 2006).

Compared to low-yielding cows, high-yielding cows use significantly more body energy reserves for milk secretion and have a longer negative energy balance (Ensminger et al., 1990). If left unaddressed, this typically leads to the premature deterioration of reproductive functions, health disorders, and diminished productivity (Kostenko et al., 1990; Cjupko, 1985). In high-yielding dairy cows, the need for nutrients increases dramatically after calving. It needs to be addressed immediately to meet the requirements associated with the beginning of lactation by increasing feed. It takes several weeks for peak lactation and peak feed intake to converge. Therefore, in

Table – Violation of the reproductive function of alimentary origin due to deficiency or excess of macronutrients

A type of alimentary infertility	Nature of violations
Excess energy	- diseases of the ovaries, disorders of their function; - negative impact on hormonal status; - violation of sexual cycles, their inferiority, weak manifestations of estrus and desire; - increase in the frequency of insemination/decrease in fertility; - abortions; - difficult births; - retention of droppings; - lengthening of the interval from childbirth to the first estrus; - progression of inflammation of the uterus, its subinvolution; - infertility.
Energy deficiency	- delayed onset of maturity; - formation of persistent corpora lutea, follicle cysts, and functional disorders of the ovaries; - violation of the rhythm of the sexual cycle and the process of ovulation, an increase in the number of missed or «silent» («hidden») estrus; - low fertility; - increase in the death of egg cells and the frequency of embryonic mortality; - reduced embryo survival, abortions; - anestrus in the postpartum period; - increase in the frequency of ketosis, endometritis, mastitis, and postpartum paresis; - increasing intervals between calving and first ovulation, calving and estrus, and calving and fertilization.
Excess protein	- changes in hormonal balance and sexual cycle; - deterioration of the maturation of developing oocytes and embryos; - violation of intrauterine development of the fetus, occurrence of abortions; - increase in gynecological diseases (appearance of follicular cysts); - adverse impact during childbirth, litter retention; - the extension of the inter-hotel and service period; - negative impact on the course of the postpartum period, delaying the restoration of normal ovarian function, increasing the fertilization index, reducing postpartum fertility; - the birth of non-viable offspring, reduction of immunobiological properties of colostrum of cows, deterioration of resistance of newborn calves.
Protein deficiency	- alimentary infantilism in heifers, delay in their sexual and physiological maturity; - decrease in the mass of the ovaries, pituitary gland, adrenal glands, and thyroid gland, their functional activity decreases, reproductive function regulation disorders, negative impact on the rhythm of sexual cycles, infertility; - weak manifestations of estrus and desire; - low fertility; - embryo resorption, reduced embryo survival, abortions; - premature births; - lengthening of the uterine involution process; - decrease in mass, viability, and immunity of neonatal calves.
Violation of carbohydrate metabolism	- change in the amount and nature of estrous mucus; - inferiority of the sexual cycle, reduction of fertilization and fertility; - violation of fetal nutrition; - ketonuria and other metabolic diseases; - reduction of the output of calves and disruption of their development; - violation of the contractile function of the uterus, recovery of ovarian activity after calving, the interval from calving to the first ovulation, and the frequency of double first ovulations.
Violation of fat metabolism	- decrease in the level of reproductive hormones (progesterone, prostaglandins) and the growth of follicles and eggs, fertilization; - increase in the number of abortions and embryonic deaths.

many animals, a negative energy balance is observed immediately after calving when substances absent in the feed consumed for milk secretion are extracted from the tissues. Under favorable conditions, the negative balance lasts 1-2 weeks after calving, but it can last longer, up to the maximum milk yield. Live weight and fat decrease. Even when given a high-energy diet, high-yielding cows cannot always consume the necessary energy for milk production before the end of the postpartum period and the beginning of fertilization (the third decade of the second, the first decade of the third month). In such animals with a standard lactation period, the live weight and body condition required before calving may not be achieved during the dry period (Ibtisham et al., 2018).

In Holstein's calves, pre-calving live weight is also an essential factor affecting subsequent reproductive performance and the frequency of culling for slaughter. With a live weight of up to 400 kg and 401-440 kg, the number of fertilized animals within 6 and 21 weeks (after the start of insemination) was less (49-79% and 60-87%) than in animals with a live weight of 441-470 kg (68 -89%), 471-510 kg (68-87%), 511-540 kg (75-88%) and 541 kg and more (77-87%). The difference between the percentage of fertilized animals in two terms in the first two groups was the most significant and amounted to 30% and 27%; the lowest this difference was in animals with the most significant live weight (only 10%). Reproductive capacity was weakened in animals with low live weight due to negative energy balance after calving. The fewest animals were inseminated quickly (after six weeks) after calving.

Given that, in dairy cows as opposed to meat cows, the distribution of nutrients in the diet is more directed to milk production, the relationship between energy balance and condition during calving and after it will be more noticeable. The speed and degree of body weight loss in the early lactation period in dairy cows also affect the intervals between calving and the first ovulation, between calving and the first estrus, as well as on fertilization during a single mating and the length of the period between calving and fertilization (Gnojevyj, 2006).

Wiltbank et al. (1962) studied the effect of energy level on the reproductive performance of sexually mature Hereford cows. The results show that energy levels can affect reproduction in the mature beef cow nursing a calf. The proportion of cows diagnosed with pregnancy during the experiment was 95%, 77%, 95%, and 20% for the high-high, high-low, low-high, and low-low diets, respectively.

The results of studies by Dunn et al. (1969) show that the level of energy intake can significantly influence reproductive performance in 2-year-old heifers nursing their first calves. Calvary frequency 120 days after calving was directly related to post-calving energy levels. 87% of cows fed a high-energy diet after calving were pregnant, compared to 72% of cows fed a moderate level of nutrition, and 64% of cows fed a low-energy diet. The onset of oestrus was delayed in cows receiving low energy levels before calving. The low pregnancy rate in cows fed low energy after calving was attributed to the fact that 30% of Hereford cows and 9% of Angus cows did not exhibit signs of estrus.

A report (Hejrsan, 1982) shows that Friesian cows lost less than 35 kg of body weight during the early lactation period, and the average interval to the first mating was 72 days. If the weight loss of cows exceeded 35 kg, this period increased to 104 days. The author considers an increase in missed or «silent» estruses to be one of the main factors leading to extending the interval before the first pairing.

Konervan (cited by Vizner, 1976) believes that with an insufficient supply of energy with feed, the body limits reproduction in favor of lactation. It becomes evident that all attempts to treat such cows at this stage typically remain unsuccessful.

In this regard, Popov & Suhov (2003) note that in many dairy farms, the lifespan of cows does not exceed 2.8-3 lactations. Sidorenko et al. (2009) concluded that insufficient or excessive feeding increases the frequency of diseases such as ketosis, endometritis, mastitis, postpartum paresis, and functional disorders of the ovaries. Kalchreuter (1978) established that a lack of energy and an excess of protein in the diet leads to a violation of the rhythm of the sexual cycle, shifts in the timing of the onset of the first stage of arousal, the formation of persistent yellow bodies, follicle cysts.

Violations of the reproductive function in animals caused by insufficient energy intake are associated with a specific state of specific deficiency. Therefore, attention is increasingly focused on the influence of particular dietary components (Koshovyj, 2004). With a low energy level of the rations and weight loss, the body's protection against the effects of stress factors decreases in females. As a result of a decrease in the morphofunctional activity of the endocrine glands, the rhythm of sexual cycles and the process of ovulation are disturbed. This is manifested by delayed insemination after childbirth and low fertility. It is reported (Hejrsan, 1982) that ovulation occurs on average about the 10th day after the cow passes the lowest point of negative energy balance and begins to accumulate energy in the body. This is probably related to the long service period of highly productive cows when they are exhausted from the previous lactation and do not have time to accumulate enough biological energy in the body during the dry period. A high loss of live weight in cows during the first two months of lactation, especially during the calving period, may also be attributed to inadequate training for high dry matter consumption. In this regard, in highly productive herds, try to prevent a significant loss of live weight by cows during the first 60 days of lactation – no more than 60 kg or an average of 1 kg per day. If this happens, the cows have tragic consequences regarding productivity in the subsequent lactation and reproductive capacity.

A low-level and unbalanced diet of dairy cows at the beginning of lactation negatively affects reproductive function (Osetrov & Marchuk, 1969); a low level of feeding, provided the diet is complete, allows cows to exhibit estrus usually and even fertilize. Still, in the case of exhaustion or a sharp decrease in fatness, there is a long delay in the manifestation of the first stage of arousal of the sexual cycle after childbirth, which is less dangerous (Gnojevyj, 2006).

One of the cases of herd infertility caused by insufficient nutrition is hypoglycemia. This may result from inhibiting or decreasing the hormone level responsible for gonadotropin secretion from the hypothalamus. This, in turn, reduces the secretion of gonadotropin from the pituitary gland and, thus, decreases sexual activity (Gnojevyj, 2006).

Excessive loss of body weight in the early period of lactation is a phenomenon frequently observed in productive animals which reduces the reproduction possibilities of cows. As already noted, this leads to an increase in the number of missed or «hidden» oestrus to an increase in the infertility of cows (Gnojevyj, 2006). Energy restriction in high-producing cows can harm fertility through effects on hypothalamic and ovarian function (Swanson, 1989).

With a negative energy balance, energy is used primarily to support vital activity and ensure lactation, and it is lacking for increasing body weight and reproduction. Atrophic changes begin in the genitals: the size of the ovaries decreases, and follicles do not mature. Cows with a negative energy balance during early lactation have a higher risk of anestrus than cows with a balanced energy level. Anestrus can persist until the energy balance is restored. This can explain the negative relationship between productivity and reproductive capacity in Holstein cows with stable long-term lactation. However, if sexual cyclicity manifests itself, fertilization may be low, the death of egg cells and the frequency of embryonic mortality increase, and abortions are observed.

The resulting negative energy balance and the rate of mobilization of the body's reserves are directly related to the postpartum interval to the first ovulation and a lower conception rate. Delays in the onset of regular ovarian activity, which limits the number of estrous cycles before reproduction, may cause the observed decrease in fertility. Negative energy balance probably acts similarly to undernutrition and may manifest in delayed ovarian activity through effects on pulsatile luteinizing hormone secretion. Lower availability of glucose and insulin may also reduce luteinizing hormone pulsatility or limit ovarian response to gonadotropins. Alternatively, releasing endogenous opioids due to increased feed intake or other lactational hormonal reactions may result in neuronal or pituitary inhibition of pulsatile luteinizing hormone production required for ovarian follicle development (Butler & Smith, 1989).

Under energy deficiency in pregnant cows, calves have low birth weight and unstable and slow growth (Linn et al., 1990).

More apparent violations of sexual cycles are observed with alimentary obesity. Sometimes in practical work, they seek to increase the energy value of rations in the first months of lactation to boost the reproductive capacity of cows by feeding more concentrated feed. It is noted that the highly concentrated type of cow feeding harms their fertility since the protein content in large quantities disrupts the sexual cycle and fertilization and leads to the appearance of cysts on the ovaries (Pösö & Lindberg, 1994; Tjutjunnik & Misjureva, 1998).

In addition, it can lead to «fatty liver» syndrome and obesity in cows, which, in turn, negatively affects the reproductive performance of cows (Beal et al., 1978). Thus, the concentrated type of feeding, starting with giving more than 300 g per 1 kg of milk, negatively affects intermediate metabolism and, ultimately, the reproduction process (Reshetnikova et al., 1978; Ostashko et al., 1982), leads to retention of litter, subinvolution of the uterus, endometritis, ovarian disease (Akimochkina, 1973), reduces fertilization in the first litter by 20-40%, leads to inferior sexual cycles, an increase in the frequency of insemination and the accumulation of days of infertility (Zvjerjeva et al., 1981), early culling due to lactation disruptions (Huszenicza et al., 1987), digestive disorders in newborns (Dzhakupov, 2008).

Overfeeding cows leads to progression (3 times) of inflammation of the uterus, impaired ovarian function (2 times), a 30% decrease in primary fertilization, and an increase (2 times) in the percentage of culling (Akimochkina, 1973).

Excessive energy intake during late lactation and the dry period can cause «fat cow» problems, which reduces reproductive performance in the subsequent lactation. When heifers are fed insufficient energy, they reach sexual maturity later (Brown, 1990; Yaremcio & Kreplin, 2009).

Caution is advised when feeding excessive nutrients before or after calving. This is costly, and animals with excess physical conditions have lower reproductive performance and more incredible difficulty calving than animals with moderate physical conditions (Elrod & Butler, 1993). Plank (1978) observes that overfeeding cows significantly reduces the number of births with normal uterine involution by almost half, increases the incidence of metritis after parturition by 2.5 times, and doubles the number of cows with ovarian cysts. However, Gundorov (1981) and Farries (1979) established that the increased level of feeding in the dry period contributed to increased productivity and did not negatively affect the health of animals and their reproductive function. Excessive feeding causes complications during calving (difficult births) and a decrease in dry matter consumption in the first half of lactation, which in turn leads to an increase in the number of cases of certain metabolic diseases (fat cow syndrome, ketosis, etc.) and a decrease in milk production.

Excessive energy consumption in the second half of lactation and the dry period can lead to complications related to cow obesity. In cows with excessive live weight, there are significantly more cases of difficult calving, placenta accretes, infectious infection of the uterus, and ovarian cysts. Such disorders of the reproductive system are often a secondary consequence of disorders associated with excessive accumulation of energy reserves in the body. Excessively rapid subcutaneous and visceral fat mobilization can lead to fat accumulation in the liver. This causes the animals to lose their appetite, exacerbating the energy deficit and, as mentioned above, delays the return of the ovaries to regular activity (Lavelin, 2009).

Excessive energy intake during late lactation and dry periods can lead to «fat cow» problems. Cows in excess condition at calving are more likely to have placental abruption, more uterine infections, and more cystic ovaries. They are also more likely to have metabolic disorders and refuse food more often. All these problems can lead to poor reproductive performance (Elrod & Butler, 1993).

While studying the effect of intensive feeding of cows on reproductive function after parturition, Swensson & Olsson (1982) found that with a slight increase in the amount of feed, the first stage of arousal of the sexual cycle after parturition appeared on the 46th day. Fertilization occurred after 86 days, simultaneously with a significant amount of additional feed; these terms were longer after 59 and 106 days. Konermann (1979), under similar conditions of the experiment, notes that with tiny additional feed allowances in the dry period after parturition, uterine involution did not complete within a month in only 17.7% of cows, ovarian cysts were present in 19%, fertilization after the first insemination was 50% and culling due to infertility – 13% of animals; with large additional feed allowances, these indicators were 50%, 45%, 33%, and 21%, respectively.

Concerning beef cows, the levels of their feeding before calving and after calving significantly affect the reproductive function. A high level of pre-calving feeding resulted in a shorter interval to the first estrus than a low level, regardless of the level of post-calving feeding. Post-calving feeding had little effect on the reproductive function of cows in good condition at calving but markedly affected those who received unsatisfactory pre-calving diets. In such animals, estrus was observed 90 days after calving. The condition or body weight of cows at calving is relatively more important than the feeding level during this period. Cows that were in low condition at calving but were fed a complete feed to restore body weight after calving had an average interval to first ovulation of about 76 days.

The cow's energy balance during the heat can also significantly affect its fertilization. If the body weight decreases during this period, then the probability of fertilization in such cows decreases compared to cows with an increase in body weight. There is a direct relationship between the condition of cows and their fertilization, although this is not always observed. First, there should be a specific limit since overfed females are worse at impregnation than factory-bred animals. Secondly, there is probably an indicator of critical body weight or critical condition, below which the reproductive function deteriorates, but only if the cow is still in a negative energy balance. Above this crucial level of change in body weight and energy balance, the reproductive function of cows does not deteriorate (Gnojevyj, 2006).

Thus, there is a relationship between the energy status and the reproductive capacity of dairy cows when many are in a state of negative or stressed energy balance just when it is necessary to restore the ability to bear. The better the cow's condition during calving, the greater the loss of body weight can occur before reaching its critical level, after which deterioration of the reproductive function of animals occurs under the influence of the feeding factor. The above data are of great practical importance - they indicate the need for constant control of the energy supply of the mass of cows and their condition.

Protein

The ration quality largely depends on its protein content, which plays a significant role in obtaining products from animals and in the reproduction of livestock (Miettinen, 1996). This is explained by the fact that all enzymes and many hormones are made of protein, which is included in the composition of vital vitamins as a colloidal medium. Therefore, the lack of this substance or essential amino acids leads to disorders of the function of enzymes, vitamins, and hormonal disorders (Koshovyj, 2004; Ruban et al., 2017).

The effect of protein on reproductive functions is a complex process (Bindari et al., 2013). For reasons not yet fully understood, in some cases, a large amount of crude protein in the diet is associated with high fertility). Prolonged protein deficiency has been reported to reduce reproductive performance (Bindari et al., 2013). Insufficient protein in the animal's diet in the first half of lactation leads to a decrease in milk productivity and a deterioration of the animal's reproductive functions. On the other hand, an excessive amount of protein increases the cost of the diet and can harm the reproductive functions of the animal.

Protein deficiency is often combined with an insufficient energy level of feeding and increases the negative impact of the latter on the rhythm of sexual cycles, fertilization, and embryo survival. This is accompanied by a high level of urea in milk due to decreased protein concentration. If the protein is excessive concerning the energy of the diet, then the level of urea in milk is high, even though the level of protein content is average. Any of these situations is accompanied by a decrease in the level of reproduction in cows (Carroll et al., 1988).

The researchers searched for a possible explanation for how crude protein can affect cow fertility. The following are the phenomena that occur in the body that give some reason for the interaction between protein in the diet and the fertility of the cow: an excessive amount of ammonia in the animal's body leads to a high content of urea in the blood, which, in turn, has a toxic effect on the eggs and development embryo; the type and amount of crude protein in an animal's diet can alter the balance of reproductive hormones. The level of progesterone decreases under the influence of a high amount of urea in the blood; an excessive amount of crude protein in the diet of a cow in the first half of lactation increases the negative energy balance and delays the return of the ovary to normal functioning.

It has long been known that a lack of protein in the diet leads to overspending on feed, irrational use, deterioration of animal health, reduced fertility and productivity, and non-viability of offspring (Gnojevyj, 2006). Heifers raised due to feeding inadequate and unbalanced rations, that is, due to a lack of protein in them, suffer from alimentary infantilism - their underdevelopment in the usual terms. This is especially evident in the underdevelopment of the genitals and the delay in the physiological maturity of animals (Paccard & Tillie, 1986).

A lack of protein in females is characterized by a decrease in motility and bielectric activity of the uterine muscles, cell atrophy, and a decrease in the weight of the ovaries, pituitary gland, adrenal glands, and a decrease in their functional activity, as well as a violation and decrease in the activity of the thyroid gland.

A deficiency of protein and carbohydrates combined with poor feeding in ruminants inhibits the action of the microflora (microbes, ciliates, and fungi) of the foreguts, which leads to a decrease in bacterial protein synthesis, and the development of hypoproteinemia, hypoaminoacidemia, and reduced functions (Bertoni et al., 1996).

A decrease in protein in the body leads to the inhibition of enzymatic systems (hypoenzemia and ansemia) and a decrease in the level of metabolic processes in the body. A reduction in the contractile function of the uterus due to hypoproteinemia leads to the inability of spermatozoa to advance in the genital organs of the female, which leads to alimentary infertility (Petrov et al., 1988).

Disruption of metabolic processes due to a lack of protein in cows reduces the general reactivity of the body, including the reaction to the male, irritation of the vagina, and penetration of sperm into the genital tract, as a result of which sexual function is impaired (Bajmatov & Shpil'man, 1980).

Decreasing the protein level in the rations of deep-bodied cows by two times, the norm led to a prolongation of the process of uterine involution and consequently, to a decrease in fertilizing ability and an increase in the probability of abortions (Chabaev et al., 2014).

With protein deficiency in pregnant cows, calves at birth had low birth weight, slow growth, and reduced immunity due to a lack of in globulin content in colostrum (Linn et al., 1990).

Meanwhile, it has been known for a long time (Dawson, 1983) that the value of protein is essential and that it is not only a matter of its quantity in feed but also the presence of certain defined amino acids (Sinclair et al., 2014; Ruban et al. et al., 2017). We are still talking about 7-9 amino acids, which are not synthesized in the body and must be present in feed. A lack of protein or essential amino acids leads to a weakening of the function of enzymes, hormonal disorders, and phenomena of vitamin deficiency, hormonal disorders. This violates many body functions, including reproductive functions (Koshovyj, 2004; Ruban et al., 2017).

The same type of feeding with beer groats and beet pulp harms the fertility of female cattle. Possessing lactating properties, these feeds are very poor in tryptophan content; therefore, the female's body fills the lack of this amino acid at the expense of the body's reserves, and the lack of amino acid in the body leads to ovarian dysfunction and infertility (Jertuev, 1996).

A dosage of 60 g or less of digestible protein per 1 feed unit and a deficiency in amino acid composition, especially essential amino acids, leads to disturbances in the work of the glands of internal secretion, and the production of their hormones decreases. As a result, the sexual cycle in females is disturbed, the number of abortions increases, and the mechanisms regulating sexual functions are disturbed.

In many scientific literature reviews, data indicate the negative impact of excessive protein in the diet on the reproductive function of cows. It has been found that reproductive performance can be impaired if the protein is fed in amounts that far exceed the cow's requirements (Bindari et al., 2013). Protein overfeeding during breeding and early pregnancy, mainly if the rumen receives an inadequate energy supply, may be associated with reduced fertility (Cheng et al., 2015). This reduction in fertility may result from a decrease in uterine pH during the luteal phase of the estrous cycle in cattle fed high doses of degradable protein (Ibtisham et al., 2018).

In particular, cows that were on a diet with a protein content of 12.7%, 16.3%, and 19.3% in terms of dry matter and given 30 kg of milk per day had, respectively, 69, 96, and 106 days of the service period and the ratio of the pairing/fertilization rate – 1.47; 1.87; 2.47. Based on the results of this study, it can be concluded that protein content levels in the diet of more than 12.7% were excessive, as it negatively affected the reproductive function of cows (Gnojevyj, 2006). In the studies of several authors, it was found that feeding high-yielding dairy cows with unbalanced and inferior forage rations with an increased amount of concentrates led to an increase in the fertilization index, a lengthening of the service period, an increase in abortions and gynecological diseases.

An excessive decrease in protein, which can often be observed in production, can lead to metabolic disorders. With hypoproteinemia in animals, the motility and bioelectric activity of the uterine muscles decrease, the mass of the ovaries, pituitary gland, and adrenal glands decrease, their functional activity decreases, the activity of the thyroid gland changes, and the liver function is disturbed. It is clear that under such conditions, the reproductive function of cows deteriorates. At the same time, an excess of protein in the diet, as already noted, has an equally adverse effect on reproduction. In cows whose rations had significantly more protein than the norm, there were few growing follicles in the ovaries and many in various stages of atresia. In such conditions, every year, 25-30% of cows remained barren (Stupova, 1973).

Increasing evidence suggests that excessive protein intake in early lactation may harm postpartum fertility.

When increasing the level of protein supply in terms of digestible protein in dairy cows in the winter period from 80-85 g to 110 g per 1 feed unit, it was noted that cows came into heat on the 38th day after calving. They had extended inter calving periods, increased index fertilization, and decreased reproductive function.

It was found that animals that received higher caloric rations came into heat much earlier (within 60 days) after calving in contrast to females with lower caloric diets; however, they had a violation of the sexual cycle and a lengthening of the inter-calving period.

Feeding highly concentrated feed for three years to cows with productivity of 7,500 kg per lactation resulted in the animals having a 31-33% increase in follicular cysts (Vinnichuk, 1992).

According to Canfield et al. (1990), animals fed a high-protein diet had a lower first insemination rate (31% vs. 48%) and a higher plasma urea. The days to the lowest energy balance point were correlated with the days to the first ovulation. Luteinizing hormone pulse frequency increases, and pulse amplitude decreases 14 days postpartum compared with samples taken after the nadir of energy balance. These data suggest that energy balance status is essential in determining postpartum recovery of cyclic ovarian activity.

In lactating cows, the content of luteinizing hormone was directly related to protein feeding, and the amount of progesterone was inversely proportional. Still, protein intake did not affect hormonal supply in lean cows. In another study, cows fed 13%, 15%, and 17% crude protein during three lactations had a fertilization index of 2.3, 2.6, and 2.7 and 123, 141, and 139 days of the service period, respectively. As we can see, even in the second experiment, the fertilization index of cows decreased at a protein-feeding rate of more than 13% concerning the diet's dry matter (Ayres et al., 1990).

Cows fed a diet containing 16% protein from soybeans treated with formaldehyde and untreated soybeans with a protein content of 16% and 20% in the diet, respectively, had the following effects: fertilization rate – 69%, 56%, and 44%, service period – 84, 98 and 102 days. Thus, increasing the rate of protein consumption by cows harmed the level of their fertilization and the length of their service period. The service period's duration and the cows' insemination index did not differ significantly when cows were kept on diets with a dry matter content of 9% to 14.5% crude protein. The authors concluded that the fertility rate of cows decreased with excess protein in the diet. At the same time, energy intake remained constant, and live weight loss increased to meet energy needs and increase milk yield alternatively. Fertilization rates may increase with an excess of protein in the diet, but energy intake must also increase, and live weight loss decrease as additional milk is produced (Popov, 1974).

For fertilization of cows whose diet contained 85 g or 105 g of digestible protein per 1 feed unit, 1.5 times fewer inseminations were spent, and their service period was, on average, 23 days shorter compared to cows whose diet contained 130 g or 150 g of digestible protein per 1 feed unit.

The problem of protein overfeeding can arise when using irrigated cultural pastures and introducing high doses (200-360 kg/ha) of nitrogen into them. In cows grazing on such pastures, the assimilation of nitrogenous, mineral substances, and carotene decreased, leading to a decline in feed intake, frequent grazing, and the birth of non-viable offspring (Popov, 1974).

Nitrates and nitrites significantly affect the reproductive function of nitrogenous substances. Under normal conditions, nitrates in the rumen of ruminants are successively reduced to nitrites and ammonia. Bacteria use the latter for protein synthesis. Suppose there is an excessive content of nitrates in the feed. In that case, they can enter the blood and cause dilation of blood vessels, affect cerebral blood circulation, and aggravate the blood circulation of the pregnant uterus. In connection with the widespread use of excessive rates of nitrogenous fertilizers, large amounts of nitrates and nitrites can accumulate in feed, which causes animal poisoning.

The introduction of nitrates in the amount of 600 mg per 1 kg of live weight of cows and heifers leads to violations of indicators of reproductive capacity.

When heifers were fed with nitrates every day at 440 and 660 mg/kg body weight for three sexual cycles before the first insemination or from 40, 150, or 240 days from the beginning of pregnancy to slaughter, which was carried out 30 days after calving, animals of the control group became pregnant on average after 1.3 sexual cycles. In the group that received 440 mg/kg of nitrates, cows became pregnant after 1.4 cycles and in the group that received 660 mg/kg of nitrates, the average was for 2.6 cycles. In the last group, there were two abortions; other differences in the sexual function of the animals were not observed. This information warns about the need to monitor animal diets for nitrates and nitrites.

Excessive feeding of protein or urea has been associated with reduced pregnancy rates in dairy and beef cattle (Blanchard et al., 1990; Smith & Chase, 2010). Exposure to high levels of ammonia or urea can impair oocyte maturation and subsequent fertilization or maturation of developing embryos. However, providing adequate energy to eliminate excess ammonia or urea can prevent reduced fertility in dry cows or heifers (Patterson et al., 2007). In addition, not all studies observed a negative effect of elevated blood urea nitrogen concentrations on embryo quality or pregnancy rate (Kappel & Zidenberg, 1999). Overfeeding protein during the breeding season and early pregnancy, mainly if the rumen receives an inadequate energy supply, may be associated with reduced fecundity (Dunn & Moss, 1992). This reduction in fertility may result from a decrease in uterine pH during the luteal phase of the estrous cycle in cattle that are fed high levels of degradable protein.

In addition to high rates of nitrogenous fertilizers, violations of their harvesting technology, excessive humidity, introduction into the soil, and treatment of plants with carbamate pesticides and herbicides also significantly affect the content of non-protein nitrogen-containing compounds in silos. These factors lead to the accumulation of non-protein nitrogen in the vegetative parts of the plant in the form of amines, nitrites, and nitrates, which turn into ammonium nitrogen during silage ripening. Feeding animals ensiled feed with a high nitrate content can cause the formation of endogenous nitrosamines in the intestines of animals, which have a high carcinogenic potential. Nitrosamines can be formed in ensiled fodder under the action of nitrogen oxides and plant nitrates.

It is shown that a significant amount of ammonium nitrogen accumulates in corn silage due to violations of its harvesting and storage technology, increasing from October to April by approximately 2-4 times, reaching 30-35% of the total amount of nitrogen. Feeding such silage to dry cows caused a violation of the intrauterine development of the fetus, reduced the immunobiological properties of the colostrum of cows, and worsened the resistance of newborn calves (Crowley, 1975; Kavun et al., 1999).

For many years, urea, a synthetic substance containing 46% nitrogen, has been used for cattle feed in countries with developed animal husbandry. However, there still needs to be a consensus on its harmlessness to the reproductive function of cows and heifers. It was reported (Belen'kij, 1975) that derivatives of urea metabolism can contribute to infertility, harm the motor function of the muscles of the reproductive tract of females, and directly the sexual function in general. However, this was not confirmed in other experiments. In particular, in a long-term study (Erb et al., 1976; Erdman, 1995) on Holstein heifers during two lactations, the effect of feeding urea on the activity of ovaries and sex hormones was studied. After the second calving, the timing of the first ovulation or the interval between ovulations did not differ in the animals. Urea feeding significantly increased the progesterone content in the blood plasma of animals in all periods of the experiment. Only single cases of abortions, litter retention, and fertilization disorders were noted in all groups.

Krok & Gnojevyj (1971) conducted profound histological studies of the internal organs of heifers and their embryos at 1.5 and 4 months of age in connection with long-term feeding of Simmental heifers with corn silage prepared with the addition of 0.5% urea or also silage, ammoniated with 25% ammonia water just before feeding. Under the condition of a sufficiently high level of balancing of rations in terms of energy, readily available carbohydrates, and macro- and microelements, the replacement of 25% of digestible protein with urea or ammonia water in the composition of corn silage, as evidenced by the authors' research, did not negatively affect the health and reproductive function of animals. Based on the above research results, it is impossible to draw an unambiguous conclusion about the influence of urea or other synthetic nitrogenous substances on the reproduction of ruminants. However, based on these data, as well as other generalizations made (Lusli & Mak-Donald, 1973; Bull & Tampling, 1975), it can be concluded that the use of urea and other synthetic substances without control for its content in the diet of non-protein nitrogen, carbohydrates, minerals substances, including sulfur, does not give the desired effect.

It was found (Lusli & MacDonald, 1973) that cows with blood urea levels greater than 20 mg% had problems with fertilization. In particular, when the level of urea nitrogen in the vaginal fluid of cows exceeded 40 mg%, not a single cow became pregnant. This is due to the excessive consumption of protein by animals. The energy value of the diet determines the accumulation of microbial protein in the rumen of animals, the amount of protein, and its degree of cleavage. Violating this rule may result in a situation where, due to the limited growth of microorganisms, the ammonia produced during protein breakdown cannot be converted into microbial protein without a residue. Excess ammonia will be absorbed into the blood, adversely affecting animal health and reproductive function.

Based on the research carried out by Gustafsson & Carlsson (1993), it was concluded that for optimal reproductive efficiency, the concentration of urea in milk might be higher than the current average value and that the deterioration of protein quality in silage may reduce the reproductive efficiency of the herd. At the same time, a large-scale field study and a long-term feeding study by Kertz (2010) did not show any significant adverse effects on reproduction when fed urea.

A certain ratio between protein and soluble carbohydrates is necessary for the ordinary course of the reproduction function: there should be 80-150 g of sugar per 100 g of protein. In standard winter rations, the ratio of protein and sugar is, on average, 0.4-0.2. In such cases, the vitality of the microflora of the rumen decreases, which negatively affects the microbiological processes of fiber breakdown and assimilation of other nutrients.

An increase in the content of digestible protein (by 57%) and sugar (by 40%) adversely affects parturition, the postpartum period, and the condition of newborn calves (Shevchenko, 1983). The different ratio of sugar to protein and sugar to starch in balanced rations of dry cows has little effect on milk productivity.

In most, but not for all, published studies, diets high in crude protein reduced reproductive performance. Ferguson & Chalupa (1989) resolved some inconsistencies in published reports. Their models showed that the type and amount of protein fed explained much of the variation in conception rate. Age and feed energy concentration were identified as modifiers of protein effects on reproduction. Protein nutrition can affect reproduction due to the toxic effect of ammonia and its metabolites on gametes and early embryos due to amino acid deficiency and exacerbation of negative energy balance.

Bomko (2014) reported that there is clear effect of different levels of crude protein, its quickly and poorly soluble fractions, lysine, and methionine in the diets of high-yielding cows on milk productivity and reproductive performance during the first 100 days of lactation. It has been proven that the optimal level of crude protein in the diet of highly productive cows (45 kg or more milk per day) of the central zone of the Forest Steppe of Ukraine during the milking period is 18%, lysine – 1.1%, methionine – 0.6%, the low-dissolved fraction of protein – 40 -50% of its total amount. This ensures an increase in milk productivity of cows by 9.9% and a reduction in live weight losses during the calving period by 31.6%.

Studies conducted at Oregon State University and in Israel showed that cows fed excess protein (more than 10-15% above requirement) required more inseminations to inseminate and had longer calving intervals. Other studies have shown no harmful effects of high-protein feeding. Thus, excess protein may be harmful in some situations but not others. Some of the following effects have been shown to account for the poor reproduction sometimes seen with excessive protein in the diet:

- High blood urea level can be toxic to sperm, eggs, and the developing embryo.
- Hormone balance can be altered - progesterone level is low when blood urea level is increased.
- In early lactating cows, high protein levels can exacerbate negative energy balance and delay recovery of normal ovarian function (Bindari et al., 2013).

At the same time, according to Chapa et al. (2001), protein supplements did not affect the reproduction of cows in the postpartum group.

Thus, both protein deficiency in the diet and its excess amount negatively affect the reproductive function of ruminants. The problem is incredibly complicated when a high rate of protein is used, which is easily broken down in the rumen liquid or against the background of diets deficient in energy. Under such conditions, an excessive amount of ammonia can be formed in the rumen, which is not converted into microbial protein. All this leads to stress on the metabolism and, as a result, violations of the reproductive function of animals.

Carbohydrates

Carbohydrates make up 70-80% of the dry matter of plant feed and are the primary source of energy for animals and the microflora of their gastrointestinal tract. Forages from green plants are dominated by structural carbohydrates – poorly hydrolyzable fiber, cellulose, hemicelluloses, and pectins. It is known that a lack of fiber in the diets of ruminants causes digestive disorders, and its excess suppresses the processes of digestion of organic matter. Therefore, fiber's concentration and structural composition in fodder largely determine its energy value (Gnojevyj, 2006).

Carbohydrates in cows' bodies and heifers are part of the intercellular substance and determine the amount and nature of estrous mucus. An insufficient amount of estrous mucus is accompanied by inferior (anestrous) sexual cycles. At the same time, after fertilization, the sperm of the wild boar cannot move to the place of fertilization (in the upper third of the oviduct), and the animals remain unfertilized, that is, infertile.

The diet often lacks easily digestible carbohydrates – sugar and starch (Reynolds, 2005; Rodney et al., 2018; Useni et al., 2018; Francesio et al., 2020). Feeding high-starch diets can be an effective strategy to improve economic variables related to reproduction in dairy cows. Specifically, feeding cows with standard body condition scores high-starch diets during the first 50 DIM improved performance and reproductive performance of dairy cows in early lactation (Sirjani et al., 2020, 2021). Dyck (2009) reported that cows fed a high starch diet tended to lose less body shape, have a shorter interval from calving to first ovulation, and have a higher frequency of double first ovulations.

At the same time, according to Dyck et al. (2011), the source and concentration of dietary starch had little effect on the performance or metabolic status of postpartum cows. The results of studies by McDougall et al. (2018) do not confirm a positive effect on reproduction from increased starch in the diet of cows bred seasonally on pasture. In the studies of Keskin et al. (2016), different starch levels had no effect on postpartum reproductive traits.

Glucose is necessary to synthesize milk lactose; a certain amount goes to forming glycerol and milk fat triglycerides in the mammary gland. In addition, it is necessary to form several essential amino acids, milk proteins synthesized in the mammary gland (Jernst et al., 1982). Glucose is the primary circulating form of carbohydrates. Its concentration must be maintained in the blood sufficiently to ensure the vital activity of the brain, adipose tissue, and mammary gland (Bergman, 1983). Glucose utilization increases significantly during pregnancy and lactation. Thus, after calving, the blood glucose content is low (Sheremeta & Gruntkovs'kyj, 2011). If, in the subsequent stage of labor, its concentration decreases from 48 mg% to 35.7 mg%, this leads to deterioration of the contractile function of the uterus (Demchuk, 1995). The time required to recover ovarian activity after calving depends on the glucose level in the cows' plasma (Merelles, 1990), related to its significant content in preovulatory follicles (Boryczko et al., 1995). In addition, in vitro, glucose increases egg fertilization (Arashima, 1995).

Low blood glucose concentrations after calving are associated with infertility in postpartum dairy cows, possibly because glucose is a master regulator of hormones and metabolites that control reproductive processes (Lucy et al., 2013).

Therefore, the glucose level in the blood corresponds to the intensity of metabolism and is regulated by several precise hormonal and nervous mechanisms. In females, the metabolic processes of glucose significantly affect the effectiveness of all stages of the reproductive function (Sheremeta & Gruntkovskyj, 2011). Understanding the homeoretic mechanisms that involve glucose and collectively influence postpartum uterine health, estrus cyclicity, and pregnancy establishment should facilitate the development of methods to improve postpartum fertility in dairy cows (Lucy et al., 2014).

The need for glucose is especially great during pregnancy and lactation (Miettinen, 1996). It has been established that about 60-70% of a dairy cow's glucose requirement is for milk production. During pregnancy, the developing fetus needs 30% to 50% of all the glucose in the mother's body.

The total glucose consumption per day is from 900 g to 1300 g, and 38.8 to 56.5% is spent on milk synthesis in cows with the milk productivity from 7 to 15 kg. The higher the productivity, the more glucose is spent on milk synthesis. In cows with a productivity of 25 kg to 36 kg of milk, glucose consumption was from 1730 g to 2296 g per day. Glucose consumption for milk synthesis was from 64.1 to 73.2%, for oxidation in tissues, including fruits – from 440 g to 643 g per day.

Inadequate provision of glucose precursors to cows leads to a decrease in its concentration in the blood and an increase in the content of ketones and free fatty acids, a prerequisite for ketosis in animals. Ketosis or acetonemia is usually accompanied by a lack of appetite in cows and most often occurs in the first six weeks after calving, with the peak of the disease around the third week. Animals suffering from this disease are characterized by increased excitability and loss of productivity; they have problems with fertilization, as a result of which the service period increases. Ketone bodies, in addition to the general toxic effect, reduce the level of non-specific resistance of the body.

Afanasev (1972) established that the sexual cycle is disturbed, and their fertility is reduced with the increased content of ketone bodies in the blood of animals. Out of the 401 cows he examined, the ketone bodies' content was average only in 98 (24.4%). In the remaining 303 (75.6%) infertile animals, this indicator was overestimated: 10.1-15.0 mg% in 109 (27.2%), 15.1 – 20.0 mg% in 72 (18%), 20.1 – 30.0 mg% in 101 (25.2%) and 30.1 – 50 mg% in 21 (5.2%). Out of 251 cows in which the content of ketone bodies in the blood exceeded 12 mg%, only 107 (43%) were fertilized, and 144 (57%) were culled from the group.

One of the most important indicators of the diet that ensure the assimilation of nutrients is the sugar-protein ratio (Gnojevyj, 2013; Mischenko et al., 2021). According to Kurilov et al. (1973), the optimal sugar-protein ratio of the ration of a cow with a milk yield of 23-30 liters is 1.2-1.3 for a ratio of starch to sugar of 1.5-2.0. A rational combination of difficult-to-dissolve and easily-soluble carbohydrates and difficult-to-dissolve and easy-to-dissolve nitrogenous substances in the diet increases ruminants' productivity and ability to reproduce.

Thus, among carbohydrates, the most significant influence on the reproductive function of ruminant animals is the easily soluble ones - sugar and starch as a source of glucose entering the blood. The latter plays a significant role in the nutrition of the fetus and the prevention of ketonuria and other metabolic diseases. In dry cows, they help increase the output of calves and their better development in the first 12 months of life.

Lipids

Fats are classified as lipids, biological compounds that dissolve in organic solvents. Ruminant reproduction is closely related to energy availability, as hormone secretion depends on the energy status of animals (Wathes et al., 2007). Fatty acids are an essential energy source, so a sufficient amount (2-3%) of fatty acids can improve reproductive function in dairy animals (Ibtisham et al., 2018).

The effect of fat contents on cattle reproduction is the subject of many studies (Hemler & Lands, 1980; Elrod & Butler, 1993; Useni et al., 2018). Lipids perform several essential functions in the animals. There are reports that lipids take part in transmitting nerve impulses, carrying genetic information, binding enzymes to intracellular structures, and interacting with enzymes and substrates on membranes. Some lipid-dependent enzymes have been discovered. In addition, lipids retain several nitrogenous substances in the body and contribute to the absorption, transportation, and deposition of fat-soluble vitamins.

The content of unsaturated fatty acids in fruit tissues is almost the same as in newborn ruminants. This is due to the interrelationship of lipid metabolism between the mother's body and the developing fetus. The mother's blood is the only source of linoleic acid and its derivatives available to the fetus.

Because fatty acids and cholesterol are substrates for hormone synthesis, increasing dietary fat may increase levels of reproductive hormones (progesterone, prostaglandins), or fat may directly affect the reproductive axis (Ibtisham et al., 2018). Thus, the effect of fat may be independent or additive to the effect of increasing energy availability. Studies (Smith & Chase, 2010; Bindari et al., 2013) showed that high-fat diets for cyclic heifers and postpartum cows increased progesterone production and corpus luteum lifespan. Higher progesterone levels during the luteal phase usually lead to improved fertility. An increase in dietary fat also leads to an increase in follicle growth. Small and medium-sized follicles are present in cows, and heifers fed high-fat diets (Brown, 1990; Randel, 1990; Yaremcio & Kreplin, 2009). In addition, increased growth of follicles is often accompanied by increased estrogen and/or progesterone production. These changes in follicular growth and hormone production can enhance reproduction (Hemler & Lands, 1980; Brown, 1990; Bindari et al., 2013).

Violation of fat metabolism in the body of cows reduces egg production and fertility and increases the number of abortions and embryonic mortality (Glaz et al., 2011).

It was established (Noble & Shand, 1982) that of all the lipid fractions in the mother's blood plasma, only non-esterified fatty acids reach the fetus directly. Therefore, improving the status of unsaturated fatty acids in the calf's body immediately after birth is of practical importance, and the quality of colostrum and milk is decisive.

In the presence of high-molecular fatty acids in cows' diet in the amount of 54-62% of those secreted with milk, the duration of the service period was shortened, and the number of inseminations for fertilization decreased (Rivis, 1997).

Feeding fat to beef cows approximately 60 days before calving can improve body performance in the upcoming breeding season. Postpartum dietary supplementation with high-linoleic acid lipids can impair reproductive performance in beef cows (Hess et al., 2005). Instead, in the studies of Alexander et al. (2002), high-fat supplementation did not improve the body condition of heifers before and after parturition.

The above studies indicate the need to control the level and forms of fatty acids in cows' diets to improve their reproductive capacity. High reproductive capacity in cows can only be expected when addressing the issue of providing them with lipids up to the norm, including unsaturated fatty acids.

Conclusion

Normal functioning of the body, including the reproductive system, is possible only by obtaining nutrients from food - biologically significant elements necessary for maintaining life. Macronutrients serve as building material for cells (proteins), are converted into energy (carbohydrates), and perform the function of a depot for storing its reserves (fats). They play the role of direct participants in the most important biochemical processes, and their deficiency or excess leads to metabolic disorders, which, in turn, is a direct cause of infertility.

Among dietary influences, energy balance is the most essential factor associated with poor reproductive performance in animals. All physiological processes accompanied by chemical and biological reactions are related to the body's energy transformation, which, in turn, is the primary nutrient necessary for feeding, so insufficient energy intake harms its reproductive activity. In particular, an excess of energy can lead to ovarian disease and dysfunction, negatively impacting hormonal status. This, in turn, causes disruptions in sexual cycles, resulting in inferiority, a weak manifestation of estrus, and reduced desire. It also contributes to an increased frequency of insemination and a decrease in fertility. Other consequences may include abortions, difficult births, retention of the placenta, a prolonged interval from childbirth to the first estrus, the progression of uterine inflammation, subinvolution, and infertility. Energy deficiency causes a delay in puberty, formation of persistent corpora lutea, cysts of follicles, functional disorders of the ovaries, violation of the rhythm of the sexual cycle and the process of ovulation, an increase in the number of missed or «silent» («hidden») estrus, low fertility, increased death of egg cells and the frequency of embryonic mortality, reduced survival of embryos and abortions, anestrus in the postpartum period, increased frequency of ketosis, endometritis, mastitis, and postpartum paresis, increased intervals between calving and first ovulation, between calving and first estrus, calving, and fertilization.

The effect of protein on reproductive functions is an intricate and complex process, causing disorders both in excess and in deficiency. On one hand, these encompass changes in the hormonal balance and sexual cycle, deterioration of oocyte maturation and embryo development, disruption of intrauterine development of the fetus and the occurrence of abortions, increased frequency of gynecological diseases (appearance of follicular cysts), adverse effects during childbirth and litter retention, lengthening of the intercalary and service period, a negative effect on the course of the postpartum period, delaying the restoration of normal ovarian function, increasing the fertilization index, reducing postpartum fertility, giving birth to non-viable offspring, reducing the immunobiological properties of cow's colostrum, worsening the resistance of newborn calves. While, protein deficiency leads to alimentary infantilism in heifers, delay in their sexual and physiological maturity, decrease in the mass of the ovaries, pituitary gland, adrenal glands, and thyroid gland, decrease in their functional activity, impaired regulation of reproductive function, negative impact on the rhythm of sexual cycles and infertility, weak manifestation of estrus and desire, low fertility, resorption of embryos, reduced survival of embryos and abortions, premature births, prolongation of the process of involution of the uterus, reduced weight, viability and immunity of neonatal calves.

Violation of carbohydrate metabolism is associated with changes in the amount and nature of estrous mucus, sexual cyclical impairment, reduced fertilization, and fertility, impaired fetal nutrition, ketonuria, and other metabolic diseases, decreased output of calves, impaired development, the impaired contractile function of the uterus, restoration of ovarian activity after calving, the interval from calving to first ovulation and frequency of double first ovulations.

Disruption of fat metabolism results in a decrease in the level of reproductive hormones (progesterone, prostaglandins) and the growth of follicles and eggs, fertilization, an increase in the number of abortions, and embryonic mortality.

Therefore, the control of the intake of the necessary content of macronutrients - proteins, carbohydrates, and fats - contributes to proper metabolism and, consequently, the correct functioning of the reproductive function, and therefore a preventive measure of alimentary infertility.

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