Theoretical and Applied Veterinary Medicine

ISSN 2663-1156 (print)
ISSN 2663-1164 (online)
Theoretical and Applied Veterinary Medicine, 10(3), 33–44
doi: 10.32819/2022.10015

Review articles

Alimentary infertility in female cattle: I – prevalence, the relationship between feeding and reproductive ability (Overview)

P. M. Skliarov*, S. V. Naumenko, V. I. Koshevoy**, S. Y. Fedorenko**, D. D. Bilyi*, V. V. Vakulyk*, J. V. Kolesnyk*, J. M. Homych*, V. S. Fedorenko****
**Dnipro State Agrarian and Economic University, Dnipro, Ukraine*
***State Biotechnological University, Kharkiv, Ukraine*

Received: 12 October 2022
Revised: 26 October 2022
Accepted: 10 November 2022

Dnipro State Agrarian and Economic University, Sergii Efremov Str., 25, Dnipro, 49600, Ukraine

Tel.: +38-097-338-75-57
E-mail: *skliarov.p.m@dsau.dp.ua*

State Biotechnological University, Alchevskykh str., 44, Kharkiv, 61002, Ukraine

Tel.: +38-057-700-38-88
E-mail: *info@btu.kharkov.ua*

#**Corresponding author:**
P. M. Skliarov
skliarov.p.m@dsau.dp.ua

Abstract. Among the many causes of reproductive dysfunction in female cattle leading to infertility, feeding factors occupy an important place. Moreover, the state of nutrient deficiency nowadays determines the main etiologic factor of decreased reproductive ability of cows and heifers. Literature review shows that feeding cows and heifers is directly related to reproduction. It is shown that the causes of the alimentary form of infertility in female cattle can be various situations, unbalanced daily ration, deficiency or excess of one or more elements, and even type of feed. At the same time, nutritional factors can cause infertility in combination with others. The relationship between nutrition and reproductive performance offers significant potential for optimizing reproductive performance in cattle. By manipulating nutrient intake, livestock producers can strive to support reproductive performance. Therefore, uncovering and better understanding the complex interactions between feeding and various reproductive processes is important to address the increasing challenges associated with declining fertility in cattle. Numerous reviews indicate that feeding affects reproduction, but the precise mechanisms by which feeding mediates the reproductive process remain largely unclear. The main problem is that the degree of excess, deficiency, or imbalance required to alter reproduction is still unclear. The best recommendation is to establish a feeding program for dairy cows that is balanced in all nutrients and meets all known nutrient requirements. However, further research is needed on the role of feed substances in the manifestation of sexual function in cows and heifers. A complete understanding of how feeding affects reproduction may provide an alternative approach.

Keywords: cows; heifers; diet; disorders of reproductive function

Аліментарна неплідність самок великої рогатої худоби: I – поширення, зв'язок між годівлею і відтворною здатністю (літературний огляд)

Анотація. Серед багатьох причин порушення репродуктивної функції самок великої рогатої худоби, що призводять до неплідності, вагоме місце належить факторам годівлі. Більш того, аліментарно-дефіцитний стан на сьогодні визначається основним етіологічним фактором зниження відтворної здатності корів і телиць. З огляду літературних джерел випливає, що годівля корів та телиць безпосередньо пов'язана з відтворенням. Було показано, що причинами аліментарної форми неплідності самок великої рогатої худоби можуть бути різні ситуації в незбалансованості добового раціону, нестачі або надлишку якогось одного або кількох елементів, а то й виду корму. При цьому аліментарні фактори можуть бути як безпосередньою причиною неплідності, так і у поєднанні з іншими. Взаємозв'язок між наукою про годівлю та відтворною здатністю забезпечує значний потенціал для оптимізації репродуктивної ефективності великої рогатої худоби. Маніпулюючи споживанням поживних речовин, тваринники можуть прагнути підтримувати функцію відтворення. Тому важливо розгадати та краще зрозуміти складну взаємодію між годівлею та різними репродуктивними процесами, щоб вирішити дедалі серйозніші проблеми зниження плодючості великої рогатої худоби. Численні огляди однозначно продемонстрували, що годівля впливає на відтворення, але точні механізми, за допомогою яких годівля опосередковує репродуктивний процес, у більшості випадків залишаються не з'ясованими. Основна проблема полягає в тому, що ступінь надлишку, дефіциту або дисбалансу, який необхідний для зміни відтворення, досі неясний. Найкращою рекомендацією на даний момент є забезпечення програми годівлі для молочних корів, збалансованої за всіма поживними речовинами та відповідної всім відомим потреби в поживних речовинах. Однак необхідні подальші дослідження щодо ролі активних речовин корму у прояві статевої функції корів та телиць. Більш повне розуміння того, як годівля впливає на відтворення, може стати альтернативним підходом до управління репродукцією в комерційних системах, які не залежать від використання екзогенних гормонів.

Ключові слова: корови; телиці; раціон; порушення репродуктивної функції

Cite this article: Skliarov, P. M., Naumenko, S. V., Koshevoy, V. I., Fedorenko, S. Y., Bilyi, D. D., Vakulyk, V. V., Kolesnyk, J. V., Homych, J. M., & Fedorenko, V. S. (2022). Alimentary infertility in female cattle: I – prevalence, the relationship between feeding and reproductive ability (Overview). *Theoretical and Applied Veterinary Medicine*, 10(3), 33–44. doi: 10.32819/2022.10015

Introduction

Among the many reasons for impaired reproductive function in female cattle, which leads to infertility, an important role belongs to feeding factors. Moreover, the state of nutritional deficiency today is determined by the main etiological factor of a decrease in the reproductive capacity of cows and heifers (Mwaanga & Janowski, 2000; Koshovyj, 2004; Abraham, 2017; Mikhailova et al., 2021).

Reproduction of the herd in dairy cattle breeding is very complex, where technology and animal feeding factors come to the fore. Still, in most farms, they do not ensure compliance with the rules for compensating the energy and nutrients spent by animals on vital activities and the production of products, which negatively affects their functional state, causes disturbances in metabolism, neurohumoral regulation of the reproductive system, and disturbances in reproductive function in general (Carruthers, 1995; Koshovyj, 2004; Gnojevyj, 2006; Mikhailova et al., 2021).

The relationship between feeding and reproduction is becoming increasingly important to farmers, veterinarians, feed dealers, and animal nutrition experts. It is the most important factor affecting the financial viability of livestock enterprises. Feeding plays an essential role in the manifestation of sexual function in cows. It affects fertility and can occur at several stages of the reproductive cycle and in most cases affects the reproductive axis. Livestock breeders and researchers have long recognized the importance of proper animal nutrition for successful reproduction. Good reproductive performance positively affects the active life span of cows in the herd and plays a significant role in the economics of the dairy herd. Many scientists have studied the effect of feeding on fertility in cattle. Differences in feeding probably explain much of the variation in reproductive performance between herds and between animals within herds (Wiltbank et al., 1964; McDowell, 1972; Holness et al., 1978; Pradhan & Nakagoshi, 2008).

Alimentary infertility is one of the most common forms of impaired fertility caused by a decrease or increase in the energy level of diets (ratio of proteins, carbohydrates, fats, macro- and microelements), their improper composition, as well as the use of low-quality feeds (Voloskov, 1960; Kamenski & Sablik, 1991; Hramcov et al., 2007; Kalynovs'kyj, 2014; Skliarov et al., 2021).

The transition of animal breeding to intensive feeding to obtain high animal productivity requires not only maintaining a high level of metabolic processes in their organism but also preserving their health, which closely borders on reproduction (McClure, 1995; Gnoevy, 2006; Riznichuk, 2016; Wang et al., 2022). The whole experience of animal husbandry shows that the increase in livestock population is possible only with rational and expanded use of breeding stock, where factors that ensure the full nutrition of animals are of paramount importance. Therefore, it is possible to successfully overcome the difficulties with animal reproduction and ensure the prevention of infertility by applying the developed measures based on the identified causes (Gnojevyj, 2006; Evans and Zeng, 2017; Maruf, 2019).

Nevertheless, even though the influence of feeding factors on the reproductive function of female cattle has been studied quite fully and in detail, the recommended animal feeding norms for production are still empirical and insufficiently defined. Therefore, production should have information both on individual indicators and in the form of animal feeding systems, since difficulties in realizing the factors directly affecting their reproductive capacity are also associated with many conditions that, one way or another, are essential in solving this problem (Gnoevy, 2006; Pankov, 2008; Sharapa and Bojko, 2018; Sammad et al., 2022).

Thus, given that infertility of female cattle leads to the disruption of reproduction technology and management of the livestock industry as a whole, the analysis of alimentary factors, which are one of the most common causes of the reduced reproductive capacity of cows and heifers, is relevant.

Spread of alimentary infertility of cows and heifers

Infertility in female cattle has a significant prevalence and, according to various researchers, has considerable variability from farm to farm (Agarwal, 1978; Narasimha Rao & Kotayya, 1980; Parkinson et al., 2009; Kumar & Singh, 2018) (Table 1).

In a study by Mikkelsen et al. (1986), the percentage of infertility among cows and heifers was 10%, including: among heifers aged 18 to 24 months – 20.9%, first-calf heifers 30–36 months - 27.8%, cows aged 4 to 9 years – 3.2%, and nine years and older – 21.8%. In private farms, infertility averaged 25.4% of cows (Homych & Skljarov, 2021).

Alimentary factors can be the cause of infertility in combination with other reasons (Mee, 2008; Truhachev et al., 2008; Nelson, 2010; Rizos et al., 2010; Kalynovs'kyj & Zarembljuk, 2014; Bobrova & Zemlyankin, 2017; Muratbayev et al. al., 2018; Voronina & Barkova, 2021). Climatic, artificially acquired, alimentary, and symptomatic infertility are considered to be the most prevalent forms (Poljancev & Podbereznyj, 2004; Lapina & Shuvalova, 2007; Truhachev et al., 2011; Gavrilov, 2016; Shuvaeva, 2016). Alimentary, symptomatic, and artificially acquired forms of infertility are often registered in Ukraine (Zvereva & Homin, 1976; Gryshhuk, 2012; Jablons'kyj, 2014; Gryshhuk et al., 2015; Kalynovs'kyj et al., 2016; Revunets et al., 2020). According to other data, among all forms of infertility in cows, alimentary and symptomatic are the most common and interconnected, and in many cases, alimentary factors contribute to or even underlie the occurrence of symptomatic infertility (Niboyet, 1963; Griga, 2003; Gavrilenko, 2009; Vahitov et al., 2012; Hasanov & Bagmanov, 2013; Kalynovs'kyj et al., 2014; Bagmanov et al., 2015; Knjazeva et al., 2015; Fedorenko et al., 2016; Sharapa, 2017; Grigor'eva & Zaharovskij, 2018; Zhelavskij et al., 2018).

Gavrilenko (2009) established a certain pattern of manifestation of certain forms of infertility in cows of different ages:

- in cows of the first lactation, climatic (99.3%) and alimentary (93.5%) patterns are observed in winter; symptomatic (81.5%) and artificially acquired (75.3%) – during the year;
- in cows with 2–10 lactations climatic form of infertility is registered in winter (73.3%), exploitative – in all months of the year (100%), symptomatic – during the year (71.3%), artificially acquired (65.9%) and alimentary – during stable housing (50,8%);
- in cows with more than ten lactations, senile, exploitative, climatic, alimentary, and artificially acquired forms of infertility appear throughout the year (100%), while symptomatic infertility is not stable.

The following results were obtained in similar studies by Sverlova & Sverlova (2016):

- in cows of the first lactation, climatic (49.3%) and alimentary (33.5%) forms of infertility are observed in winter, symptomatic (51.5%) and artificially acquired (25.3%) – during the year;
- in cows of 2–10 lactations climatic form of infertility is registered in winter (33.3%), exploitative – in all months of the year (45.0%), symptomatic – during the year (61.3%), artificially acquired (35.4%) and alimentary – during stable housing (30.8%).

Today, nutritional infertility is one of the most common forms (Miettinen, 1996; Budancev, 2005; Ponomarev et al., 2007; Safonov, 2008; Truhachev et al., 2008; Pinaeva et al., 2010; Bagmanov et al., 2011; Vojtenko et al., 2015; Dorohova & Bazhenova, 2016) and in most countries of the world is 20-25% (Sulaymonov et al., 2021), reaching 70% (Revunec' & Gryshhuk, 2016) and even 72–76% (Rozum et al., 2010). According to Manojlenko (2015), this form has significant variations in prevalence and covers 16-50% of infertile cows. As reported by Zhelavskij et al. (2018), alimentary infertility of cattle is directly related to the provision of the fodder base of farms. It accounts for 17–23% of the general etiostructure of reproductive diseases. According to other data, nutritional infertility is diagnosed annually in 25–30% of cows, which indicates a sufficient spread of this problem in dairy farming (Poljancev, 1986; Valjushkin & Kamoshenkov, 2005). In the conditions of private

Table 1 – Prevalence of infertility among female cattle

Spread, %	Source	Spread, %	Source
3.0	Pargaonkar & Bakshi, 1987	12.0	Kumar et al., 2006
4.2	Narladkar et al., 1994	13.5	Rozum et al., 2010
5.0	Francos, 1974; Ayalon, 1984	13.7–22.5	Fajzrahmanov, 2012
5.5–33.3	Namboothiripad & Raja, 1972	14.4–27.0	Khan & Luktuke, 1967
5.8–23.2	Vahitov et al., 2012	15.0	Cheremjakova & Nekrasov, 2008
6.8	Purohit, 2008	15.8	Sharma et al., 1991
7.0–17.0	Purohit, 2005	16.4–28.2	Bhosrekar, 1973
7.0–25.0	Sorur et al., 1982	16.6–58.8	Nuru & Dennis, 1976
7.3	Dhoble, 1996	17.0	Novikova et al., 2021
7.4–18.6	Singh et al., 1983	17.8	Dhoble, 1996
7.5–10.1	Gustafsson & Emanuelson, 2002	19.8	Kaikini et al., 1981
8.0	Pargaonkar & Bakshi, 1987	24.0	Bartlett et al., 1986
8.2–9.3	Pandey et al., 1982	25.1	Moss et al., 2002
8.33	Marai et al., 1992	25.9	Kaikini et al., 1983
8.98	Rao et al., 1976	26.5–27.1	Bajmisheva et al., 2017
9.4–23.2	Bagmanov et al., 2015	28.4	Selvaraj et al., 2003
9.77	Pandey et al., 1994	40.0	Kuz'mich, 2002; Hasanov & Bagmanov, 2013; Demchenko & Baban', 2020
10.0	Hewett, 1968; Thatcher et al., 1993; Peter, 1996	47.5	Sotnikova et al., 2014

farms of private property, alimentary infertility is also the most common, accounting for 29.8% of the total number of infertile cows (Homych & Skljarov, 2021). According to Hohrin (2004), in 30–60% of infertile cows, fertility impairment is caused by nutritional factors. The alimentary form was registered in 30.5% of infertile cows (Ishhuk, 2020). In private-sector farms, 34.5% of heifers of mating age were culled due to infertility and barrenness due to anaphrodisiac disease, exhaustion, and obesity, defects in feeding and maintenance (Udovichenko et al., 2018). Petrujkić et al. (2010) report that the etiology of herd infertility in 40–75% is dominated by poor and unbalanced feeding. Asoev & Bazhenova (2009), analyzing the data from obstetric and gynecological dispensaries, showed that the infertility of cows and heifers in more than 50% of cases is caused by feeding disorders. In Gorjuk's (2001) studies, the percentage of animals with alimentary infertility was 57.5–62.9%.

According to Ryslina et al. (2016), most often, disturbances of the reproductive function, in particular, disorders of the dynamics of the birth process (90–100% of cases), are registered in the winter-spring season, which is caused by the mass of calving and the imbalance of the diet during this period (Gavrilov, 2016).

The relationship between the feeding and reproductive capacity of animals

The course of the biological rhythm from fertilization and birth to the retirement of the animal from the production process is a determining factor affecting the organization of livestock reproduction (Ferguson, 1996; Goncharenko, 2003; Roche et al., 2011; Baimishev et al., 2018; Sharapa et al. al., 2021; Kumaresan & Srivastava, 2022). Biological rhythm is subject to a natural cycle, which, as a rule, is directly influenced by environmental conditions. First of all, it concerns feeding conditions of animals and negative changes which, especially lack of energy, protein, vitamins, and minerals, cause disturbances in the development and functioning of both reproductive organs and the whole organism. Therefore, feeding conditions are necessary for timely sexual maturation and the normal course of the whole biological rhythm of animal reproduction (Ferguson, 1991; Koshovyj, 2004; Pankov, 2008; Izquierdo et al., 2021; Antonov, 2022).

Feeding disorders lead to deep disturbances of all types of metabolism – proteins, carbohydrates, lipids, vitamins, macro- and microelements in the organism of maternal stock and, as a consequence, to dysfunction of the endocrine system, decrease in the activity of hormones and enzymes regulating the functions of reproductive organs (Linn, 1989; Houe et al., 2001; Boland & Lonergan, 2003; Samohin, 2003; Kilic et al., 2007).

Nutritional factors directly affect the sexual function of animals (Pankov, 2008; Smith & Chase, 2010; Bindari et al., 2013; Swecker, 2014; Cargile & Tracy, 2021; Sammad et al., 2022). In numerical works the authors are convincing, and it is recognized as an axiom in the negative influence of nutritional deficiency factors on the reproductive function of animals (Vizner, 1976; Balogh & Varda, 1980; Godovanyj, 1982; Arbeiter et al., 1983; Fankel, 1983; Valjushkin & Kamoshenkov, 2005; Skliarov et al., 2021).

Studer (1998) identified several relationships between feeding and fecundity:

- anestrus occurs in high-yielding lean cows with a body mass index decrease of 0.75-1.0;
- obese dry cows develop fatty liver dystrophy and associated postpartum diseases;
- heifers with good milk production but prolonged anestrus;
- dry cows with imbalanced diets develop milk fever, placenta retention, rennet displacement, metritis, or endometritis during the transition period;
- lactating cows with mid-lactation disease, especially limb problems, have reduced fertility;
- healthy lactating cows with low fertility have high blood or milk urea nitrogen concentrations.

Complete feeding of cows before conception and in the first

third of pregnancy ensured high fertility and the birth of strong and viable calves (Semenov et al., 1991). Excessive feeding of cows leads to obesity, difficult births, delayed litter, reduced viability of offspring, impaired function of the pituitary-adrenal system, increased period of uterine involution, and ovarian diseases (Plank, 1978; Petit, 1979; Fronk & Braund, 1980; Sommer, 1980; Kolb, 1981; Molchanov, 1981; Denisov, 1982; Lotthammer, 1991; Baranski et al., 2003). On the other hand, the absence, deficiency, or excess of one of the nutrients in the diet, even if the animal is fed satisfactorily, can cause infertility (Miettinen, 1996; Kalynovs'kyj, 2014; Ryslina et al., 2016; Udovichenko et al., 2018). In particular, undernutrition, unbalanced and inferior feeding during the dry period in calving females increases the probability of lengthening the processes of uterine involution (subinvolution), which creates conditions for extending the service period, delays the onset of sexual cycles after childbirth, reduces the ability to fertilize, and increases embryonic mortality (Il'inskij, 1983; Koshovyj, 2004; Amin, 2014). Unbalanced and inadequate feeding of heifers after weaning from their mothers leads to the underdevelopment of genital organs, atrophy, formation of follicular cysts, uterine atony, etc. (Goncharov & Karpov, 1981; Il'inskij et al., 1984).

Feeding unbalanced rations or a large amount of low-quality silage is the cause of impaired reproductive performance and the manifestation of pathologies during pregnancy, childbirth, and the postpartum period. At such feed consumption, the hormonal background is disturbed, which leads to the embryonic death of the fetus, as the production of substances that ensure the normal development of the zygote and embryos is disturbed (Il'inskij, 1983).

Unbalanced feeding of cows and heifers 60 days before calving negatively affects their metabolism, future milk production, reproductive capacity, and health indicators, as well as the resistance of newborn calves. Unbalanced feeding of females during the dry period lengthens the postpartum period and reduces the fertility of females by 14%. (Kuznecov & Kuznecov, 2003).

Deviation towards reduction of the share of energy, organic and inorganic substances (complete proteins, vitamins, macro- and microelements) leads, first of all, to impaired reproductive capacity of cows and heifers, as the reproduction function is a mirror of the organism's condition (Cheremnjakova & Nekrasov, 2008). These disorders vary in a wide range. They may be temporary or long-term and affect all components of the reproductive process without exception: morphological and functional state of the organs of the self-regulation system: hypothalamus–hypophysis–gonads–uterus; readiness and ability to develop oocytes from maturing follicles into physiologically determined follicles; ability and readiness for fertilization, which is possible with regular sexual cycles without violations of internal and external signs of their manifestation; absence of violations of embryo implantation in the mucosa of the uterus; functioning of the fetoplacental complex, fetal development, pregnancy, childbirth; the birth of full-grown offspring, which can quickly reach puberty after directed rearing; the course of the postnatal period; the timing and completeness of sexual desire after childbirth. (Koshovyj, 2004; Skliarov et al., 2021).

A low level of feeding or an imbalance of the daily ration in cows can lead to prolonged, difficult births (Dann et al., 2006; Bagmanov & Safiullov, 2007; Bahrami-Yekdangi et al., 2022), delayed litter (Alšić et al., 2008; Könyves et al., 2009; Kamel et al., 2022), subinvolutions of the uterus (Bagmanov & Safiullov, 2007; Stravsky et al., 2020; Skliarov & Zubkov, 2021), abortions (Kozlo & Legoshin, 1979; Filippov, 1994; Olson et al., 2021), endometritis (Skliarov & Zubkov, 2021; Taniguchi et al., 2021; Vallejo-Timaran et al., 2020), ovarian dysfunction (Vostroilova, 2007; Chen et al., 2015; Zubkov & Skliarov , 2020), mastitis development (Erskine, 1993; Libera et al., 2021; Brennecke et al., 2022), metabolic disorders (Carruthers, 1995; Samohin, 2003; Mikhailova et al., 2021; Sulaymanov et al., 2021), depression of sexual function and multiple repetitions of inferior sexual cycles (Sergienko, 1978; Eremina, 2009; Schoonover, 1981), decrease in the weight of the newborn and the cow itself (Mitin, 1981; Olson, 2021; Pivtorak & Mil, 2022), and delayed puberty in heifers born to such cows (Bonomi, 1979; Schoonover, 1981; Bomko et al., 2019).

The main causes of deficiency are related to seasonal losses of nutrients in feed and losses during storage (Frye et al., 1991). Undernutrition leads to loss of body weight and body condition, delays the onset of puberty, increases the postpartum time to fertilization, interferes with regular ovarian cycling through reduced gonadotropin secretion, and increases infertility (Capuco et al., 1990; Boland et al., 2001; Bindari et al., 2013).

During calving, many complications arise, which to one degree or another, are associated with an imbalance in the cow's nutrition (Table 2):

- fat cow syndrome: a condition caused by overfeeding of the cow during the dry period and late stage of lactation. This condition results in obesity in the cow, loss of appetite, and excessive body mobilization in early lactation;
- labor paresis: a condition caused by acute calcium deficiency. Calcium deficiency results from the release of large amounts of calcium from the mother's blood during or on the first day after calving. The condition is partly caused by excessive amounts of calcium or an imbalance of calcium and phosphorus in the animal's diet. If not treated promptly, this condition can lead to paralysis or death;
- displaced rennet: a condition in which the stomach is displaced to the left or right side relative to its normal state. The main cause of this problem is excessive concentration in the diet combined with increased abdominal volume after calving;
- ketosis: a metabolic disorder condition occurring in cows with insufficient or excessive energy reserves; the cow loses her appetite, resulting in reduced milk production (Zubkova et al., 2012).
- Lin et al. (1990) established a link between some metabolic and reproductive disorders.

Both types of disorders can occur independently of each other, but the occurrence of a metabolic disorder increases the chance of a reproductive disorder. For example, a cow with parturition paresis is twice as likely to have placenta accreta and almost nine times more likely to develop dystocia (calving difficulty) than animals that do not have parturition paresis (Linn et al., 1990).

Due to unbalanced feeding and improper cow housing, difficult births, litter retention, infertility in cows, and calf mortality,

Table 2 – Relationship between some metabolic and reproductive disorders (Zubkova et al., 2012)

Disorders related to reproduction	Disorders related to feeding			
	fat cow syndrome	milk fever	rennet displacement	ketosis
Dystocia	•	•		
Growth of the placenta	•	•		
Metritis	•	•	•	•
Deterioration of fertilization	•	•	•	•

especially in the spring period, were observed (Dobrynin, 1973; Varenikov et al., 2012; Seifi et al., 2007). Rodin et al. (1975) also noted subinvolution of the uterus and persistent corpus luteum in the ovaries.

Tievs (1962), Luckij et al. (1978), Houe et al. (2001), and Porfir'ev (2009) noted the particular susceptibility of high-yielding animals to errors in feeding and keeping, in particular, first-borns in the winter-spring period of keeping (Ryslina et al., 2016). The lack of nutrients in the diet is a chronic stressor of hormonal regulation. It leads to the slow depletion of the anterior pituitary system. This condition of the adrenal cortex can lead to the cessation of gonadotropin formation and, as a consequence, to functional disorders of the sexual cycle.

Vizner (1976), and Lobodin and Nezhdanov (2011) claimed that with an increase in the level of productivity, the metabolism increases, and this puts a heavy burden on the entire body, which in the case of a lack of significant excess of certain substances leads primarily to a disturbance of the reproductive function.

Pavlicek and Masljenovie (1980) observed that when cows were fed differently, their fecundity was 86.2 and 150.2 days and the insemination index was 1.76 and 3.36 respectively.

Sexual maturity of animals is more related to body size and weight than to age. According to some authors, under good feeding conditions, heifers reach such a state when their body weight is 2/3, and according to others, – half the weight of adult animals. Not only body weight but also fat content can be significant. It is shown that in conditions of average daily weight gain of heifers at the age of 7–12 months at the level of 454 g, their fertility is high. However, this indicator does not improve when the average daily weight gain of heifers increases to 681 g. When the average daily weight gain decreases to 227 g, their sexual maturity is significantly delayed (Gnojevyj, 2006).

Beef breed animals with high average daily weight gain usually have high fertility and a well-developed pelvis at the time of calving, which favors delivery without complications. In the future, they will be characterized by a high reproductive capacity (Fleck et al., 1980).

Alimentary infertility can also occur with a monotonous diet, for example, if concentrates or corn silage predominate in the diet (Mikhailova et al., 2021; Vojtenko and Zajakina, 2021).

Regardless of methods of synchronizing heat in cattle, fertilization rates can vary depending on feeding conditions and fattening status, especially during the mating season (Poljancev, 1986). When the nutritive value of heifer diets was increased by 20 MJ/d during this period, body weight levels under appetite control conditions (progesterone and prostaglandin) increased by 50–60% compared to the normal diet. The negative effect of restricted feeding on the fertility of beef cows has been repeatedly reported in the UK (Gowan and Etches, 1979).

A satisfactory fertilization rate has been reported in dairy cows fed a complete diet. They were treated with prostaglandin on day 43 of lactation and then performed artificial insemination at 72 and 96 hours. The authors concluded that «feed stress» may be one of the reasons for the inability to control appetite in dairy cows (Donaldson et al., 1970).

Modern production measures to synchronize estrus in cows should undoubtedly be aimed at studying the effect of «feed» and other types of stress on the efficiency of the first artificial insemination. This will make it possible to determine such conditions of feeding and maintenance of cows, which will allow them to achieve the maximum level of fertility, both in natural reproduction and in control of appetite in cows (Gnojevyj, 2006).

The influence of feeding on maturity

In most cases reported in the literature and practice, diet and energy restriction delay the onset of puberty. Live weight is the main factor affecting puberty in animals. Thus, restricted feeding, which retards growth, leads to an increase in the age of maturity. Poor nutrition delays maturity reduces fertility, and increases pregnancy loss in heifers (Fleck et al., 1980). Wiltbank et al. (1966) point out the critical ratio of age to live weight that must be achieved before heifers become sexually mature. According to Topps (1977), cattle grazing semi-arid tropical pastures can obtain only 40–80% of their energy requirements from pasture. This limitation often results in delayed sexual maturity in heifers up to 9 months of age (Robinson, 1990). Insufficient protein intake, which is quite common in cattle grazing low protein (<8%) tropical and subtropical pastures, has been shown to result in delayed maturity. Oyedipe et al. (1982) reported a negative correlation between dietary protein levels and age of maturity. Generally, the onset of puberty occurs when the heifer reaches about 40–50% of adult animal weight (Youngquist and Threlfall, 2007).

The effect of feeding on pregnancy

Feeding has a more significant impact on normal fetal development and the course of pregnancy. Improper feeding can cause premature births, malformations, and weak calves due to a lack of protein, energy, vitamins, and minerals (Zubkova et al., 2012). Miscarriages often occur due to poor feeding, consumption of moldy feed, or cases where feed contains high amounts of estrogen (Kuznetsov & Kuznetsov, 2010).

If the embryo successfully implants in the uterus, its survival is linked to the mother's survival. A large amount of nutrients must be stored in the mother's body, which is used to cause a short-term nutritional imbalance. Unlike short-term imbalance, long-term imbalance is very difficult to detect and can interfere with normal fetal development (Zubkova et al., 2012).

Poor housing conditions and nutrient deficiencies during the last two months of pregnancy in female cattle prolong the period of uterine involution and the development of postpartum uterine subinvolution. Dietary reduction by 20% in heifers from the second to the sixth month of pregnancy resulted in a 27.5% decrease in total protein and its fractions in amniotic fluid. The level of calcium and phosphorus in the third month of pregnancy was lower by 31.3% (Kalashnik & Pavlenko, 2007).

The influence of feeding on postpartum fertility

The reproductive performance of the postpartum cow is related to feeding status (Van Niekerk, 1982). Postpartum weight loss due to inadequate feeding or high lactation requirements prolongs the period of postpartum anestrus. Feeding plays an essential role in initiating postpartum ovarian activity in all farm animals. If animals are poorly fed during this period, as is often the case in tropical pastoral systems, postpartum infertility, prolonged calving intervals or feeding anestrus are common (Smith & Somade, 1994).

Cows should be well-fed for 22–55 days before parturition and, if possible, for 90 days after parturition (Olivares et al., 1981). McClure (1968) found that cows with glucose concentrations less than 30 mg per 100 ml of blood usually return to normal. Thus, successful insemination requires cows to be on adequate or increased nutrition and gain weight during the calving season (Van Niekerk, 1982).

Effect of feeding on lactation

In the last 30 days of pregnancy, lactation begins with colostrum production and final fetal growth. By the 270th day of gestation, the uterus and fetus require more than 1600 kcal of energy per day (Bell et al., 1995). Severe anorexia or an imbalance in nutrient intake can predispose an animal to several metabolic diseases that constitute a complex of congenital diseases (Markusfeld, 1993). These diseases are not independent but may increase the risk of further problems. For example, Curtis et al (1983) reported that cows with hypocalcemia have an increased risk of developing dystocia, fetal retention, and ketosis. Dystocia and retention of fetal membranes are

predisposing factors for postpartum uterine diseases. Disturbance of intake and energy metabolism may lead to increased levels of circulating ketone bodies. Miettinen (1990) reported that cows with higher concentrations of circulating ketone bodies had more days to conception, lower insemination index, and fewer days of infertility. Cows with serum beta-hydroxybutyrate concentrations of 1100 µmol/L at the first and second weeks of lactation had an increased risk of insemination failure (Walsh et al., 2004). Eliminating genetic differences in milk yields using parental averages resulted in a trend toward higher milk yields in heifers fed an intensive diet (Rincker et al., 2011).

Feeding cattle in the tropics is usually dependent on natural pastures and crop by-products. The crude protein content of forages is often less than 7.5 %, which reduces rumen efficiency and true digestibility. As a result, lactating cows cannot meet their nutrient requirements and lose weight and condition during lactation. This prolongs the anestrus period of lactation and cows tend to calve a year later (Ward et al., 1971). The percentage change in body weight of cows during the first two weeks after calving is inversely proportional to the number of days to first ovulation (Butler et al., 1981).

Jernst et al. (1970) noted that, with poor feeding and care, cows often produce the best milk not at the beginning of lactation but in the middle and even at the end.

Conclusion

A review of the available literature shows that the nutrition of cows and heifers is directly related to their reproduction. It has been shown that the cause of the alimentary form of infertility in female cattle can be various imbalances of daily ration, deficiency or excess of one or more elements, or even type of feed. At the same time, nutritional factors can cause infertility in combination with others.

The relationship between feeding and reproductive performance offers significant potential for optimizing reproductive performance in cattle. By manipulating nutrient intake, cattle producers can strive to maintain reproductive performance. Therefore, unraveling and better understanding the complex interactions between feeding and various reproductive processes is necessary to address the increasing challenges associated with declining fertility in cattle.

Numerous reviews indicate that feeding affects reproductive function, but the exact mechanisms by which feeding mediates the reproductive process remain largely unclear. The main problem is that the degree of excess, deficiency, or imbalance required to alter reproduction has not yet been elucidated. The best recommendation is to establish a feeding program for dairy cows that is balanced in all nutrients and meets all known nutrient requirements.

However, further research is needed on the role of feed substances in the manifestation of sexual function in cows and heifers. A full understanding of how feeding affects reproduction may provide an alternative approach to reproductive management in commercial systems that is not dependent on exogenous hormones.

Acknowledgment

The presented study is a part of research at the Department of Veterinary Surgery and Reproductology of the Dnipro State Agrarian and Economic University on the topic «Clinical correction of ecological destructions of anthropogenic origin in domestic animals of the Prydniprovsk industrial region» (state registration number 0115U002143) and the Department of Veterinary Surgery and Reproduction of the State Biotechnology University on the topic «Development and implementation of innovative methods and solutions using information and technical devices in veterinary reproduction» (state registration number 0114U005415).

The authors received no other external financial support for the research, authorship, or publication of this article.

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