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Physiological particularities of calves' organisms in early postnatal ontogenesis

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Abstract. This article presents a synthesis of the specialized literature regarding some aspects of the physiological state, growth, and development of calves in early postnatal ontogenesis. Calves have a distinct physiology, by comparison to adult cattle, adapted to their period of rapid development. Studying the physiology of calves during the early postnatal period is essential for ensuring their healthy growth and development, directly influencing long-term health and productivity. This critical period is marked by numerous physiological changes and adaptations, and understanding them is vital for implementing effective management and care strategies.
Keywords: calves, physiological peculiarities, postnatal ontogenesis.

Particularități fiziologice ale organismului vițeilor în ontogeneza postnatală timpurie

Rezumat. Acest articol prezintă o sinteză a literaturii de specialitate privind unele aspecte ale stării fiziologice, creșterii și dezvoltării vițeilor în ontogeneza postnatală timpurie. Viței au o fiziologie distinctă, comparativ cu bovinele adulte, adaptată la perioada lor de dezvoltare rapidă. Studiul fiziologiei vițeilor în perioada postnatală timpurie este esențial pentru asigurarea unei creșteri și dezvoltări sănătoase a acestora, influențând în mod direct sănătatea și productivitatea pe termen lung. Această perioadă critică este marcată de numeroase schimbări fiziologice și adaptări, iar înțelegerea lor este vitală pentru implementarea unor strategii eficiente de management și îngrijire.
Cuvinte-cheie: viței, particularități fiziologice, ontogeneza postnatală.

1. Introduction

Numerous experiments and world practice have shown that many problems that arise in the process of animal breeding cannot be solved without an in-depth study of the development of the organism at various developmental stages of postnatal ontogenesis. From the very beginning, from the amphimixis of the sperm with the egg, when the zygote is formed and until senescence, living organisms go through various stages and complex processes of ontogenesis [1, 2].

In each period of development, the organism is different from a physiological point of view. The early postnatal period is of great importance because, as the calves are born, they lose contact with the mother's organism, which leads to a complex restructuring of the physiological systems. The physiological systems of the calves' organisms during this period are characterized by their immaturity, thus, their organisms are sensitive to all the external conditions to which they are exposed [1, 3, 4].

The growth and development of the organism's functional systems in the first stages of postnatal ontogenesis occurs unevenly and is characterized by a pronounced heterochronism. In the process of evolutionary development, the calves' organisms have developed a series of protective and adaptive mechanisms to maintain homeostasis.

2. Nervous system

If we refer to the nervous system, in newborn calves it is an immaturity of the cerebral cortex, which performs a constant regulation of all physiological processes, ensuring the unity of the organism with the external environment. Therefore, many physiological processes during the neonatal period are carried out on the basis of unconditioned reflexes, for example, the sucking reflex, motor or protective reflexes. Conditioned reflexes are gradually formed throughout life and make it possible for the organism to adapt to changing environmental conditions.

3. Thermoregulation

Thermoregulation is a complex neuro-humoral process of maintaining a constant body temperature using physical and chemical processes. Newborn calves are characterized by imperfect thermoregulation due to poor development of the internal thermoregulatory system. This is due to the peculiarity of the central nervous system, as its regulatory effect on thermoregulation gradually increases. There is every reason to believe that the formation of thermoregulation in ontogeny consists in the maturation of the temperature information integration apparatus and the development of control signals to peripheral thermoregulation effectors.

4. Respiratory system

The respiratory system begins to function from the moment of birth. At birth, the first extrauterine respiratory movements occur, which are facilitated by the resulting significant negative pressure in the pleural cavity that favours the expansion of the lungs. Its function is regulated in the neonatal phase by the reticular formation of the brainstem, which has a significant regulatory effect on the functional state of the respiratory centre and other autonomic functions. Newborn calves have rapid and shallow breathing in the first hours after birth. Typically, the respiratory rate of a newborn calf is about 30-60 breaths per minute. This gradually normalizes as the calf adapts to the outside environment. During the first few days, the calves' lungs develop and expand to replace the amniotic fluid with air. During this period, it is important to ensure that the calf breathes properly and does not have respiratory problems.

5. Digestive system

Newborn calves do not have a fully developed digestive system to digest solid food. Their digestive system is adapted to process milk, which is their main source of nutrition. The stomach of calves is divided into four compartments: rumen, reticulum, omasum and abomasum. At birth, the rumen and reticulum are underdeveloped, while the abomasum is functional and essential for milk digestion [5].

Calves have well-developed swallowing reflexes that allow them to consume milk without inhaling. However, at first their reflexes can sometimes be immature and calves may require close supervision to prevent milk aspirating into the airways.

The digestive system of calves undergoes significant changes in the first months of life. In the early days, calves are dependent on milk for their nutrition. The stomach of calves is predominantly of "proventricular" type with a relatively well-developed abomasum. During this period, the stomach lining is adapted for the digestion of lactose and milk protein. As calves grow, the digestive system goes through a transition to a "ruminant" digestive system. The intestinal microflora begins to develop and the rumen begins to form, adapting to the diet based on solid fodder. This transition is essential for developing the ability to digest fibrous forages and maximizing nutritional efficiency.

As one of the characteristics of the gastrointestinal tract of newborn calves, it should be noted that it is devoid of microflora. During birth, passing through the narrow birth canals, the calf swallows different microflora, thus, the microflora of the mucous membrane of the genital tract enters its gastrointestinal tract. From the very first day the gastrointestinal tract of the calf is populated with lacto-bacteria, bifidu-bacteria, enterococci, E. coli, staphylococci and a small number of other bacteria. Being located in the intestines, they constantly compete with each other. This temporary instability of microflora composition is called the period of transient dysbiosis. During the colostrum period, the intestinal microbial landscape stabilizes, both quantitatively and qualitatively. The composition of the normal microflora of the intestines of healthy calves consists of an equal amount of lacto-bacteria, bifidu-bacteria and E. coli, which then gradually becomes unbalanced and the number of potentially pathogenic bacteria and the concentration of E. coli decreases and populates the posterior part of the the intestine. One of the most important functions of the normal microflora is that it, together with the host organism, provides resistance to colonization by foreign microorganisms [6].

Liquid calf feed constitutes the majority of the diet until the calf begins to consume sufficient solid feed. In order to assimilate the milk, the calf only uses the abomasum. This is made possible by means of the esophageal gullet, which is formed reflexively and through which the milk reaches directly from the esophagus into the abomasum. In the acidic environment, the milk coagulates, forming a lump of milk, which gradually breaks down in the intestines, so the calf can assimilate all the nutrients. As the calf begins to grow and receive solid food, the function of the stomach compartments also develops. The newborn calf, therefore, finds it difficult to break down solid food. He can chew food even after a few weeks of life, but only around the age of 6-8 months he does become a real ruminant and can "procure" his nutrients from roughage as well [7].

After birth, physiologically mature calves assume a confident standing posture. During this period, a high excitability of the alimentary centre is registered. This is expressed through exploratory food reactions and the manifestation of the sucking reflex. Endogenous stimulation of the alimentary centre in calves lasts about 3 hours and manifests itself in the form of movements in searching for mothers [8, 9, 10]. The calf begins to suckle within the first three hours after birth. In the case of a delay in feeding a newborn, the food centre loses its excitability. The amount of milk sucked is regulated by the capacity of the calf's stomach cavity. As soon as the milk fills the stomach cavity and expands it, the receptors are excited. The related impulses that appear in this case trigger the inhibition reflex of the alimentary centre, which is expressed by the cessation of sucking movements. Long and irregular intervals between feedings cause a strong excitation of the alimentary center. When the alimentary centre is strongly excited, the time of inhibition of the alimentary centre during feeding is prolonged, and overfeeding of newborn calves is recorded, which can lead to diarrhea [11].

The gastrointestinal tract of newborn calves has the following relative parameters: the capacity of the rumen – 730 ml, the capacity of the abomasum – 1250 ml, the length of the small intestine is 14.5-16 m, the length of the large one is 2.3-3 m. In the neonatal phase, in calves the capacity of the rumen and especially of the abomasum increases rapidly (Figure 1) [12].

Prestomach tissues in newborn calves are poorly differentiated. In the first weeks of postnatal life, there is an intensive growth and differentiation of the cellular elements of the mucous membrane. The functional system of the abomasum at birth reaches such a degree of maturity that it fully ensures the adaptation of calves to a new way of feeding. A

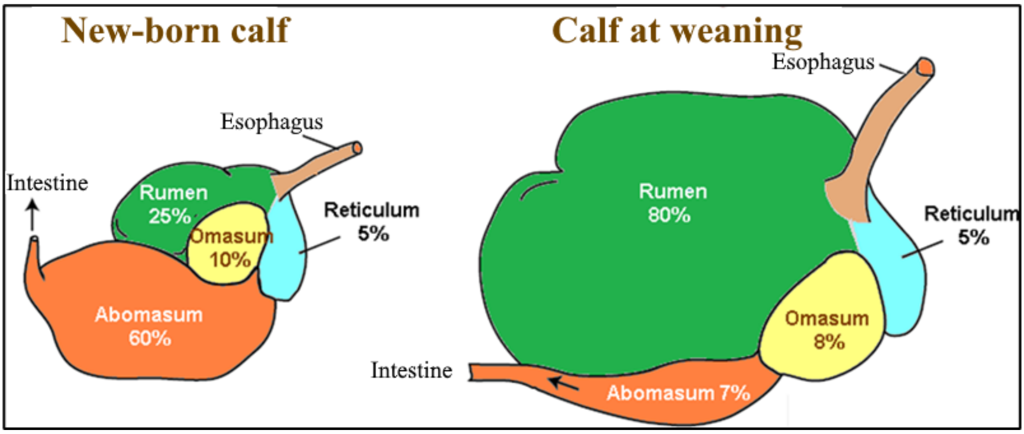

Figure 1. Stages in the development of prestomachs in calves.

high activity of oxidative enzymes is recorded in the parietal cells of the abomasum. The principal cells in the abomasum glands in newborn calves are still few and they secrete pepsin, renin and lipase. The predominant enzyme of the gastric juice in the neonatal phase is renin, which coagulates the milk. In general, clot secretion in newborn calves is poor. In the newborn period there is little pepsin and chymosin in the abomasum. In the first 2-4 days, free hydrochloric acid is formed in minimal amounts and this provides the necessary conditions for the assimilation of some components of maternal colostrum, which are extremely important for the organism of newborns in the first days of life. The increase in the amount of HCl in the content of the abomasum occurs from the end of the first month of life, after the gradual development of nervous tissue and the function of the glandular epithelium. During the absence of hydrochloric acid in the clot, the function of activating the conversion of pepsinogen into pepsin is performed by lactic acid, which is formed as a result of the breakdown of glycogen [13]. According to Coleen M. Jones [7], the acidity of the clot during this period depends on the acidity of the colostrum and the time elapsed after its administration.

Due to the fact that the development of digestive organs has not been completed yet, the digestive enzymes are initially adapted only for digesting the nutrients of colostrum and milk. The major importance at this time belongs to the parietal digestion. The reflex mechanism for regulating the functions of the abomasum has limited capabilities and, due to this, spontaneous secretion occurs. By the end of the neonatal phase, the secretory activity of the abomasum increases, the reflex and hormonal phases of the regulation of secretion from the abomasum begin to be clearly manifested.

In the intestine, due to the presence of lactic acid, secretin is formed by the mucous membrane of the anterior part, which in turn stimulates the secretion of pancreatic juice. Pancreatic juice contains trypsinogen, which is transformed into trypsin under the action of enteropeptidase. The trypsin of the intestine in newborn calves, as well as the pepsin of the stomach, predominantly performs the proteolysis of casein. The bile of newborns is poor in bile acids and does not significantly activate pancreatic juice enzymes. Intestinal glands secrete phosphatase, galactosidase and other enzymes of intestinal juice in small amounts. In newborn calves, the villi are well developed, while the glandular and muscular structures are less developed, with parietal digestion predominating. Albumin and globulins from colostrum, without being subjected to hydrolysis, reach the intestine and, unchanged, are absorbed through the intestinal wall into the blood [14,15]. This ensures the creation of a new internal environment in the newborn, thus, creating its own natural physiological immunity. Lysozyme also enters the calf's blood out of the colostrum. Gamma globulins and lysozyme are not formed in the neonatal phase. The timing of the first feeding and the observance of appropriate intervals between feedings are of great immunobiological importance for the newborn.

6. Immune System

The body protection function against various pathogens is implemented by special organs, tissues and cells, which are part of a system called immune system. Calves are born with an immature immune system that develops gradually in the first months of life. In the first period, the body immunity is supported by colostrum, which provides essential antibodies for the protection against diseases. The transfer of immunoglobulins through colostrum is crucial for the protection of calves until their own immune systems become functional.

The level of immunoglobulins in colostrum on the first day after birth is several times higher than in the mother's blood. In the first hours in newborns, the absorption of immunoglobulins is conditioned by a high permeability of the intestinal mucosa. The main types of immunoglobulins in colostrum are Ig A, G and M [14, 15]. The high immunoglobulin content in colostrum does not last long. In 6 hours, the average capacity of the intestinal walls to absorb immunoglobulins decreases by a third. By 24 hours, the walls absorb less than 10% of what could have been absorbed initially [7]. Thus, in one day, the number of immunoglobulins is reduced by 2 times and in two days by 4 times. The duration of colostral immunity is short, the half-life of IgM is 3-5 days, IgG – 10-25 days, IgA – 4-6 days [8, 16]. The immunity of a newborn calf is sufficient if the immunoglobulin content in the colostrum is at least 50 g/l and this corresponds to a density of 1.048 g/cm^3 [8, 17, 18,].

The immunoglobulins that are absorbed by the intestinal mucosa enter the lymphatic tract and from there into the blood, and serve to protect the organism from infections in the form of humoral antibodies. Since these antibodies were formed as a result of the mother's immune response, they are directed primarily against those microbes which the mother's organism came into contact with. Antibodies also have some opsonizing activity against other pathogens with a similar antigenic structure. Colostral antibodies are also involved in the local protection mechanism [11].

The supplying of colostral antibodies to newborns is determined by the immunoglobulin content in the colostrum, the amount of colostrum drunk and the permeability of the intestinal walls. Leukocytes are transmitted to newborns along with colostrum and increase in the blood of calves after the first feeding by 1.5-2 times. They pass into the mammary gland shortly before birth and can reach a concentration that is tens times higher than their level in blood. Colostral lymphocytes produce antibodies, mainly IgA, and perform an adaptive transfer of cellular immunity, especially delayed-type hypersensitivity [11].

The synthesis of immunoglobulins in calves begins with the formation of IgM, then IgA and IgG. M Class immunoglobulins can block the spread of the pathogen agent in the organism, but are ineffective against toxins. Therefore, young animals are very sensitive to poisoning and toxicoinfections [19].

In the neonatal period, it is necessary to emphasize that the barrier function of the liver in newborn calves is insufficient, the neutralization of toxic substances is weak, therefore, calves often have cases of intestinal intoxication and inflammation in the gastrointestinal tract. The excretory function of the liver in calves is at a low level. In the first days of life, the activity of the calf's liver depends on the amount of proteins in the blood, hematopoietin. During this period there is a lower capacity to bind and release bilirubin than in older calves. All this indicates that the liver during this period is functionally immature [20].

There are noted some features in the functioning of the immune system and non-specific resistance of calves in the neonatal and early postnatal period. Before the intake of colostrum, in the blood of calves it is a low content of total proteins, immunoglobulins, leukocytes, including lymphocytes, amino acids and other defense factors. After the first administration of colostrum, these indicators increase significantly during the first week. Then, a slight decrease in these parameters is recorded, particularly, in the period from the 14th day to the 21st one. During this period, the activity of the passive immunity, received from the mother-cows altogether with the colostrum, decreases, and the calves' own immunity is just forming. This period of life is characterized by a low content of own immunoglobulins, low phagocytic activity; mucous membranes and skin are easily accessible to pathogenic microflora. Thus, timely feeding with high-quality colostrum plays a crucial role in raising healthy offspring [21].

In the early postnatal period of ontogenesis, cellular factors of immunity predominate and they compensate for the deficiency of humoral factors, which are formed during the growth and development of calves in different periods. Thus, 80% of the lymphocytes in the lymph nodes, spleen and blood are T cells. At the same time, there is a deficiency of helper T cells and suppressor T cells, which affects the development of humoral immunity. The immune system in calves begins to stabilize at 1.5-2 months, and the final formation of cellular defense factors is completed by 6 months of age. A weak humoral response during this period is associated, on the one hand, with the presence of maternal antibodies which block incoming antigens, and, on the other hand, with an underdevelopment of B immune system, which is responsible for the synthesis of various classes of immunoglobulins. Later on, with age, the phagocytic activity of calves decreases slightly, while the activity of humoral factors increases significantly.

The implementation of the immune response is achieved through the interaction of cellular and humoral immunity connection laws. The cellular connection is represented by the functioning of T cells, while the humoral one is represented by B cells and the formation of antibodies. The place to form T and B lymphocytes is the bone marrow, from which these types of cells migrate to the thymus, lymph nodes and spleen [19].

Serum bactericidal activity is a complex indicator due to the combined action of immunoglobulins, complement, muramidase, beta-lysine, that is, the sum of the action of all antimicrobial factors. Lysozyme acts on gram-positive bacteria, while complement lyses gram-negative bacteria and many protozoa. An important role in implementing the bactericidal activity of blood is attributed to the immune cells, such as T and B lymphocytes, macrophages and neutrophils. T cells, through secreted factors, regulate the activity of macrophages that synthesize lysozyme [22].

It is believed that the reduced resistance in calves in early ontogeny is associated with a special biochemical state of body cells. The presence of age-related characteristics of non-specific resistance was confirmed as early as 1979 by Plyashchenko and Sidorov [23], who observed an increase in the level of phagocytosis in calves up to five days old, then, starting at ten days old, a sharp decrease was observed. At the same time, the formation of bactericidal activity of blood serum continued gradually. Therefore, by ten days of age in calves, the high level of phagocytic activity compensates for the low level of bactericidal activity. In the next 2-3 weeks of life, there is a rapid increase in humoral factors, which reach a relative stability at the age of 6 months, and the final formation at the age of 11-12 months [10, 11].

7. Conclusions

Calves go through a series of significant physiological changes in the postnatal period, starting with the adaptation of the digestive and respiratory systems up to the development of the immune system and the ability to regulate their body temperature. Understanding these physiological aspects in the breeding, maintenance and operation of animals is essential for optimizing the calf's growth and welfare. Careful monitoring of the physiological characteristics of the organism during the critical periods of ontogenesis contributes to ensuring a healthy transition from the early postnatal period – a period in which important physiological processes change rapidly and in which the foundations are laid for the future productivity of the organism in adulthood.

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