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REVIEW ARTICLE

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SCIENTIFIC AND PRACTICAL ASPECTS OF THE USE OF PRO-, PRE- AND SYNBIOTICS IN THE FEEDING OF RUMINANTS AGAINTS THE BACKGROUND OF RESEARCH CONDUCTED IN UKRAINE

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ABSTRACT

The review article provides up-to-date scientific information on the characteristics, classification and mechanisms of biological action of pro-, pre- and synbiotics in the digestive tract of ruminants. The literature sources of recent years on the influence of pro-, pre- and synbiotic supplements (when adding them to the diets of ruminants) on the metabolic processes in the body, intensity of growth, development and the quality of products obtained from domestic ruminant animals are systematized and analyzed. Emphasis is placed on the fact that the degree of metabolic and productive action of these diet supplements in ruminants is determined primarily by the qualitative composition, technology of production, method of storage and quantity added to fodder. It is noted that the main mechanism of pro-, pre- and synbiotics action when entering the digestive tract of ruminant animals is optimizing the composition of its microflora, strengthening the barrier functions of the rumen, reticulum, omasum, abomasum and intestine, as well as activation of interferon synthesis by blood leukocytes, stimulation of digestive functions and strengthening immune status. Also it is stated that the use of these fodder additives in the diet optimizes the quantitative and qualitative composition of the symbiotic microbiota of the digestive tract, has an immunostimulatory effect, activates metabolic processes and improves the productive qualities of ruminants.

Key words: ruminants, probiotics, prebiotics, synbiotics, classification, mechanism of biological action, productivity

INTRODUCTION

Probiotics are living strains of microorganisms that, entering the digestive tract of animals, optimize the quantitative and qualitative composition of microbiota and have a stimulating effect on its metabolic activity [Caramia 2004, Chaucheyras-Durand and Durand 2010, Bondarenko 2010, Dekker and Ukraintsev 2012, Uyeno et al. 2015, Markowiak and Śliżewska 2018, Vovk et al. 2021]. Translated from Latin, the term ‘probiotic’ means: *pro* – ‘for’, *bios* – ‘life’.

Prebiotics are indigestible components of various species of microorganisms and a number of plants that selectively stimulate the microflora in different parts of the digestive tract of animals [Lomax and Calder 2009, Kravchenko et al. 2014, Malkoch et al. 2014, Tarasenko and Filippova 2014, Uyeno et al. 2015, Sethy et al. 2017, Singh et al. 2017, Markowiak and Śliżewska 2018]. Unlike probiotics, prebiotics have a stimulating effect on the metabolic activity of the microbiota present in the digestive tract, promoting its active growth and development. One of the important advantages of prebiotics is that they are resistant to gastric acidity, absorption and hydrolysis by enzymes of the gastrointestinal tract of ruminants [Uyeno et al. 2015, Sethy et al. 2017].

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Synbiotics are complex preparations that contain rational combinations of pro- and prebiotics [Hamasalim 2016, Markowiak and Śliżewska 2018, Radzikowski et al. 2020]. Once in the digestive tract, synbiotics have a synergistic effect on optimizing the microbiocenosis of the rumen, reticulum, omasum, abomasum and colon, activate its metabolic activity, improve the substrate provision of energetic and synthetic processes of organs and tissues, which is expressed in increased productivity of ruminants [Markowiak and Śliżewska 2018, Radzikowski et al. 2020].

Characteristics, classification and mechanism of biological action of probiotics

The most commonly used microorganisms used as probiotics in animal husbandry are: lactic acid streptococci, yeasts, bifidobacteria, non-pathogenic *Escherichia coli* strains, bacilli, enterococci and lactobacilli [Vovk et al. 2021]. Probiotic preparations are divided into separate groups according to the physical state and technology of their manufacture [Krysenko et al. 2010]. By physical state, probiotics are divided into dry and liquid. Dry probiotic preparations include: tablets, powders, granules and dried cultures of microorganisms. Liquid probiotics include preparations in the form of solutions and suspensions in which microorganisms have not been lyophilized.

According to the manufacturing technology, probiotics are divided into preparations: based on live non-pathogenic microorganisms; based on metabolites or components of non-pathogenic microflora; based on compounds of microbial and other origin, stimulating metabolic activity of bifidobacteria and lactobacilli in the digestive tract of animals/ruminants; based on structural components and metabolites of microorganisms in various combinations that stimulate the activity of non-pathogenic microbiota of the animal digestive tract; based on strains of microorganisms and their structural components and metabolites with specified characteristics; based on components of plant and animal origin able for stimulating vital activity of animal useful microbiota in digestive tract; based on genetic engineering technologies [Vovk et al. 2021].

The mechanism of probiotics' biological action in ruminants has only been partially elucidated, but recent research has shown that it is complex and multifaceted. It is established that the metabolic effect of probiotics in the digestive tract of ruminants largely depends on the quantitative and qualitative composition of microorganisms and technology of probiotic preparations [Bondarenko 2010, Polishchuk and Bulavkina 2010, Mazurenko 2011, Reshetnichenko et al. 2012, Kyldiyarova 2016]. It has been experimentally proven that the use of probiotics in the diet of ruminants enhances the barrier functions of intestinal mucosal cells by activating the processes of cytoskeletons' phosphorylation of their protein structures and stimulates secretion of mucus and chlorides [Caramia 2004, Krysenko et al. 2010].

Probiotics have a wide range of antagonistic activity against pathogenic and conditionally pathogenic microorganisms in the digestive tract of animals [Bondarenko 2010]. They have a positive effect on the metabolism of animals, which is the ability of probiotics to reduce the permeability of tissue barriers to toxins. Probiotics also have a detoxifying effect on compounds formed in the host under the influence of pathogens [Charalampopoulos and Rastall 2009, Kolisnik et al. 2010, Kotsumbas et al. 2013, Kordon 2014]. Probiotic preparations, in contrast to antibiotics, which inhibit immune functions in the body, stimulate the synthesis of antibodies against pathogens [Mazurenko 2011].

Producing biologically active substances, probiotics stimulate the symbiotic microbiota of the rumen, reticulum, omasum, abomasum and colon to synthesis of mediators that activate the functioning of digestive processes, liver, cardiovascular and circulatory systems and thus have a positive effect on metabolic processes in ruminants [Mazurenko 2011]. Scientific studies have shown that metabolites produced by probiotics have anti-allergic effects by inhibiting histidine decarboxylation processes and activating histidine synthesis in animal organs and tissues [Dekker and Ukraintsev 2012]. It has also been confirmed that the introduction of probiotic preparations based on bifidobacteria and lactobacilli in animal diets activates interferon synthesis by leukocytes, strengthens cellular and humoral immunity, immune status and non-specific resistance [Shevyakov and Sobolev 2013, Ashraf and Shah 2014].

Probiotic preparations based on aerobic spore-forming bacteria stimulate lymphocyte activity in animals at the level of phytohemagglutinin and coenzyme-A, increase the activity of secretory immunoglobulins, macrophages and natural killer cells [Icy 2011]. An important mechanism of probiotics' action when they enter the digestive tract of ruminants is the regulatory effect on the synthesis of immunoregulatory cytokines, especially interferons, which perform an important physiological function in maintaining homeostasis in animals because they have pronounced antiviral, antibacterial, immunomodulatory, anti-inflammatory and antiproliferative activity [Vovk et al. 2021].

Characteristics, classification and mechanism of biological action of prebiotics

The most common prebiotics used as bioadditives in the diet of ruminants today are: mannan oligosaccharides, fructooligosaccharides, galactooligosaccharides, lactulose, lactiol, β-glucans, inulin [Vovk and Polovyi 2020].

Mannan oligosaccharides are short-chain low-molecular-weight carbohydrate fragments of the cell wall of the yeast *Saccharomyces cerevisiae*. Mannans make up approximately 30% of the cell wall mass and are contained on its outer membranes [Egorov and Mokrinskaya 2010, Singh et al. 2017]. They consist of many α-1,2, and α-1,3 N-linked glycan side chains attached to the α-1,6-linked mannose monomer. To obtain mannan oligosaccharides, yeast cells are lysed and the resulting culture is centrifuged to isolate components of the cell wall. The components of the cell wall are washed and dried by spraying [Singh et al. 2017].

Features of biological action of different classes of prebiotics in the digestive tract of ruminants

One of the main functions of mannan oligosaccharides is their competitive binding to gram-negative bacteria. The latter easily bind to D-mannose receptors of oligosaccharides on the epithelium of the gastrointestinal tract, and later such a complex is separated from the mucous membrane and leaves the digestive tract, significantly reducing the presence of pathogenic microflora [Singh et al. 2017]. Mannan oligosaccharides have a pronounced phagocytic and immunomodulatory effect in animals [Franklin et al. 2005].

Fructooligosaccharides are chemicals in the fructan class. They have low molecular weight and low polymerization level [Sethy et al. 2017]. Short-chain fructooligosaccharides are obtained by fermentation of sucrose. Sugar beets or sugar cane, which are rich in sucrose, are used as raw materials for its production [Egorov and Mokrinskaya 2010]

Research by Czaczyk and Wojciechowska [2003] has shown that fructooligosaccharides are indigestible in animals from the oral cavity to the intestine. It has been established that the enzymes of saliva, stomach and intestinal mucosa of animals are not able to hydrolyze β-(1,2) bonds of fructosyl fructose. Fructosyloligosaccharides have been shown to be readily available substrates for the rumen and colon microflora of ruminants.

Prebiotics based on galactooligosaccharides contain a wide range of sugars – from disaccharides to octasaccharides. The biological action of commercial galactooligosaccharides in the body of young animals is similar to the action of such compounds of breast milk in the digestive tract of children [Sharon and Ofek 2000]. Experimental studies have shown that galactooligosaccharides in the digestive tract of animals stimulate the growth and development of bifido-, lacto-, enterobacteria and streptococci [Seki et al. 2007].

Lactulose is a semi-synthetic disaccharide, which is mainly produced by lactobacilli or bifidobacteria. Lactulose consists of galactose and fructose. It is a prebiotic carbohydrate that stimulates the growth and development of useful microflora in the gastrointestinal tract and at the same time inhibits the growth of pathogenic bacteria such as *Salmonella* [Vovk and Polovyi 2020]. Lactulose is usually obtained from an alkaline solution of lactose by its chemical and enzymatic isomerization using β-galactosidases [Schuster-Wolff-Bühring et al. 2010].

The prebiotic lactiol is obtained from lactose by its hydrolysis. Feeding lactiol to young animals stimulates the activity of bifidobacteria and lactobacilli and reduces the number of bacterioids of *Clostridium* species in the digestive tract [Ouwehand and Vesterlund 2004].

Lactulose and lactiol have a positive effect on feed intake in young ruminants, changing the microbial balance and biochemical composition of the cecum contents. In vivo studies have shown that these prebiotics in the digestive tract of animals promote the reproduction of gram-positive bacteria, mainly belonging to the genera *Bifidobacterium* and *Lactobacillus*. Lactulose and lactiol activate the formation of short-chain fatty acids by the microbiota of the animal cecum, as well as increase the permeability of the intestinal mucosa and the solubility of minerals in the colon [Seki et al. 2007].

β-glucans are polymers of glucose in the cell wall of the yeast *Saccharomyces cerevisiae* and cereal grains such as barley and oats [Singh et al. 2017], consisting of β-1,3 and β-1,6 related D-glucopyranosyl units. They account 50 to 60% of the yeast cell wall mass. Unlike mannan oligosaccharides, β-glucans are contained in the inner part of the cell wall. They provide its structure and density [Sethy et al. 2017, Singh et al. 2017]. The biological action of β-glucans in the digestive tract of animals is determined by the degree of their branching, molecular weight and tertiary structure [Russo et al. 2012].

Experimental studies have shown that β-glucans, which have high molecular weight, enhance phagocytic, cytotoxic and antimicrobial activity, in particular macrophages [Brown and Gordon 2003]. They help produce reactive oxygen and nitrogen intermediates and clear tissues of apoptotic cells [Brown and Gordon 2003, Gantner et al. 2005]. In addition to stimulating innate immune responses, β-glucans increase the production of anti-inflammatory cytokines and chemokines and promote the access of leukocytes to sites of infectious lesions [Vetvicka and Yvin 2004]. The mechanism by which β-glucans stimulate immune responses belongs to the Dectin-1 receptor, which is expressed on monocytes, macrophages, neutrophils, dendritic cells, spleen T-cells and can recognize carbohydrates with β-1,3 and β-1,6 glucan bonds [Gantner et al. 2005, Sonck et al. 2009]. When β-glucans bind to Dectin-1, they become phosphorylated and thus induce phagocytosis [Brown and Gordon 2003].

Inulin is a plant fructoolysaccharide from the class of fructans, which contains 6–10% of sugars such as glucose, fructose and sucrose. Digestive enzymes in the stomach and intestines of animals are not able to break down the glucoside bonds of inulin. In plant cells, inulin performs energy and cryoprotective functions. Plants contain inulins with different lengths of the carbohydrate chain, for example: in wheat, onions, bananas there are short-chain inulins; in garlic and Jerusalem artichoke – medium chain; in artichoke and chicory – long-chain. Inulin in animals has a pronounced activating effect on the immune system directly or indirectly [Van Loo et al. 1995].

Indirect effects of inulin as a prebiotic are stimulating the growth and development of useful intestinal microflora, as well as inhibiting the proliferation of pathogenic microbiota, leading to an increase in useful bifidobacteria and reducing the population of pathogenic bacteria [Berg 1985]. The direct effect includes the stimulating effect of inulin on phagocytosis by phagocytic blood cells [Wójcik et al. 2007] and nonspecific mechanisms of humoral immunity [Milewski et al. 2007]. Inulin also activates the production of short-chain fatty acids in the multichambered stomach of ruminants and the large intestine of monogastric animals, acidifies the environment of the colon, promoting mucin production in intestinal-associated lymphoid tissues [Lomax and Calder 2009]. Inulin has been shown to intensify cytokine production by spleen cells and to stimulate the immune response to carcinogenic agents [Watzl et al. 2005].

Characteristics of synbiotics

Synbiotics are feed additives to animal diets that contain various combinations of pro- and prebiotics [Hamasalim 2016]. They have a synergistic effect on optimizing the qualitative and quantitative ratio of the microflora of the multichambered stomach and colon, neutralize pathogenic microbiota in these parts of the digestive tract, strengthen the immune defenses of ruminants [Hamasalim 2016, Markowiak and Śliżewska 2018, Radzikowski et al. 2020].

Currently, the diet of ruminants uses a wide range of synbiotic supplements with different combinations of pro- and prebiotics. The most commonly used synbiotic additives to the diet of ruminants are various combinations of *Bifidobacterium* and *Lactobacillus* [Markowiak and Śliżewska 2018].

Productive and metabolic action of pro-, pre- and synbiotics by the use of their supplements in the rations of ruminants

Probiotics

At birth, the gastrointestinal tract in ruminants is sterile concerning the presence of microbiota [Honcharuk 2010, Mazurenko 2011]. Colonization of the digestive tract by microorganisms begins in the large intestine in the first days after birth and lasts until approximately 12 weeks of age [Mazurenko 2011]. In young ruminants, probiotic supplements are mostly used for stabilization the colon microbiota and prevent diarrhea [Mazurenko 2011, Uyeno et al. 2015, Markowiak and Śliżewska 2018]. In the first weeks of life in the pancreas and colon of calves decreases the number of lactobacilli and bifidobacteria [Mazurenko 2011], so increasing their intake with diet reduces the possibility of pathogenic microorganisms adhesion to the intestinal mucosa [Chaucheyras-Durand and Durand 2010]. In particular, the use of probiotic supplements based on lactobacilli in the diets of calves during milk feeding period strengthens their immune defenses and the intensity of growth and development [Honcharuk 2010, Markowiak and Śliżewska 2018].

Probiotic supplement 'Probioactive' based on *Bacillus subtilis* bacteria, added to the diet of dairy calves, optimizes their hematological parameters, improves the digestibility of feed nutrients, stimulates their growth and development [Honcharuk 2010]. In ruminants during the period of active functioning of the multichambered stomach, probiotic supplements are used mainly to stimulate the absorption of fiber by the cicatricial microbiota and for this purpose are introduced into the diet mainly preparations based on yeast *Saccharomyces cerevisiae* [Markowiak and Śliżewska 2018, Vovk et al. 2021]. Such additives to animal diets stabilize the acidity of the cicatricial environment, which allows symbiotic protozoa to actively break down fiber and reduce lactate and methane production by bacteria [Nocek and Kautz 2006, Desnoyers et al. 2009, Robinson and Erasmus 2009]. Scientific studies have shown that the use of these yeast probiotic supplements in feeding cows stimulates ruminal fermentation, significantly increases fiber absorption and milk productivity [Chung et al. 2011, Uyeno et al. 2015, Vovk et al. 2021].

The introduction of probiotic supplements containing yeast *Saccharomyces cerevisiae* in the diets of fattening cattle increases the efficiency of feed nutrient uptake, increases the average daily gain and live weight before slaughter [Uyeno et al. 2015]. The use of probiotics in the diets of cows based on the culture of the fungus *Aspergillus oryzae* increases the milk productivity of animals, content of protein and dry matter in milk [Markowiak and Śliżewska 2018]. In the feeding of adult ruminants in order to prevent acidosis when consuming high amounts of concentrated feed, probiotic supplements are also often used in the diet, which include lactate-producing bacteria *Enterococcus* and *Lactobacillus* [Nocek and Kautz 2006, Uyeno et al. 2015].

Studies on pregnant and lactating ewes have shown that the introduction of probiotic supplements containing bacteria of *Bacillus liheniformis* and *subtilis* strains significantly increases protein and fat content in milk, increases body weight of newborn lambs and their viability [Brossard et al. 2006, Kritas et al. 2006].

Probiotic supplements are beneficial for animal health and rumen function. In study Adjei-Fremah et al. [2016] the transcriptional profile in whole blood collected from probiotics-treated cows was investigated in response to stimulation with lipopoly-saccharides (LPS) *in vitro*. Treatment with LPS resulted in increased expression of TLR4 and transcription factor NFkB. The regulation of the genes involved in inflammation signaling pathway suggests that probiotics may stimulate the innate immune response of animal against parasitic and bacterial infections.

Numerous studies revealed that probiotic supplementation in a ruminant diet improves the growth of beneficial rumen microbes, thus enhancing nutrient intake and digestibility, milk production, and reproductive and feed efficiency, along with immunomodulation. Furthermore, probiotic applications have proven to minimize adverse environmental consequences, including reduced methane emissions from ruminants' anaerobic fermentation. Mechanism of action of probiotics by which they exhibit beneficial effects is still not clear. Thus, more definitive research is needed to select the most effective strains of probiotics and their cost-benefit analysis [Kulkarni et al. 2022]. The most important publications on the effectiveness of selected probiotics in ruminant nutrition are presented in Table 1.

Prebiotics

It is known that the periods of birth and transition from dairy to plant feeding are especially important in the cultivation of young ruminants. Therefore, the effective use of prebiotic supplements in the diets of calves, lambs and goats can stimulate metabolic processes in their bodies, strengthen the immune system, reduce the incidence of infectious diseases, increase the growth and development intensity of animals [Karput and Babina 2008, Mukhina et al. 2008, Malkoch et al. 2014, Kravchenko et al. 2014, Uyeno et al. 2015, Sviatenko and Kucheriavy 2016, Sethy et al. 2017, Singh et al. 2017, Vovk and Polovyi 2020]. Studies have shown that the introduction of fructooligosaccharides in the diets of calves reduces the incidence and severity of clinical signs of intestinal infections by inhibiting the reproduction of pathogenic intestinal enterobacteria [Quigley et al. 2002]. It has also been shown that the addition of galactosyl lactose to milk substitutes has a stimulating effect on the growth and health of calves during feeding them with milk [Quigley et al. 1997].

The use of cellooligosaccharides supplement (containing glucose with β-1–4 bonds) in whole-milk feeding of Holstein calves promoted increase in number of butyric acid producing bacteria in the intestines of these animals [Louis and Flint 2009]. Studies by other authors have shown that the use of these oligosaccharides in whole milk significantly increased the average daily gain and efficiency of feed use in calves [Hasunuma et al. 2011]. According to researchers, this is due to increased fermentation in the rumen, as a result of which the level of short-chain fatty acids, including propionate, in the rumen fluid of calves receiving oligosaccharides was significantly higher than in calves not receiving such supplements [Hasunuma et al. 2011]. Studies in newborn calves have shown that the addition of β-glucans to drinking milk increases their rumen pH and digestibility of nutrients [Kim et al. 2011].

Mannan oligosaccharides added to calf formula increase body weight gain and feed intake [Ghosh and Mehla 2012]. The introduction of synthetic lactulose supplements to milk replacer increases the average daily weight gain of calves and improves the composition of the intestinal microflora, while stimulating the growth of probiotic bacteria [Fleige et al. 2007]. Additions of fructooligosaccharides to the diets of calves increase their productivity by improving the transformation of feed nutrients in the body, which contributes to weight gain [Grand et al. 2013]. Iunulin and lactose supplements in the diet inhibit the mRNA expression of pathogenic microorganisms in the digestive tract of calves, which significantly reduces the occurrence of inflammatory processes in the intestinal mucosa [Masanetz et al. 2011]. Mannan oligosaccharides and β-glucans, introduced into milk substitutes, have been shown to stimulate calves' immune systems and thus reduce the incidence and severity of enteric diseases [Quigley et al. 2002].

The use of lactulose as a milk substitute for calves has a stimulating effect on the quantitative composition of T-cells in the immune structures of the gastrointestinal tract and activates mRNA expression of anti-inflammatory cytokines. Studies of these authors have shown that in bulls that received lactulose in the diet, in the mucous membrane of the ileum significantly increased transcription of the IgA Fc-receptor [Fleige et al. 2007]. It is proved that the use of inulin and lactose supplements in feed formula for calves increases the level of hemoglobin in the blood, activates the expression of mRNA markers of small intestinal mucosa associated with inhibition of inflammatory processes and enhances mRNA expression of interleukin in mesenteric lymph nodes [Masanetz et al. 2011]. Feeding calves with mannan oligosaccharides in milk significantly increases levels of IgG in plasma [Lazarevic et al. 2010]. The use of hydrolyzed yeast *Saccharomyces cerevisiae* in the diet of calves increases the concentration of IgA and IgG in the blood [Kim et al. 2011].

Additions of prebiotics in the diets of adult animals are used to a much lesser extent than in young animals, and they are mainly used to stimulate the activity of symbiotic microorganisms in the rumen [Vovk and Polovyi 2020]. Prebiotics have a positive effect on ruminal diges-

Table 1. Role of selected probiotics in ruminant nutrition as modulators of production efficiency

Probiotics type	Ruminant	Performance effect	References
Saccharomyces cerevisiae	Crossbred cattle	Increased ADG and ruminal propionate concentration	Liu et al. [2021]
Saccharomyces cerevisiae and *Clostridium butyricum*	Macheng black × Boer crossbred goats	Improved DMI and ADG and improved digestibility of DM, NDF, and ADF; enhanced rumen fermentation; tended to alleviate adverse effects of heat stress	Cai et al. [2021]
Saccharomyces cerevisiae	Sohagi ewes and lambs	Improved milk yield, milk protein, fats, and solid non-fats; increased ADG in lambs	Elaref et al. [2020]
Saccharomyces cerevisiae	Qinchuan cattle	Promoted the growth of fibrolytic bacteria, increased digestibility of ADF and NDF, improved growth performance	Peng et al. [2020]
Lactobacillus plantarum, Saccharomyces cerevisiae, and *Megasphaera elsdenii*	Arabian lambs	Digestibility of DM and OM; improved ADG and feed efficiency in 0–21 days	Direkvandi et al. [2020a, b]
Saccharomyces cerevisiae, Bacillus subtilis, and *Enterococcus faecalis*	Saanen dairy goats	Increased feed intake and milk production; improved intestinal microecology	Ma et al. [2020]
ProbioSacc (*Saccharomyces cerevisiae*)	Holstein cows	Increased concentrations of milk fat, milk yield, and total solids	Nasiri et al. [2019]
PrimaLac (*Lactobacillus acidophilus, Lactobacillus casei, Bifidobacterium thermophilum*, and *Enterococcus faecium*)	Lactating Sanjabi ewes	Increased yields of milk, milk fat, protein, and lactose	Kafilzadeh et al. [2019]
Lactobacillus acidophilus	Surti buffalo calves	Tended to alleviate sub-acute ruminal acidosis symptoms	Arik et al. [2019]
Saccharomyces cerevisiae	Murrah buffaloes	Increased milk yield and milk fat content	Ahmad Para et al. [2019]
Lactobacillus acidophilus	Murrah buffalo calves	Improved DMI, ADG, and daily feed conversion efficiency; improved apparent digestibility of nutrients	Sharma et al. [2018]
Fastrack Microbial pack (*Lactobacillus acidophilus, Saccharomyces cerevisiae, Enterococcus faecium, Aspergillus oryzae*, active dry yeast culture)	Dairy cows	Improved immune response	Adjei-Fremah et al. [2018a]
Lactobacillus plantarum P-8 and *Lactobacillus casei*	Holstein dairy cows	Increased milk yield	Xu et al. [2017]
Saccharomyces cerevisiae (Original XP; Diamond V)	Holstein dairy cows	Increased milk yield; ameliorates heat stress and improves net energy balance	Zhu et al. [2016]
Saccharomyces cerevisiae	Cattle	Improves ruminal fermentation, DMI, and NDF digestibility	Elghandour et al. [2015]
Multispecies probiotic	Calves	Improved weight gain	Bayatkouhsar et al. [2013]
Saccharomyces cerevisiae	Dairy cows	Increased milk yield and quality, increased feed efficiency, reduced ruminal acidosis	Poppy et al. [2012]
Lactobacillus casei ssp. *casei*	Calves	Increased ADG; improved feed efficiency and plasma insulin concentration	Hasunuma et al. [2011]
Multistrain probiotic	Lactating cows	Increased milk production	Vibhute et al. [2011]
L. acidophilus, L. plantarum, L. acidophilus 27sc	Calves	Improved body weight gain; enhanced IgG response	Al-Saiady [2010]
Bacillus cereus, *Saccharomyces boulardii*	Sheep	Both probiotics enhanced humoral immunity	Roos et al. [2010]
Yeast culture	Holstein heifers	Increased milk fat and feed digestion, decreased ruminal pH	Lascano et al. [2009]
Prevotella bryantii	Dairy cows	Increased milk fat and feed digestion, decreased ruminal pH	Chiquette et al. [2008]

ADG average daily gain, *ADF* acid detergent fiber, *NDF* neutral detergent fiber, *OM* organic matter, *DMI* dry matter intake, *FCR* feed conversion ratio.

tion, especially cellulolysis and microbial protein synthesis. The most common prebiotics used in cattle diets are products derived from *Saccharomyces cerevisiae* yeast strains [Mukhina et al. 2008, Bezpalko 2012, Bezpalko 2013].

The mechanism of yeast prebiotics action has not been elucidated in detail. It has been proven that they activate the rate of enzymatic processes in the symbiotic ruminal microflora [Uyeno et al. 2015]. Prebiotic preparations derived from the yeast strains *Saccharomyces cerevisiae* are particularly effective in stabilizing the pH of the rumen and stimulating the metabolic activity of the protozoan population, which rapidly absorb starch and thus compete effectively with lactate-producing bacteria [Desnoyers et al. 2009, Robinson and Erasmus 2009, Bezpalko 2012, Bezpalko 2013, Uyeno et al. 2015]. Yeast prebiotics, getting into the rumen of ruminants, reduce the formation of methane gas during fermentation. These prebiotics stimulate the growth and development of rumenal microflora, which produces organic acids, oligosaccharides, B vitamins, amino acids and thus indirectly increase the cellulosolytic activity of bacteria [Uyeno et al. 2015].

The use of yeast prebiotic supplements in the diets of cows increases their milk productivity [Desnoyers et al. 2009, Bezpalko 2012, Bezpalko 2013]. The positive effect of yeast prebiotic supplements on cows' diets is activation of their rumen fermentation processes [Desnoyers et al. 2009, Robinson and Erasmus 2009, Vovk and Polovyi 2020]. Results Franklin et al. [2005] indicate that supplementation of mannan oligosaccharide to cows during the dry period enhanced their immune response to rotavirus and tended to enhance the subsequent transfer of rotavirus antibodies to calves. In fattening cattle, pH stabilization of the cicatricial content due to the use of yeast prebiotics increases the efficiency of feed nutrients' absorption, resulting in increased average daily gain and live weight of animals [Uyeno et al. 2015].

Synbiotics

The use of synbiotic (*cellooligosaccharide* + *dextran* + *Lactobacillus casci JCM1134*) in ration of female Holstein calves improved daily body weight gain, plasma insulin concentration and decreased fecal *Escherichia coli* counts [Hasunuma et al. 2011]. The use of synbiotic (freeze-dried *Lactobacillus casci* 1.0 · 10 CEU + 5% dextran + glucose polymer) in the amount of 10 g per cow per day increased resistance to mastitis, high air temperature and humidity, improved milk yield, decreased somatic cell count in milk [Yasuda et al. 2007].

Prebiotic inulin and its synbiotic with yeast *S. cerevisiae* positively impact the development of almost all morphological structures of rumen saccus dorsalis, rumen saccus ventralis, and intestine; moreover, calves from the synbiotic group showed better results in virtually all parameters. However, both inulin and synbiotic did not affect the weight and relative weight of different parts of the stomach. Tested synbiotic has the potential to promote the development of the rumen and other parts of the digestive canal of calves [Jonova et al. 2021]. Valencia et al. [2017] gave thirty Holstein calves presented with infectious diarrhea during the second week following birth, standardized product containing a combination of probiotics, ß-glucans, and glyconutrients (GLY) in support of antibiotic therapy during the early rearing phase (day 7 to day 45 following birth). In conclusion that daily provision of 5 g of a standardized product containing probiotics, ß-glucans, and glyconutrients to diarrheic calves under antibiotic therapy will promote health and enhance early growth performance.

Four cannulated Holstein steers were feeding a standardized mixture of synbiotic-glyconutrients (GLY), it is concluded that supplementation does not affect the site and extent of digestion of OM and NDF, but enhances net ruminal microbial synthesis, postruminal and total tract N digestion and increases ruminal pH and modifies rumen fermentation [Núñez-Benítez et al. 2021].

In another experiment [Castro-Pérez et al. 2021] 24 Pelibuey × Katahdin lambs (36.4 ±2.9 kg initial weight) were used to evaluate the influence of a standardized synbiotic-glyconutrient combination (GLY) on growth performance, dietary energetic, and carcass characteristics of lambs finished during a period of high ambient temperature. Supplemental GLY did not affect shoulder tissue composition or relative weight of visceral mass but improved growth performance, dietary energy, and carcass weight in lambs finished in high ambient temperatures.

CONCLUSIONS

Summing up the results of recent research, it should be emphasized that the use of pro, pre- and synbiotic supplements in the diet of ruminants activates metabolic processes in the symbiotic microflora of the multichambered stomach and colon, stimulates the intensity of microflora reproduction. These supplements help improve the absorption of nutrients, biologically active and mineral substances, improve the homeostasis of lipids and glucose in the body, stimulate the immune system in animals. Given the positive metabolic and productive effect of such supplements in the ruminants' diet, further research should focus on studying the molecular mechanisms of biological effects of these preparations in tissue structures, their interaction with genetic profiles of the digestive tract symbiotic microflora. Of significant scientific and practical interest is also research aimed at finding new classes of pro-, pre- and synbiotics, elucidation of physiological and biochemical mechanisms of their action on metabolism and productive qualities of animals depending on sex, age, physiological condition, nutritional factors.

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NAUKOWE I PRAKTYCZNE ASPEKTY WYKORZYSTANIA PRO-, PRE- I SYNBIOTYKÓW W ŻYWIENIU PRZEŻUWACZY NA TLE BADAŃ PROWADZONYCH NA UKRAINIE

STRESZCZENIE

Artykuł przeglądowy zawiera aktualne informacje naukowe dotyczące charakterystyk, klasyfikacji i mechanizmów biologicznego działania pro-, pre- i synbiotyków w przewodzie pokarmowym przeżuwaczy. Przeanalizowano i usystematyzowano dostępne źródła literaturowe ostatnich lat dotyczące wpływu suplementów pro-, pre- i synbiotycznych przy dodawaniu ich do diety udomowionych przeżuwaczy na procesy metaboliczne, intensywność wzrostu i rozwoju oraz jakość otrzymywanych produktów. Nacisk kładziony jest na fakt, że o stopniu metabolicznego i produkcyjnego działania tych suplementów u przeżuwaczy decyduje przede wszystkim skład jakościowy, technologia ich wytwarzania, sposób przechowywania oraz ilościowe wprowadzanie do diety. Należy zauważyć, że głównym mechanizmem działania pro-, pre- i synbiotyków przy dostaniu się do przewodu pokarmowego przeżuwaczy jest optymalizacja składu ich mikroflory, wzmocnienie funkcji barierowych wielokomorowego żołądka i jelit, aktywacja syntezy interferonu przez leukocyty krwi, pobudzenie funkcji trawiennych i wzmocnienie odporności organizmu. Podsumowując, podkreśla się, że stosowanie tych suplementów w diecie optymalizuje skład ilościowy i jakościowy symbiotycznej mikrobioty przewodu pokarmowego, działa immunostymulująco oraz aktywuje procesy metaboliczne i poprawia cechy produkcyjne przeżuwaczy.

Słowa kluczowe: przeżuwacze, probiotyki, prebiotyki, synbiotyki, klasyfikacja, mechanizm działania biologicznego, produktywność

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