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The Use of Probiotics in Animal Nutrition

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Abstract

This paper reviewed issues regarding the use of probiotics (feed additive) in animal feeding. Probiotics are increasingly used in commercial animal production operations to advantageously alter gastrointestinal flora, thereby improving animal health and productivity. The major outcomes from using probiotics include improvement in growth, reduction in mortality, and improvement in feed conversion efficiency. Although it is not well defined, the mechanisms of probiotics activity to achieve their role include alteration in intestinal flora, enhancement of growth of nonpathogenic bacteria, forming lactic acid and hydrogen peroxide, suppression of growth of intestinal pathogens, and enhancement of digestion and utilization of nutrients.

Different probiotics contain different microorganisms which may behave differently, as probiotics are not single entities. It has been indicated that multi-strain preparation is highly efficient in animal feeding. Finally, the efficacy of probiotics have been found to be variable depending on survival rate and stabilities of strains, doses, frequency of administration, interactions with some medicines, health and nutritional status of the animal and the effect of age, stress and genetics of animals.

Keywords: Feed additive; Probiotics

Introduction

In intensive production systems, the nutritional requirements of livestock can be met through supplementation of the limiting nutrients in concentrated form, so that they can produce large quantities of products rapidly. However, the use of feedstuffs that are rapidly fermented in the rumen can create conditions in the rumen that are suboptimal for the fibrolytic microorganisms, thereby impairing fiber digestion [1]. Moreover, nutritional quality of a feed is not only influenced by nutrient content but also by many other aspects such as, hygiene, content of anti-nutritional factors, digestibility, palatability and effect on intestinal health. Hence, the use of feed additives has been an important part of achieving this success [2].

Feed additives are materials that are used to enhance the effectiveness of nutrients and exert their effects in the gut or on the gut wall cells to the animal [3]. They are used for the purpose of promoting animal growth through their effect in increasing feed quality and palatability [2]. Besides, as they are mixed with feeds in non-therapeutic quantities and protecting the animal against all sorts of harmful environmental stresses. Low levels of additives in animal feed contribute to increase production of animal protein for human consumption thereby decrease the cost of animal products [4]. There are a number of feed additives that are used in animal feeds such as antibiotics, probiotics, oligosaccharides, enzymes and organic acids. The use of additives, make end products to be more homogenous and of better quality.

From the different additives, antibiotics have been widely used in livestock diets during the past several decades due to their therapeutic effects [5]. Antibiotics have been used to reduce the frequency of diarrhea under certain conditions and resulted in improvement in performance parameters like body weight gain (BWG) or feed conversion ratio (FCR). These beneficial effects of feed antibiotics are generally explained by modifications of the intestinal bacteria and their interaction with the host animal, including bacterial interactions with intestinal tissue as well as the immune system. Thus, the intestinal micro biota is not only involved in nutrient conversion along the gastrointestinal tract, but may also affect or support animal health [6].

Because of the concern that the use of antibiotics as feed additive might contribute to an increase of bacterial antibiotic resistance, the use of some types of antibiotics have been restricted by some countries beginning from 1970's. Further, European Union (EU) has introduc ed a total ban on the application of antibiotics as feed additives from 2006 onwards [5,7]. Consequently, the change in the consumer's demand for a safe food production coupled with the regulatory issues about the ban of antibiotic growth promoters have ensured a search for natural strategies to modulate gut development and health [6,8]. Hence, many activities were initiated to establish alternative strategies aimed to preventing the growth of pathogenic bacteria in farm animals, to maintain their health and performance. At the same time as making gains in production and efficiency, the industry has had to maximize the health and well-being of the animals and minimize the impact of the industry on the environment [2]. Accordingly, probiotics, prebiotics, organic acids, herbs and essential oils have been suggested as alternatives to antibiotics [6]. From the available alternative, there is presently an increased interest in using natural feed additives such as enzymes, bacterial direct-fed microbials and yeast to help maintain optimum ruminal digestion of feed [1].

Probiotics are live microbial feed supplements which beneficially affect the host by improving its intestinal microbial balance [9]. The application of probiotics provides a potential alternative strategy to the traditional practice of sub therapeutic antibiotic use. In relation to probiotics, several studies observed the beneficial effects on animals including growth enhancement and disease prevention [5]. However, there is still a need to clarify their effectiveness and the underlying mechanisms through which they function.

Feed additives may not be put on the market unless authorization has been given following a scientific evaluation demonstrating that the additive has no harmful effects, on human and animal health and on the environment. Authorizations are granted for specific animal species, specific conditions of use and for ten years periods. Any additives used in feed must be approved for use and then used as directed with respect to inclusion levels and duration of feeding [2]. Correspondingly, in feed regulation, probiotics are included in the group of feed additives for stabilising the microbial communities of the digestive tract in both monogastric and ruminant animals [9].

In this paper, some aspects of probiotics will be discussed. From the many issues, the historical backgrounds, the most common types, the effects exerted on animals and how they function will be highlighted.

Alternatives to Antibiotic Growth Promoters

Considering the intention of organizations and the EU to end all use of antibiotics as growth promoters by 2006, the need for novel strategies to modulate the gastrointestinal environment and microflora metabolism became of top priority [8]. Essentially, the option used to reduce antibiotic use in animals is the development of alternatives to antibiotics that work via similar mechanisms, promoting growth whilst enhancing the FCE. There are many options suggested as an alternative to antibiotic use in animals and some of them are discussed below.

It must be noted that, in considering phasing out or banning antibiotic growth promoters, the quality of any alternatives that could be developed or that are available illegally, must be assessed.

In-feed enzymes

In-feed enzymes are produced as fermentation products from fungi and bacteria and seem to only have a positive effect on the animal. They are routinely added to pig and poultry feeds and work by helping to break down certain components of the feed, such as glucans, proteins and phytates, that the animal may have problems digesting. In-feed enzymes are very effective at maximising FCE and have few drawbacks [7].

Competitive exclusion products

Competitive exclusion products are in-feed microbes consisting of a variety of species of bacteria that are marketed as being "friendly". The mechanism of action is believed to be that, by allowing such bacteria to colonise the gastrointestinal tract. This is the competitive exclusion principle [7]. It is not known how effective the treatment is but it is believed to reduce diarrhea and reduce levels of mortality.

Probiotics

Probiotics are similar to competitive exclusion products. They are believed to improve the overall health of an animal by improving the microbial balance in its gut. The problem with probiotics is the lack of evidence as to their mechanism of action and of the effects on host animals. Probiotics are effective in certain cases, notably in newborn animals or those that have been treated with antibiotics, where they have the same effect as competitive exclusion products. They may also be useful in helping to boost weight gain and feed conversion rates.

Infection control measures

The use of antimicrobials as growth promoting agents rests on their role in controlling infection in growing animals. Similarly, many of the alternatives are aimed at controlling infection, often indirectly. The "specific pathogen-free" system is used to prevent pigs from acquiring many of the diseases that require antibiotic intervention, especially respiratory disease. Vaccination is also used to offer protection against certain pathogens.

Combo strategies

Although different approaches have shown beneficial influences in modulating the fermentation process within the gastrointestinal tract when supplemented alone, evidence is growing for the efficacy of an intriguing new approach. It seems that a combination of more than one novel approach may lead to an even more favorable equilibrium of intestinal metabolism and thus animal welfare and performance. Literature concerning this strategy is still weak, even though some trials have been carried out. This approach takes into account all the different aspects of the gastrointestinal tract: microbiology, nutrient metabolism and tissue requirements [8].

Pro+pre-biotic=symbiotic: The combination of a probiotic and a prebiotic can be a synergistic strategy that beneficially affects the host by improving the survival and the implantation of a direct-fed microbial in the gastrointestinal tract, and by electively stimulating the growth and/or by activating the metabolism of a limited number of health-promoting bacteria [10]. The beneficial response can be more evident when animals are challenged by pathogens or chemicals.

Prebiotic+gut nutrient: As the intestine represents a complex environment, trying to promote the intestinal ecosystem may be best achieved through manipulation of nutrient availability and microbial activity. Following this concept, application of probiotic cultures, alone or in combination with prebiotic oligosaccharides, has been found to ameliorate microbial population patterns in the gastrointestinal tract and, in so doing, favorably affect the host [11]. There have also been a few reports [8,12] about the development of flavorings and herbal extracts for stimulating appetite, as well as for displaying antagonism toward undesirable microbes and improving the antioxidant status of the host and, in so doing, beneficially affecting the health status in swine or poultry.

Probiotics

Although the digestive tract of all animals is sterile at birth, contact with the mother and the environment leads to the establishment of a varied microflora [3]. There are hundreds of bacterial strains that inhabit both human and animal gastrointestinal tracts. These bacteria include harmful or toxic bacteria that colonize within the digestive tract and produce toxic waste products which lead to gas or bloating, diarrhea, constipation, ulcers or more serious events like food poisoning, and beneficial bacteria. Thus, offering the possibility to exert a positive and completely natural effect on health, well-being and performance of the animal through its autochtonous microflora [9]. Yet, the beneficial microorganisms produce enzymes that complement the digestive ability of the host, and their presence provides a barrier against invading pathogens [3].

As a result of legislation that prohibit the use of sub therapeutic levels of antibacterial, the use of probiotics as a possible alternative to antibiotics has received renewed interest [13]. Successful alternatives to antibiotics are likely to be most effective if they function as a controlling or stabilizing influence on the flora of the gut [14]. Digestive upsets are com mon at times of stress (e.g. weaning), in such conditions, in contrast to the use of antibiotics as nutritional modifiers, which destroy the desirable bacteria as well as the harmful species, the inclusion of probiotics in foods is preferable. Probiotics are designed to encourage certain strains of bacteria in the gut at the expense of less desirable ones [3]. It is believed that gut bacteria have requirements for specific nutrients that may not be adequately provided by the animal's diet. Therefore, feeding these nutrients may promote the growth of gut bacteria, thereby improving the microbial profile in the gut [15]. Presently, there is increasing interest concerning the use of probiotics in the livestock industry.

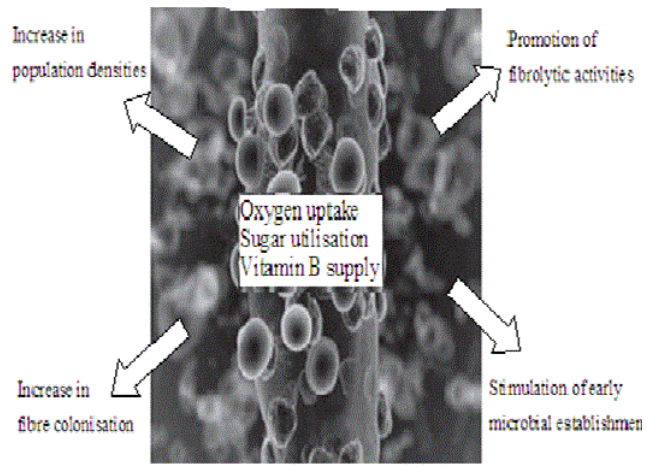

Figure 1: Main effects and mechanisms of action of probiotics on rumen microbes (fibre-degrading communities) [16].

Historical notes about probiotics

Historically, the intake of food with microbiological activity began as early as the start of human civilization, with fermented milks likely being the first foods containing active microorganisms. However, the scientific base of the beneficial effects derived by the consumption of fermented lactic products for human use began at the beginning of the 20th century [9]. In 1907, a Russian biologist postulated that the bacteria involved in yoghurt fermentation, Lactobacillus bulgaricus and Streptococcus thermophilus, suppress the putrefactive type fermentations of the intestinal flora and that consumption of these played a role in maintaining health [13,17]. Later, different studies demonstrated the relevant role of the intestinal microflora in the mechanisms of local and systemic defence in front of certain pathogens. Only at the end of the century, it became clear that intestinal microflora had several functions, including metabolic, trophic and protective ones [18]. The health benefits derived from the consumption of foods containing *Lactobacillus* acidophilus, *Bifidobacterium and L. casei* are now well documented [2]. In the 1960's and 1970s they were rediscovered for human and animal nutrition.

The value of these new products consisting of live microorganisms was based on the hypothesis that the intake of high levels of certain specific bacteria, with no negative effects on host, could somehow reduce the capacity for the pathogenic bacteria to colonise up to undesirable levels in the digestive tract of the host [17]. The first potent products for animal nutrition to fulfill the specific requirements for feed additives did not appear on the market until the mid-1980's.

Modes of action of probiotics

It was assumed that the effect of probiotics was linked to the gastrointestinal tract and effects on incidence of diarrhea and other gut infections were expected. However, recent work in several different countries has indicated that the effects may be more general [19]. The reason for diverge mechanisms may be due to the different types of probiotics [5]. Probiotics are believed to improve the overall health of an animal by improving the microbial balance in its gut. In general, the mode of action of probiotic feed additives is mainly based on competitive exclusion, bacterial antagonism, and immune modulation [7,20] .

Competitive exclusion: Competitive exclusion is defined by the ability of normal microflora to protect against the harmful establishment of pathogens. The concept of competitive exclusion indicates that cultures of selected, beneficial microorganisms, supplemented to the feed, compete with potentially harmful bacteria in terms of adhesion sites and organic substrates (mainly carbon and energy sources) [20]. The adhesion to the digestive tract wall could be for different purposes: to prevent colonization by pathogenic microorganisms or to compete for nutrients.

Adhesion to the digestive tract wall to prevent colonization by pathogenic microorganisms: Detrimental bacteria need to become attached to the gut wall to exert their harmful effects [3]. Therefore, an expected effect of the addition of probiotics to the gastrointestinal tract is an increase in normal microflora colonization with inhibition of the adhesion of harmful pathogens on the intestinal epithelium [5], thereby blocking receptor sites and preventing the attachment of other bacteria including harmful species. By doing so, the probiotic bacteria exclude pathogens and thus prevent them from causing infection [7]. The mechanism of colonization is suggested to be associated with certain species within the microflora which can influence the expression of glycol conjugates on epithelial cells that may serve as receptors for the adhesion of bacteria [21].

Different studies have shown the potential of probiotics to decrease the risk of infections and intestinal disorders. Hillman, et al. showed that the growth of *E. coli* was successfully inhibited by different strains of Lactobacilli. Moreover, it has been reported that, a combination of different lactic acid bacteria significantly reduced the levels of Salmonella in caecal contents of broilers which had been orally inoculated with the pathogen. In addition, in piglets, attachment of E. coli to the small intestinal epithelium has been reported to be inhibited by dietary supplementation with *Enterococcus faecium*.

Competing with pathogenic bacteria for nutrients in the gut: Probiotics may compete for nutrients and absorption sites with pathogenic bacteria. In addition, competition for energy and nutrients between probiotic and other bacteria may result in a suppression of pathogenic species. The gut is such a rich source of nutrients that it may seem unlikely that microorganisms could not find sufficient food for growth. Probiotics possess a high fermentative activity and stimulate digestion. Lactobacilli are known to produce lactic acid and proteolytic enzymes which can enhance nutrient digestion in the gastrointestinal tract [22]. Different studies demonstrated that probiotics maximized crude protein and energy digestibility compared with those in non-probiotic treatments [22]. However, it should be noted be that the environment only has to be deficient in one essential nutrient in order to inhibit microbial growth. In addition, the ability to rapidly utilize an energy source may reduce the log phase of bacterial growth and make it impossible for the organism to resist the flushing effect exerted by peristalsis [5].

Bacterial antagonism: Probiotic microorganisms, once established in the gut, may produce substances with bactericidal or bacteriostatic properties [7,20].

Bactericidal activity: Lactobacilli ferment lactose to lactic acid, thereby reducing the pH to a level that harmful bacteria cannot tolerate. Hydrogen peroxide is also produced, which inhibits the growth of Gram-negative bacteria [3]. These substances have a detrimental impact on harmful bacteria, which is primarily due to a lowering of the gut pH. A decrease in pH may partially offset the low secretion of hydrochloric acid in the stomach of weanling piglets. Moreover, live yeasts ferment sugars derived from the degradation of starch, thus competing with the lactic-acid-producing bacteria, and thereby stabilize rumen pH and reduce the risk of acidosis [3]. Improvement in early digestion and intake is brought about by alterations in the numbers and species of microorganisms in the rumen [3].

Neutralization of enterotoxins produced by pathogenic bacteria that cause fluid loss: Probiotic bacteria produce a variety of substances that include organic acids, antioxidants and bacteriocins [3]. These compounds may reduce not only the number of viable pathogenic organisms but may also affect bacterial metabolism and toxin production. Bacteriocins produced by lactic acid bacteria have been reported to be able to permeate the outer membrane of gram-negative bacteria and subsequently induce the inactivation of gram-negative bacteria in conjunction with other enhancing anti-microbial environmental factors such as low temperatures, organic acids and detergents [23].

In addition, they can prevent amine synthesis. Coliform bacteria decarboxylate amino acids to produce amines, which irritate the gut, are toxic and are concurrent with the incidence of diarrhea. If desirable bacteria prevent the coliforms proliferating, then amine production will also be prevented [3].

Immune modulation: Probiotics act as a stimulus for the immune system. Though, analysis and research into the ability of probiotics to influence the immune system of animals and humans is a recent development. According to Lan et al. microbial communities can support the animal's defence against invading pathogens by stimulating gastrointestinal immune response. This may aid the development of the immune system by stimulation of the production of antibodies and increased phagocytic activity [3]. As the immune system is engaged following exposure to probiotic bacteria, any hostile bacteria are also noticed, following increased surveillance by leukocytes, and thus potential pathogens are eliminated [7]. Some probiotic strains such as *Lactobacillus* have proven to be capable of stimulating the immune system. Fuller explained the immune system to be stimulated in two ways. They can either migrate through the gut wall as viable cells or multiply to a limited extent or antigens released by the dead organisms can be absorbed and stimulate the immune system directly. It is the product of this change which induces the immune response. And currently, it appears to be some relationship between the ability of a strain to translocate and the ability to be immunogenic [19].

However, it is difficult to completely conclude that probiotics contribute significantly to the immune system of the host as they are not intended to eradicate invasive pathogens in the gastrointestinal tract. Therefore, such observed improvements or positive effects are always somewhat compromised due to the animals immune system status and the various applied situations [5]. In addition to the above discussed, other postulated effects include beneficial interaction with bile salts, increased digestive enzyme production, more efficient absorption of nutrients, and greater vitamin production. Several mechanisms have been proposed to explain the effects of probiotics and it is likely that the positive results reported in the different animal studies are due to a combination of some, if not all, of these [3].

Probiotics in animal feeding

Modern rearing methods which include unnatural rearing conditions and diets induce stress and can cause changes in the composition of the microflora which compromise the animal's resistance to infection [19]. Thus, the aim of the probiotic approach is to repair the deficiencies in the microflora and restore the animal's resistance to disease. Such a treatment does not introduce any foreign chemicals into the animal's internal environment and does not run the risk of contaminating the carcass and introducing hazardous chemicals into the food chain. Probiotics are now replacing the chemical growth promoters for farm animals and claims have also been made for increasing resistance to disease. Probiotics are preparations based on live microorganisms that are consumed as food and feed additives, and which have a beneficial effect on the health status of humans or animals. It is said that probiotics help prevent imbalances, and enhance the growth of the healthy microflora [17]. Besides, probiotics are widely produced, promoted and marketed.

Microorganisms used as probiotics in animal nutrition: Most probiotic products utilize one or more of several types of bacteria. The most commonly used bacterial probiotics are the strains of *Bifidobacterium, Enterococcus, Lactobacillus, Bacillus, Pediococcus* and *Streptococcus.* Some products contain viable yeast and other fungi in addition to bacteria. There are marked differences between the various probiotic groups regarding their properties, origin and mode of action.

The following table shows probiotics that are commonly used in animal nutrition summarized from many l iteratures [2,9,15,17,20,24].

Genus	Species
Bifidobacterium	*B. lactis* *B. longum* *B. pseudolongum* *B. thermophilum*

	B. bifidum
Enterococcus	*E. faecalis*
Lactobacillus	*L. acidophilus* *L. amylovorus* *L. brevis* *L. casei* *L. farmicinis* *L. fermentum* *L. plantarum* *L. reuteri* *L. rhamnosus*
Lactococcus	*L. lactis*
Leuconosto	*L. citreum* *L. lactis* *L. mesenteroides*
Pediococcus	*P. acidilactici* *P. pentosaceus subsp. Pentosaceous*
Streptococcus	*S. infantarius* *S. salivarius*
Bacillus	*B. cereus* *B. licheniformi* *B. subtilis*
Saccharomyces	*S. cerevisiae (S. boulardii)* *S. pastorianus (S. carlsbergensis)*
Aspergyllus	*A. oriza* *niger*

Table 1: Probiotics commonly used in animal feed.

The use of probiotics as farm animal feed supplements dates back to the 1970's. They were originally incorporated into feed to increase the animal's growth and to improve its health by increasing its resistance to disease [19]. Yet, use of probiotics in humans and animal species such as young pigs has been widely reported in the scientific literature. Numerous studies have shown that humans or animals fed probiotics have altered intestinal bacterial populations, improved resistance to disease, reduced shedding of pathogens when challenged orally, increased intestinal immunity, reduced disease symptoms, and improved health [15].

Certain microorganisms which are intentionally added to the feed (probiotics) counteract possible disruptions of the equilibrium and lead to eubiosis. Thus the colonisation of the intestine by undesirable microorganisms can be suppressed. As yet, not all actions of probiotics have been satisfactorily explained by science. Their overall positive effects, based on developing metabolic activity, comprise both direct and especially indirect effects (Figure 2) [9].

Probiotic is a generic term, and products can contain yeast cells, bacterial cultures, or both that stimulate microorganisms capable of modifying the gastrointestinal environment to increase health status and improve feed efficiency.

Administration of probiotic strains separately and in combination significantly improved feed intake, FCE, daily weight gain and total body weight in chicken, pig, sheep, goat, cattle and equine.

In monogastric animals, strains of *Lactobacilli, Bacillus subtilis* and *Streptococci* have been used as probiotics. The use of these probiotics has been shown to help improve gain and feed efficiency in poultry and swine. However, other researchers have observed no significant response in swine [13].

In ruminant animals, the application of yeast (*Saccharomyces cerevisiae*) in the form of live culture, or dead cells with culture extracts, has proved successful in beneficially modifying rumen fermentation [5]. Probiotics have been used to potentially replace or decrease the use of antibiotics in neonatal and stressed calves, to enhance milk production in dairy cows, and to improve daily gain and feed efficiency in beef cattle [26]. However, performance results of experiments where cattle were fed probiotics are generally inconsistent.

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Effects of Probiotics on Animal Health and Performance

Effects of probiotics on cattle health and performance

Though study of probiotics for human and animal use has increased since the mid 1950's, Yoon and Stern [27] explained that the study of production responses by growing and lactating ruminants, and interest in the corresponding mode of action of probiotics, is more recent. Indeed, the increased interest about pathogen contamination of meat and meat products has resulted in a recent surge of experiments evaluating the efficacy of probiotics [1].

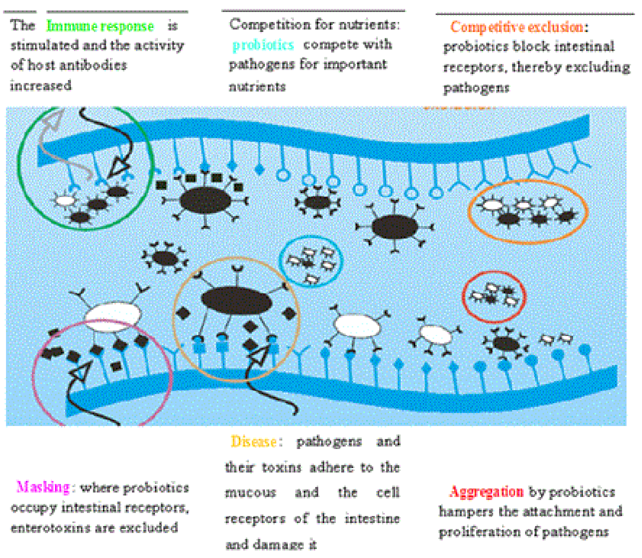

Figure 2: Microbiological interactions in the intestine [9].

In ruminants, yeast cultures can stimulate forage intake by increasing the rate of digestion of fibre in the rumen in the first 24 h after its consumption. This improvement in early digestion and intake is brought about by alterations in the numbers and species of microorganisms in the rumen. The increase in forage intake can result in improved live weight gain, milk yield and milk fat content, although the effects are often small in dairy cows [3].

Pre-ruminant calves

Though there are published studies that have evaluated various DFM formulas in the diet of un-weaned calves, the effect of DFM on young calves is much less clear [15].

Based on studies in the newborn dairy calf, Newman and Jacques [28] concluded that the normal population of gastrointestinal microbes is extremely beneficial for preventing infection. In support, Fuller [29] observed that germ-free animals are much more susceptible to disease than are inoculated animals. Different results suggest that probiotics are beneficial for establishing and maintaining a positive microbial balance in newborn calves by decreasing the prevalence of coliforms. Moreover, a decreased incidence of diarrhea has generally been associated with an increased shedding of *Lactobacillus* [30]. In the contrary, the *Lactobacillus* population decreases when animals are stressed, and stress often leads to an increased incidence of diarrhea in neonates [1]. In fact, there are results that report feeding probiotics to dairy calves had no effect on fecal scores or oocyst shedding [31].

During the first 3 weeks of preruminant's life, decreasing the incidence of diarrhea is most likely a more important response than performance responses, as enteric disease is most prevalent during this period [26].

Reports about the response of feeding probiotics in performance are highly variable. There are many studies that reported no improvement in daily gain as a result of feeding DFM to dairy calves [30]. In contrast, others reported increased growth and feed efficiency by calves treated with probiotic bacteria [32,33].

Animals	Common Benefits
Pig	Improve colostrum quality, milk quality and quantity Increase litter size and vitality Increase piglet weight Reduce risk of diarrhea Improve feed efficiency, diet digestibility and meat quality Limit constipation Decrease stress
Poultry	Increase body weight gain Reduce mortality Increase carcass quality decreasing contamination Increase bone quality
Veal Calf	Promote weight gain and optimal maturation of rumen microbiota limiting acidosis Increase feed efficiency, milk yield, quality and digestive safety at weaning Reduce risk of pathogen colonization and limit shedding of human pathogens
Horse	Improve diet digestibility, milk quality and quantity Limit diarrhea

	Avoid hindgut disorders (acidosis, colic) Limit stress (Transportation, race etc.)

Table 2: Main Targets for probiotics' use in different types of animals [25].

Production branch	DWG (% of control)	FCR (% of control)
Piglet production	+4.8	-1.5
Calf production	+5.4	-2.5
Growing/fattening pigs	+3.7	-5.1
Growing/fattening cattle	+3.4	-2.7

Table 3: Influence of various probiotics on the performance of animals [9].

Hence, these benefits were hypothesized to result from improvement of intestinal conditions because of lower fecal scores (less scouring) in calves fed probiotics. Furthermore, Adams et al. [33] suggested that the increase in body-weight gain is not only during the milk feeding period but also after weaning. Finally, Quigley [15] suggested that, variation in responses is likely a function of interactions between diet, the degree of the pathogen challenge and other stressors.

Receiving cattle

Weaning, transport, fasting, assembly, vaccination, castration and dehorning are some of the stresses beef calves undergo upon entering the feedlot. These stresses result in decreased performance and increased morbidity and mortality, in part due to altered microorganisms in the rumen and lower gut. Therefore, feeding probiotics might reduce these changes in the microbial population. Krehbiel et al. [25] summarized data from several research trials, and concluded that feeding a probiotics at processing, throughout the receiving period (average of 30 days), or both resulted in a 13.2% increase in daily gain, 2.5% increase in feed consumption, and a 6.3% improvement in feed: gain. The greatest performance response to the probiotics generally occurred within the first 14 days of the receiving period. As well, morbidity was decreased by 27.7% in cattle receiving the probiotics compared with control cattle.

Feedlot cattle

The addition of yeast to intensive beef diets has increased daily live weight gain and FCE [3].

Growth: In relation with the growth of cattle, Swinney-Floyd et al. [34] reported that though bacterial DFM did not alter DM intake, ADG for the animals inoculated with the combination of *Propionibacterium* and *L. acidophilus* was greater than control calves. In line with this, Huck et al. [38] reported a tendency for greater carcass-adjusted ADG in heifers that were sequentially fed a Lacto*bacillus* and then a *Propionibacterium* or a *Propionibacterium* and then a Lacto*bacillus* probiotics between the receiving and finishing phases compared with control heifers. But, in contrast, Rust et al. [35] reported no difference for carcass-adjusted ADG in control steers versus steers supplemented with *Lactobacillus* and *Propionibacterium*. However, ADG for the average of all probiotics -treated steers was increased 6.2% over control steers. In addition, feed efficiency for the entire feeding period was improved for steers receiving certain probiotics treatments compared with control steers. Galyean et al. [36] also reported that the final BW, ADG and hot carcass weight were significantly greater for steers treated with probiotics versus the control animals. Similarly, McPeake et al. [37] reported steers fed a probiotics had greater final weight, ADG, DM intake, hot carcass weight and carcass-adjusted ADG compared with control steers. In addition, there was also a trend for improved feed efficiency as the concentration of supplemental *L. acidophilus* increased.

Carcass: With regards to carcass characteristics, different studies [35,37] indicated that, the addition of probiotics did not affect yield grade, quality grade, dressing percentage, marbling score. However, hot carcass weight was generally greater when probiotics were fed. On the other hand, Huck et al. [38] reported that the percentage of carcasses graded as was greater in heifers receiving a *Propionibacterium* probiotics in both the receiving and finishing phases than in control heifers. To this end, it can be seen that improvements in carcass characteristics as a result of probiotics are questionable, except for hot carcass weight. Because probiotics generally improve ADG, hot carcass weight would be increased if probiotics supplementation increased ADG and final BW [39]. Beauchemin et al. [1] elaborated that the positive effects of probiotics on performance might be associated with a decrease in ruminal acidosis and/or improved microbial balance in the lower gastrointestinal tract.

Milk yield and composition in dairy cows: Researches concerning the effects of probiotics in dairy cows are limited. Even in the available studies the probiotics were fed together with other additives making it difficult to judge the effects of the probiotics themselves. In the few studies available in which probiotics were fed to dairy cows, the milk yield increased by 0.75–2.0 kg/d. In general, an increased milk yield has been a consistent response, whereas changes in milk composition have been variable. In support with this, Gomez-Basauri et al. [40] described that cows fed lactic acid bacteria and mannan-oligosaccharide produced more milk. The authors reported that milk yields increased over time for lactic acid bacteria-and mannanoligosaccharide-fed cows, whereas control cows maintained constant milk yields. Furthermore, there are experiments that suggest probiotics fed alone or in combination with fungal cultures might be efficacious for increasing milk production by lactating dairy cows [41,42]. However, more research is needed before recommendations can be made have been conducted with combinations of fungal cultures and lactic acid bacteria.

Effects of probiotics on poultry health and performance: Addition of probiotics has shown beneficial effects on growth performance of poultry. In broilers, supplementation of a diet with probiotics has resulted in improved feed conversion rate and average live weight in comparison to the control group. Moreover, in a study by Mountzouris et al. administration of the multi-strain probiotic in the drinking water significantly increased average daily weight gain and feed efficiency and numerically reduced mortality rate in comparison with a negative control.

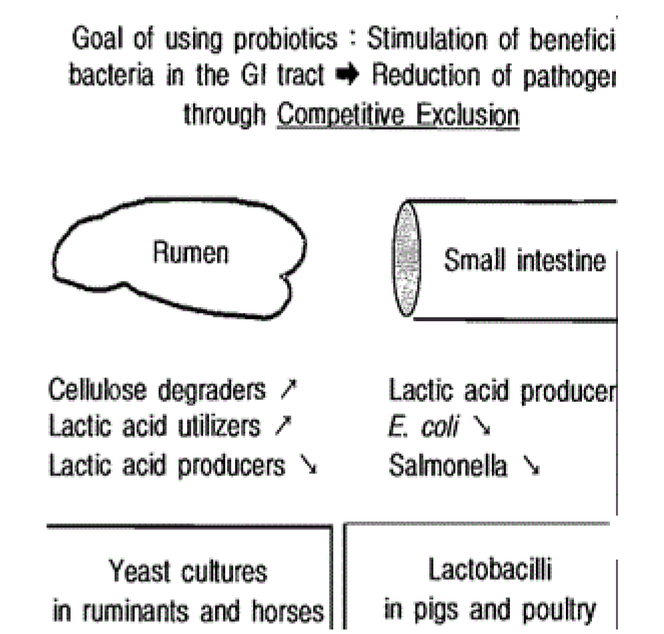

Figure 3: How probiosis can have a beneficial effect on animal nutrition.

Performance Parameters	Control	Probiotic
Feed intake (g/d)	1008.42	1119.72
FCR (g feed/g meat)	2.03	1.82
Body weight gain (g)	547.13c	920.96a
Mortality rate %	15.0b	2.5a

Table 4: Performance values of experimental broiler chick for control and probiotic dietary treatments at the age of 28-42 days.

Effects of probiotics on pig health and performance: Some reports have indicated that supplementation of probiotics improves performance in suckling pigs, weanling pigs, grower pigs and finishing pigs. Administration of the multi-strain probiotics tended to cause higher weight gain and feed efficiency. In support with this, **Giang et al.** reported that piglets fed probiotic complexes diets had higher feed intake, daily gain and better feed conversion during the 1st 2 weeks after weaning. This indicates a synergistic effect of different probiotic strains under in vivo conditions. Eventually, as a result of feeding a fermented diet, the time available for the gastrointestinal microflora to decarboxylate free amino acids present in the diet minimizes which has shown to improve performance in pigs [43].

In addition to the improved average daily gain, addition of probiotics reduced mortality rates of growing and finishing pigs. In line with this, different studies revealed that the incidence and severity of diarrhea as well as mortality rate were significantly decreased as a result of feeding probiotics. Moreover, live yeast supplementation to the diet of pigs has resulted in demonstrable reductions in the quantity of pathogenic bacteria.

Application of probiotics and recommendations for use: Although some products contain purified strains of individual organisms, most probiotics products are a combination of several species of bacteria and yeast and other fungi. Most probiotics products for calves are sold as feed additives, which are added to milk or milk replacer just prior to feeding, while others are administered as gels, pastes, or boluses. But, their application on the farm is more challenging. Adding probiotics to pelleted feeds is difficult, as temperatures and pressures used in pelleting generally kill most organisms [15].

The stabilisation of the digestive or microflora in ruminants and in monogastric animals can only be effectively achieved by continuous supplementation of the feed with probiotics because the microorganisms used in animal nutrition do not permanently colonise the intestine. Increased short-term supplementation of probiotics may be useful under certain conditions but should be followed by continuous supplementation thereafter. General guidelines on the optimal dosage and the period of supplementation are not possible because factors such as stability of the probiotic in the feed and in the digestive tract, the specific mode of action of the microbes contained in the product and the status of the intestinal microflora in the host all modulate the effect of the corresponding product [9].

The optimal dose must be determined individually for each product and each target species in feeding trials. The rate of inclusion given by the manufacturer, therefore, is based on information gained from efficacy studies [9]. In general, however, it is accepted that the inclusion rate of all probiotics should be higher when the intestinal microflora is unstable and particularly when for ruminant the diet composition contain high rapid-fermentable sugar which can entail sub-acidosis. In addition, the overall consumption of probiotics by older animals will be higher because of a higher feed intake compared to younger animals. Therefore, with continuous supplementation, the inclusion rate may be reduced during the growth of the animals without the concentration of the probiotic microorganisms in the intestine dropping below the level of efficacy.

Efficacy of probiotics: Reports of probiotics efficacy are variable but this may depend greatly on survival rate of strains, varying stabilities of strains, low probiotic doses, frequency/infrequency of administration, interactions with some medicines, health and nutritional status of the animal and the effect of age, stress, genetics and type differences of animals [14]. To be effective, the desirable microorganism should not be harmful to the host animal, should be resistant to bile and acid, should colonise the gut efficiently, should inhibit pathogenic activity, and should be viable and stable under manufacturing and storage conditions [3].

Research points to the fact that probiotics are most effective in animals during microflora development or when microflora stability is impaired. The benefit of probiotics with respect to health status and performance is expected to be highest in young animals such as piglets, newly-hatched chickens or calves, because these animals have not yet developed a stable gut microflora. Moreover, when animals undergo therapeutic treatment of diseases with antibiotics, the gut microflora is generally decimated. Therefore, administration of probiotics after antibiotic treatment assists in re-establishing a beneficial gut microflora to prevent the host from recurrent pathogenic colonisation [20].

For pigs, it is suggested that the effects of probiotics appear to be more consistent and positive in piglets rather than in growing finishing pigs. Hence, in a review of the response of pigs of various ages to the administration of probiotics, it was concluded that probiotics were effective for young pigs, in which the digestive tract is still developing after weaning. However, probiotics were less effective for growing and finishing pigs, which already have a balanced population of microorganisms [3].

With regard to cattle, similarly, improvements in animal performance may be limited in young, milk-fed calves. Rather, it appears that probiotics may be most useful under specific conditions whereby calves are exposed to immune or management challenges that may disrupt the intestinal environment. Under stress conditions, probiotics may reduce the risk of scours caused by an upset in the normal intestinal flora of calves [5]. As in the neonatal calf, the response to probiotics might be greater if administered to newly weaned and/or received beef calves, which are more prone to health problems. Gill et al. [44] suggested that extremely healthy calves and extremely sick calves might be less likely to respond to probiotics treatment.

Consequences of using probiotics growth promoters

Safety for humans: Comprehensive studies have shown that there are no hazards for probiotic users. Direct contact of registered probiotic products with skin, mouth and nose do not compromise human health. In model trials it has been established that even long-term or increased exposure do not constitute a risk to health. As a food consumer, however, man does not come into contact with the probiotics fed to the animal. As probiotics are administered exclusively via the feed, their action is restricted to the gastro-intestinal tract. Hence they are not absorbed, they cannot be transferred into foodstuffs of animal origin and hence do not lead to residues [9].

Safety for the environment: Having exerted their effect in the digestive tract, the probiotic reaches the exit of the intestine in the digesta, together with other intestinal microorganisms. On their way along the digestive tract the majority of the probiotic bacteria die off, since their growth and proliferation is severely restricted by competition from other microorganisms present in the large intestine [9]. The probiotics are already partly broken down and digested like other organic nutrients in the intestine so that only a small proportion is excreted viable in the faeces and survives in the manure to reach fields and grassland. Evidence of the harmlessness of the probiotic to the environment is one important subject for its registration. In general, any negative impact is highly unlikely since all these microorganisms are derived from nature.

Safety for animals: Overall, the microorganisms approved for animal nutrition have a very good safety record. Probiotics do not constitute any health hazard for the animal. Since they are not transferred from the intestine into the body of the animal, they do not affect any metabolic processes, nor do they have any negative impact on the animal [9]. Contrary to this, Hughes and Heritage [7] questioned the usefulness of probiotics as it remains unproven. Though, probiotics do have some strong supporters in the scientific community, these are matched by an equal number of detractors. As far as the beneficial effects of probiotics, they have been demonstrated almost exclusively under defined experimental conditions. In addition, there is the lack of evidence as to the mechanism of action and of the effects on host animals.

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