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The importance of early nutrition in broiler chickens: Hydrated gels enriched with nutrients, an innovative feeding system

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Abstract

Poultry industry constitutes one of the most significant segments of the agricultural and veterinary sector worldwide. For this reason, one of its main objectives is to improve not only the quantity but also the quality of the offered product. Over the years, the abuse of antibiotics as growth promoters has led to the development of antibiotic-resistant bacterial strains, imposing the need to find alternative solutions for animal welfare and for gastrointestinal diseases prevention, finding confirmation in the use of pre and probiotics. Various stressors, together with feed deprivation during the first few hours of chicks' life increase the chance of disease contraction and mortality. Innovative feeding systems to be administered to chicks immediately after hatching in incubation rooms are gaining ground in poultry industry. These new systems consist of complementary feeds, often in the form of hydrated gels, which provide all the nutrients and additives that chicks need during their first hours of life, promoting the development of the gastrointestinal system and preventing the documented side effects caused by fasting.

Introduction

Poultry industry is one of the fastest growing segments of the agricultural and veterinary sector. As with other industries, its main purpose is to produce the maximum with minimal input. The constant increase of ingredients' price for poultry feeding, and the consequent farmers' lower profit, are highlighting the need for a balanced and effective feed, being it the most important requirement for an economic poultry production. In recent years, many feed additives, such as antibiotics, have been extensively used to promote the rapid growth of the animals. However, this abuse led to the development of bacterial strains resistant to antibiotics, with dangerous residual effects also in eggs and meat, being a potential risk for consumers' health. Therefore, the possibility of having to cease the use of antibiotics for disease prevention and as growth promoters, considering all the harmful secondary effects, has created the need both in the consumer and in the manufacturer, to seek new alternatives. Thus, probiotics have proved to be an excellent solution, already adopted by some breeders, both for diseases prevention and for animal welfare [1,2]. The concept of competitive exclusion underlies the use of probiotics. An important event in the development of these innovative additives was the discovery that newly hatched chickens could be protected against colonization by Salmonella enteritidis by dosing a suspension of gut content obtained from healthy chickens [3].

Biotechnology thus becomes a crucial aspect in poultry feed industry's life. A good feed alone cannot prevent the onset of diseases. Changes in diet, as well as the lack of a healthy diet, can affect the balance of gut microflora, predisposing the animal to digestive disorders. Therefore, nutrition specialists and veterinarians are focusing on the correct use of nutrients and probiotics to promote animal healthy growth.

Probiotics in poultry industry

Probiotics are defined as live non-pathogenic and nontoxic microorganisms, which when administered through the digestive route, are favourable to the host's health [4]. Many investigators believe that there is an unstable balance between beneficial and nonbeneficial bacteria in the normal gut tract of healthy chickens. When balance exists, the bird shows optimal performances, but in stressful situations, the beneficial flora, especially the lactobacilli, decreases in number while there is an excessive growth of the non-beneficial bacteria. This can predispose the animal to frequent diseases, or even reduce growth parameters and feed efficiency. The microflora that establishes in the gut has the characteristics of being very stable, but also easily influenced by both diet and environmental factors.

The three most important external factors are antibiotic therapy, stress, and excessive hygiene. In nature, new-born chicks receive a complete flora from their mother's faeces, thereby providing protection against potential infections. However, farmed chickens hatch in extremely clean incubators, lacking the usually encountered microorganisms of chickens' gut. Microbiological contamination of the shell, plus gastric secretion of hydrochloric acid from the 18th day of incubation, can both affect the composition of chicken's microflora [5]. For these reasons, the immediate administration of probiotics right after birth is of paramount importance for avian species. In fact, the chicken is the extreme example of how a newborn animal deprived of contact with its mother or other adults, needs an early administration

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of a beneficial founding microflora that could protect its gastro-intestinal tract. The most common species used as probiotics in broiler nutrition mainly belong to the genera *Lactobacillus, Streptococcus, Bacillus, Bifidobacterium, Enterococcus, Aspergillus, Candida,* and *Saccharomyces*, and have a beneficial effect on broiler performance, modulation of intestinal microflora and pathogen inhibition, immunomodulation, haematobiochemical parameters, intestinal histological changes, and promotion of microbiological meat quality [6-8]. The desirable criteria that a probiotic should fulfil to be selected are many: it must be a normal inhabitant of the gut, and it must be able to adhere to the intestinal epithelium to overcome potential hurdles, such as the low stomach's pH, the presence of bile acids in the intestine, and the competition against other microorganisms in the gastro-intestinal tract. The mode of action of probiotics in poultry includes: maintenance of normal microflora by competitive exclusion and antagonism with nonbeneficial microorganisms [3,9]; increased digestive enzymatic activity and decreased bacterial enzyme activity and ammonia production [10,11]; improved feed intake and digestion [12,13]; stimulation of the immune system [14, 15]. Many studies have shown that the competitive exclusion produced by inoculating an adult microflora in day-old chicks has a positive impact on intestinal function and disease resistance. This approach allows to provide the chick with a complete adult microbiota, thus avoiding having to add one or more bacterial strains to an already formed microbiota. Given the high chicks' susceptibility to infections, this practice has a very important commercial value. The main mechanisms by which probiotics improve feed conversion efficiency include the alteration of the intestinal flora, the growth increase of non-pathogenic and anaerobic gram-positive bacteria capable of forming lactic acid and hydrogen peroxide, the growth repression of pathogenic intestinal microorganisms, and finally the digestion improvement and use of nutrients. Hence, the main results obtained from the probiotics administration are the improvement in growth rate, the reduction of chickens' mortality, and the improvement in feed conversion efficiency [16,17].

Early feeding in broilers

The "hatch window" is known as the 24 to 48 hours period during which eggs hatch [18]. The newly hatched chickens remain in the incubator until all the eggs have hatched, after which chicks are collected. After collection, chickens undergo routine treatments such as selection, vaccination, sex determination and sorting. Then they are transported to the farm. From the moment of hatching until their arrival to the farm, chickens are usually not given neither water nor food. The length of this period may vary depending on the hatchery window, the hatchery procedures and the trip's length to the farm. The time elapsed before the administration of the first water and feed can even be up to 72 hours [19,20]. While the yolk sac may be sufficient for the first few hours of chicks' survival, all the other requirements fail during the long hours until their arrival to the farm. Willemsen *et al.* [20] suggest that the deprivation of feed and water for 72 hours can have long-term negative effects on chicken's welfare and behaviour. The chicks come out from an embryonic condition in which the energy basis of their nutrition is yolk's fat and egg white's proteins. Immediately after birth, during the first hours of life there is a significant reduction in the endogenous glycogen levels, which need to be replaced preferably by glycogen from the consumption of corn starch or another source of starch. Chicks need to learn quickly to consume feed to allow their digestive system to undergo rapid anatomical and physiological transformation. Furthermore, early feed consumption also promotes the rapid development of the immune system. The chicks must also quickly learn to consume water to compensate for any dehydration that could occur from the hatch until their arrival to the farm, thus also favouring the consumption and digestibility of feed [21,22]. Recently, De Jong *et al.* [23] carried out a metaanalysis study starting from 83 experimental trials in which the effect of fasting time on the weight and productive performance of chickens at different ages was studied. This study helped to find out that although chickens were able to compensate for the delay in growth caused by fasting during the first hours of life, this compensation is not complete, as statistically significant differences were observed in live weight at 42 days of life, depending on the number of hours during which the chicks received no food from hatching [23]. Similarly, the study showed that the number of fasting hours after hatching also significantly affects the feed conversion rate, as well as mortality throughout the entire chicken fattening period. In addition to the need for feeding as soon as possible, the proportion of macronutrients in the first feed that chicks receive is crucial for their growth, as protein intake is the main nutritional factor during the first days of life. In their study, Swennen *et al.* [24], for the first five days, fed the newly hatched chicks with three different isoenergetic pre-starter diets, one low in protein, one low in carbohydrates, and one low in fats. From day six on, all chickens received the same commercial diet until their 42nd day of life. The results showed that chicks fed the low protein diet were delayed in growth compared to those who received the other two types of diet. This is explained by the fact that the efficiency of protein digestion is lower than that of lipids and carbohydrates in the first days after hatching. The digestive capacity of dietary proteins and ammino acids begins to be efficient from the tenth day of life, consequently the inclusion of highly digestible protein sources in the pre-starter diets is essential to strengthen chicks' growth. In their study, Moore *et al.* [25] confirmed that feeding chickens immediately after hatching is essential for muscle development as fetus' glycogen stores are utilized immediately after hatch, leaving the chick in a nutrient deficit state. Compared to fasted poultry, chickens fed immediately after hatching develop the pectoral thoracic and pectora supracoracoideus muscles more, resulting in a greater weight. This is likely due to low pectoral thoracic protein synthesis by fasting chickens, as well as an increased level of apoptosis. Poor development and decreased muscle weight at early stages, will likely lead to a low meat yield on the market. The investigators speculate that low levels of muscle development due to feed deprivation after hatching are directly related to satellite cell dynamics. Indeed, poultry showed low mitotic activity of satellite cells during fasting and the first day of feeding. However, although these underwent a compensatory increase in activity once fed, the response was not sufficient to equate that of chickens fed since hatching, neither with regard the activity of satellite cells, nor muscle weight. Further confirmation was given by the increase expression of the Pax7 protein in fasting chickens which, after a period of stress, appears to be related to a low level of satellite cells mitotic activity [25]. Finally, Moore *et al.* [26] also studied the importance of leucine if administered in the initial diet: leucine's metabolite, the β-hydroxy-β-methylbutyrate, promotes weight gain in turkeys, as well as the increase in satellite cell activity, with the consequent increase in pectoral muscle weight.

An innovative feeding system from incubator to farm: hydrated gels rich in nutrients

As previously explained, access to food and water immediately after hatching is of paramount importance for chicks' digestive and immune systems proper development. Nowadays, there are food management systems right in the incubator. In these systems, the hatching trays have openings in which the newly hatched chicks fall into a lower basket

where they can find double-sided feeders with sufficient feed and water for the following 24-36 hours. This first feed provides the energy needed for the basic maintenance of the chick, while yolk's high value nutrients are used for the development of the immune system and vital organs. A recent innovative method to ensure the ingestion of nutriment from the first hours of life is the administration of hydrated gels that contain an increasing variety of nutrients and additives, such as vitamins and probiotics. These gels, considered as complementary feed, are sprayed on chicks in form of droplets directly in the incubators. These droplets are quickly consumed by pecking each other. In this way, chicks ingest all the nutrients contained in the gel drops without getting wet or cold. These gels contain innovative formulations that usually include several nutrients, vitamins, minerals, highly digestible amino acids, and prebiotics that promote the stimulation of gastrointestinal development and functioning, and also influence positively the growth and the productive yield, thus favouring poultry welfare. The main ingredients that characterize and make these enriched hydrated gels unique are the following.

- Sodium chloride is the main electrolyte of the extracellular fluid, responsible for the control and distribution of water throughout the body, and consequently for the maintenance of body fluids' normal balance.
- Calcium chloride is a calcium supplement, indicated in cases of severe hypocalcaemia, hypermagnesemia, hyperkalaemia, or in case of toxicity caused by calcium channel antagonists.
- Magnesium sulphate helps decrease acetylcholine in nerve endings; it is necessary for the entry or exit of calcium, sodium, and potassium from cells, as well as for membrane stabilization.
- Potassium chloride is a potassium supplement, intracellular fluid's main cation, closely linked to cell function and metabolism, in particular carbohydrates' metabolism, glycogen storage and protein synthesis. Potassium is one of the main responsible for the transmembrane potential and is essential in the electrical excitability of muscles' nerves, including the cardiac ones. It also plays a fundamental role in the genesis and correction of acid-base metabolism disorders.
- Organic selenium has been introduced in the formulation for its important benefit compared to its inorganic form: it allows the creation of selenium reserves in tissues, mainly the muscular ones, in the form of selenomethionine. Selenomethionine is perceived as an amino acid, so it can be used in conditions of stress or need to improve antioxidant defences.
- Leucine, together with valine and isoleucine, is part of the so-called Branched Chain Amino Acids (BCAA) group. BCAAs are known for their anabolic and anti-catabolic function on muscle metabolism. The anabolic function is confirmed by the increase in protein synthesis and by the inhibition of proteolysis. However, different scientific researches show that leucine exerts a greater effect on protein metabolism than valine and isoleucine. It appears that postmeal protein synthesis of muscle tissue increases significantly more after leucine ingestion than the other two BCAAs. Although not all of the mechanisms of leucine-induced protein synthesis are known yet, some can probably be explained by the activation of the mammalian target of rapamycin (mTOR) protein, known for its role in the muscle growth process [27].
- C vitamin, or ascorbic acid, is a strong antioxidant agent that improves cellular immune response. Stressors that can threaten birds' health can include many elements, such as altered atmospheric temperature, relative humidity, inadequate human handling, feed and water deprivation. Other factors include vaccination, diseases, such as coccidiosis, confinement, excessive movement, or excessive noise, a micro-thermal core inside the transport vehicle, or even the use of inappropriate vehicles. The harmful effects of these factors and, their combination can cause mild to severe discomfort and can even lead to death. The administration of C vitamin, in a range from 100 to 200 mg per kg, is able to reverse the stress factors in chickens, and therefore improve productivity.
- Fructo-oligosaccharides (FOS) represent an important supply of dietary fiber and favour the selective growth of lactic bacteria and Bifidobacterium. Thanks to their ability to stimulate the growth of specific beneficial bacteria in the colon and to obstruct the growth of pathogenic bacteria, they are considered prebiotics. Thanks to their fermentation process, FOS can influence the intestinal epithelium by promoting the development of the mucosa and increasing resistance to intestinal diseases by creating a sort of barrier mechanism. FOS consumption reduces the appearance of ulcerative intestinal lesions, being the short-term treatment based on the ingestion of FOS and bifidobacteria, one of the best therapies for inflammation associated with active ulcerative colitis [28]. The FOS are attributed the ability to prevent constipation as they allow a better formation of the faecal bolus and promote intestinal mobility [29]. Consumption of FOS has been shown to improve the absorption of minerals such as calcium, magnesium, zinc, iron and copper. Absorption of minerals generally occurs mainly in the small intestine, although the large intestine can also represent an absorption site, thanks to the help of short-chain fatty acids derived from fermentation [28,29]. Finally, there is no experimental evidence indicating that FOS have any toxicity degree.
- Patented high-quality soluble extract obtained from a primary culture of a Saccharomyces cerevisiae yeast strain. This ingredient is an important protein source in chicken diet, being made up of 63% free amino acids, small peptides, and rich in nucleic acids derived from yeast cells' content. It is a source of highly digestible essential amino acids, such as lysine, and also contains a high level of glutamic acid, known to be palatable and useful during the first week of chick's life.

Conclusion

As previously discussed, there are many factors that can affect the welfare of broiler chickens, such as the deprivation of water and feed for long hours, inappropriate feeding, and environmental stressors. For this reason, alternative systems are increasingly necessary to compensate or avoid the side effects of bad practices implemented since the first hours of life of newly hatched chicks. The use of hydrated gels as complementary feed rich in nutrients and additives, aims to protect chickens' gastrointestinal system, promoting its development and functionality. The easy administration of these type of products directly into the incubation chambers in the form of small gel drops ensures a first nourishment to chicks to make up for the long hours of transport to the farm, without wetting or cooling them. The new technology of hydrated gel is an incredibly valid and innovative solution to help chicks in their first hours of development which, accompanying them throughout their growth, promotes not only chickens' welfare but also the achievement of a high production yield.

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