Intestinal Physiology and Impact of Disease on Neonatal Poultry

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Introduction

Under current commercial practices, hatchling poultry face great challenges to survive and produce. The development of two body systems, the gastrointestinal tract and the immune system, are mainly responsible for the success of the chick when coping with its environment. How do these systems develop? What nutrition should we provide to hatchling poultry for best performance? This article addresses these questions by highlighting the current knowledge on the development of the gastrointestinal and immune systems in neonatal stages. The effect of early nutrition on coccidiosis prevention and the current knowledge on competitive exclusion of *Salmonella* in poultry are also discussed.

Development of the Gastrointestinal Tract (GIT)

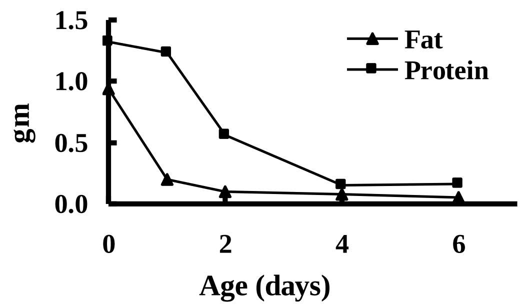
The functions of the GIT include digestion, absorption and protection. These functions, however, are not completely developed in newly-hatched poultry. The GIT undergoes a tremendous growth after hatch, and during the first week of life its growth rate may exceed that of the rest of the body by as much as five fold.. Further changes occur during later growth periods, when dietary components still play an important role as stimuli for those changes.

As hatch approaches, glycogen accumulates in the liver and is used for hatching. Lipids are transferred to the liver of the embryo and the yolk sac is internalized within the body wall. Recent findings suggest that some of the residual yolk reaches the intestine via the yolk stalk and provides digestible nutrients to stimulate maturation of the digestive and absorptive functions of the neonatal intestine. During the first days of life there is a shift from the lipid-based metabolism of the embryo to a carbohydrate-based metabolism typical of the neonate. Therefore young birds must rapidly adapt to digesting carbohydrates supplied by the diet. Understanding the factors that influence early growth, such as nutrient absorption and transition in energy metabolism, allow for the development of an optimal nutritional supplement for the young poultry.

The length and surface area of the gastrointestinal system are the most limiting factors for nutrient absorption. The faster the birds grow, the longer the villi and the higher the enterocyte density. Intestinal microflora also stimulate the growth of the microvilli. On the contrary, growth promoter antibiotics reduce the thickness of the intestinal wall and, therefore, its overall weight. Reduction of the connective tissue (primarily its reticuloendothelial component) and less competition by local microflora are some of the mechanisms suggested as the cause of the improvement in performance. Low quality ingredients (e.g feeding oxidized fats) produce a shortening in the villi that results in impaired absorption efficiency by the GIT. Consequently, the quality of the first feed should not be underestimated in hatchling poultry.

Research conducted at Novus International, Inc., has clearly documented the microscopic changes of the GIT during the first two weeks of age. The mucosa of the small intestine is the region that experiences most of the growth in the first days of life. From day 5 to 14 there are no significant differences in villus growth among the various intestinal segment (Dibner at al., 1996, 1998).

During the first day after hatch, 80% of residual yolk fat is transferred to tissues and less than 1% remains after two days. More than half of the protein is transferred to the chick during the first two days of life, with virtually no protein remaining after 4 days (Nitsan et al., 1991).



Digestive enzymes first appear during incubation, but their levels increase after hatch. It is not clear, however, whether or not the availability of digestive enzymes limits growth. Hatchlings from lines selected for high 8 week body weight have higher levels of trypsin and amylase at 3 and 9 days of age. Although digestive enzyme levels may not limit growth during the first week of life, the levels and specific activities of the enzymes relate closely to the body's needs. A rapid increases in synthesis and secretion is required to keep up with increasing feed intake (Dunnington and Siegel 1995; Nitzan et al., 1991; Noy and Sklan, 1995; Uni et al., 1995).

Amino acid and hexose transport systems in enterocyte cell membranes develop immediately before hatch and increase in number during the first week of life. Transport system capacities appear to be regulated to match nutrient inputs. Any decrease in the relative mass of gut tissue, with its high metabolic requirements and short epithelial cell life span, could represent a significant improvement in overall maintenance requirements. In restricting diets, an increase in nutrient absorption rate and nutrient transporters compensates the reduction in intestinal mass.

The GIT of young birds does not use ingredients such as tallow with the same efficiency as mature birds. Low lipid digestibility is associated more with maturation of the bile salt synthesis and reabsorption systems than with deficiencies in lipase. Saturated fats of long chain are among the most difficult fats to digest. Digestibility of relatively unsaturated fats, such as soybean oil, is much higher and not as much improved with age.

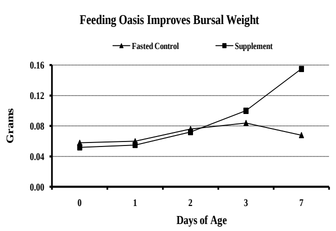
Development of the Immune System

Early feeding promotes the maturation of the immune system by affecting endogenous hormones or other immunomodulators, and by providing antigens for a full differentiation of the primary immune cells (lymphocytes B).

The primary immune organs (bursa and thymus) are populated by lymphoid tissue at hatch. The lymphocytes in the bursa are committed B cells capable of expressing only IgM. Later development of the bursa results in the appearance of circulating IgA and IgG. The migration of lymphocytes through the thymus occurs in waves during embryonic life, and by the time of hatch these lymphocytes have already populated secondary immune organs and the lamina propria and epithelium of the intestine. The cell-mediated immunity is fairly developed at hatch; however, T cells express their cytotoxicity capacities shortly after hatch .

The secondary organs (cecal tonsils, Harderian gland, Meckel's diverticulum, spleen and the lymphoid tissue of the intestinal and respiratory systems primarily) are not fully developed at hatch. Further colonization by B lymphocytes, or the development of lymphocytes already present, causes the maturation of these organs in the weeks following hatch.

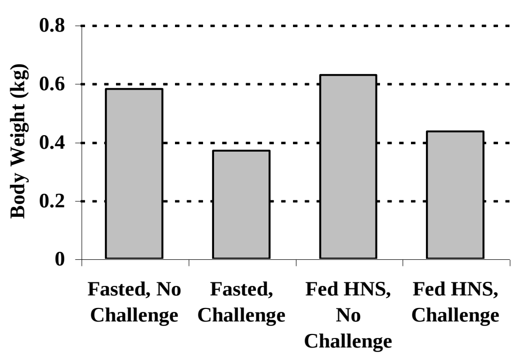
The lymphoid tissue associated to the GIT develops soon after hatch. Maternal IgG and protects chicks in the first week of life. IgA and IgA reach adult levels a few weeks after hatch. Although no scientific information exists yet, close to 80% of the immunoglobulin-producing cells are located in the intestinal mucosa in poultry. Tissue from the lamina propria with impaired lymphocyte response may be easily targeted by infectious agents, such as *Eimeria*, that produce subclinical infections and reduced production. To a certain extent, the limit between disease and normality in commercial poultry involves an economic perspective. This is clearly seen with the level of pathogenicity accepted to decide the use of an anticoccidial treatment in a flock.

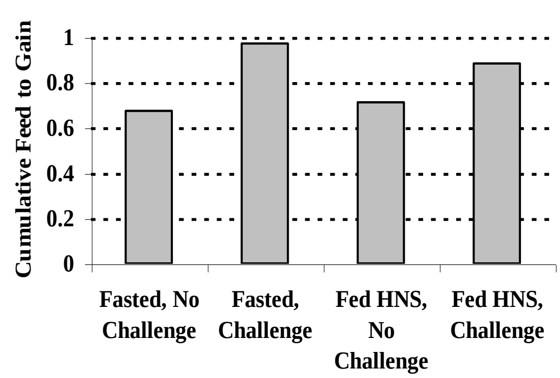


Feeding chicks a hydrated nutritional supplement (OASIS) for the first 2 days of life improves body and bursal weight at 3 week. These data support the concept of feeding early a balanced nutritional supplement to achieve maximum performance and reduce health risks by increasing immunity. In addition, a OASIS may provide a vehicle for early, controlled exposure to antigens by secondary immune tissues to promote their quick and optimal development.

Effect of Early Nutrition on Coccidiosis

A recent study in our laboratories has shown that early feeding of a OASIS improves the performance of specific pathogen free birds during a coccidiosis challenge using a 100x level of a commercial vaccine (CocciVac®, Mallinckrodt Veterinary), when compared to control, fasted birds (Dibner et al., 1998).





Early feeding of a OASIS translates into less body weight loss after coccidiosis vaccine challenge and better cumulative feed to gain when compared with birds which had been fasted on the first two days of life and then challenged on day 6.

The cocidiosis challenge model was used to impose a non-specific stress on the bird, and the results suggest that birds given an optimal nutritional formulation immediately after hatch will better cope with the environmental challenges encountered in the poultry facilities. Similar results were observed in turkey poults fed a OASIS and challenged to poult enteritis and mortality syndrome (Edens et al., 1999)

Competitive Exclusion

This term involves the administration of microflora from adult birds to recently-hatched chicks to quickly establish a mature intestinal (cecal) microflora capable of preventing *Salmonella* colonization. The Food and Drug Administration (FDA) encourages the use of direct fed microbial (DFM) bacteria instead of probiotics. Different genera of bacteria confer this protective effect. Yet, the analysis and characterization of these protective bacteria have proven to be difficult (Stavric and D'Aoust, 1993).

There is evidence that optimum protection requires the use of large mixtures of live bacteria rather than single bacterial strains, or simple mixtures with few types of live or killed bacterial cells. Intestinal anaerobes and facultative anaerobes that produce inhibitory concentrations of short-chain volatile fatty acids (lactic, propionic, succinic acids), and have hydrophobic properties qualify as effective competitive exclusion bacteria for *Salmonella* control. Since a standard protocol for selection of DFM bacteria is not available yet, the selection techniques and criteria remain variable. Cecal material that successfully protects chicks may contain, on a per gram basis, approximately 10^8 lactobacilli, 10^6 coliforms, 10^4 fecal streptococci, and more than 10^9 anaerobes including *Bacteroides*, *Bifidobacteria*, *Clostridia*, *Eubacteria*, *Fusobacterium*, *Propionibacteria*, *Veilonella* sp and several Gram-positive cocci (Stavric et al., 1991; Hinton, 1994).

Also combinations of live cultures with compounds such as complex sugars that are digested only by beneficial microorganisms, such as *Bifidobacteria* spp., but not pathogenic bacteria, such as *Salmonella*, have been tested. However, no reduction in the number of *S. typhimurium* was found in young chicks or chickens ready to slaughter that were fed these combinations (Bailey *et al.*, 1991; Oyarzabal and Conner, 1996).

Presently, there are two undefined (Broilact® and Aviguard®) and one defined (Preempt™) competitive exclusion products in the US market. A third undefined culture (Mucosal Starter Culture™) has a pending approval by the FDA. Some of the claims of these products are the protection of chicks against *Salmonella*, a reduction in the viscosity of the ileal contents, and the increased of propionic acid in the cecal contents. Even an increase in metabolizable energy value of the feed by 1.6% has been claimed. However, the use of these compounds is not generalized yet. When assessing new approaches for *Salmonella* control in a poultry integration, several measures are incorporated simultaneously and it is difficult to separate the impact of a single measure in the overall results (Schneitz et al., 1998).

Summary

Hatchling poultry undergo a shift from blood borne to oral nutrition after emergence from the shell. The presence of residual yolk may be sufficient for survival but not for optimum growth. A delay of even a day in the provision of food and water can result in substantial reductions in early growth of the gastrointestinal tract, liver and pancreas -the supply organs. Therefore, chicks must have an oral intake of high quality nutrients to achieve their maximum growth potential. Early intake of carbohydrates is required for maturation of the GIT and better utilization of amino acid and other nutrients.

The immune system may also be compromised by delayed access to quality feed. Better performance has been recorded in birds fed Oasis before being challenged with a commercial coccidiosis vaccine. This improvement in overall immunity might also apply to other bacterial or viral diseases. The excitement of these results warrants further investigations.

The ban of antibiotics in the European community has restarted the search for bacterial cultures that can competitively exclude not only *Salmonella* but other pathogens from the GIT of poultry. Since early application of these cultures is paramount for their success, early nutritional supplements can both improve the bird's immune reaction and help deliver those cultures.

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