The objective of this presentation is to establish the importance of reliably estimating the impact of enzyme addition upon the caloric level of poultry feeds. Energy has become a major limiting factor for efficient poultry production. While the conversion of vegetable and by-product animal proteins into poultry meat and eggs has always required significant inputs of energy, such was always readily available at reasonable cost from grains and available fats. The expansion of the bio-fuel generation has, seemingly permanently, altered our easy access to energy. If enzyme supplementation is to be credited as a reliable source of additional calories, the quantitative assessment of such is clearly essential. Unfortunately, metabolizable energy (ME) determinations involve a minefield of variations and experimental artifacts in which it may be questioned whether the caloric uplifts proposed for a given enzyme can in fact be reliably determined. As a separate issue, increased interest is being given to possible enzyme effects on bird health, thus implying increased involvement (or decreased involvement) of the immune system. Immune responses are energetically demanding, so a reduction in the severity of a challenge would reasonably be expected to decrease energy expenditure, making the spared calories available for production. However, this sparing would be independent of ME. Whether or not a given “calorie” is absorbed is independent of the relative efficiency of its subsequent utilization. Thus, energetic expenditures for maintenance (i.e., maintenance of health) are a function of net, not metabolizable energy. Reconciling the 2 so as to describe any caloric uplift solely in terms of ME requires judgment on the part of the nutritionist. Clearly, traditional ME assays are inappropriate as (1) they are of decreasing reliability at the lower levels of caloric uplift, and (2) do not take into account any improvement in net energy. The arbitrary selection of an age at which to conduct any such ME study brings additional questions.

Key Words: enzyme, metabolizable energy, net energy, health, immune response

Phytases have been in commercial use for over 20 years. Initially, P pollution abatement was the primary incentive for incorporating phytase into monogastric diets. However, today it is almost exclusively used for formulation savings, principally due to reduced use of inorganic phosphates; although some users also credit the enzyme with energy and amino acids, thereby increasing the savings. Initially there was only one phytase available, derived from Aspergillus niger, whereas today there are offerings from Peniophora lycii, E. coli (native and evolved), Citrobacter spp and Butiauxella. The enzymological characteristics of these enzymes differ quite markedly and as a result the values ascribed to them (in the form of matrix) differ per unit of activity employed. Nevertheless they all perform the same function - destruction of inositol hexakisphosphate (IP6) and as a result production of phosphate. Since IP6 is a potent anti-nutrient, its destruction yields benefits beyond the provision of phosphorus. In many parts of the world the dosage of phytase employed has been increasing significantly, partly to realize the financial benefits of increased P release, and partly to take advantage of the improved performance gained through extra-phosphoric effects of the phytase. The ability of the phytase to degrade IP6 and thus the value it creates is, however, very much dependent upon a multitude of nutritional factors including dietary content of vitamin D, Ca, P, fat and the presence of coccidiostats. Furthermore the release of P is dependent not only upon the dosage of the phytase, but the dietary content of IP6 and its susceptibility to attack. Susceptibility is very much dependent upon the ingredients employed in the ration. Thus phytase should not be considered as a commodity since its value is not constant and varies with each application. The maximum value extracted from a phytase is through consideration of the diet in which it is employed and adjustment of the matrices used if deemed necessary.

Key Words: phytase, efficacy, ingredients, phytate

The recent spike in the price of energy has led to increased interest in the use of enzymes to increase the energy utilization of laying hen diets in an attempt to reduce dietary costs and further enhance the efficiency of egg production. Effective evaluation of energy releasing enzymes is critical to their use and implementation of energetically efficient diets. One concern with the evaluation of energy enzymes in laying hen diets is the cost, in both time and resources, to properly validate effectiveness. Energy responses have typically been evaluated using a performance or feed efficiency model, but questions remain concerning this approach as hens no longer eat to meet energy needs. Energy restriction does typically lead to a reduction in performance, but these effects can be masked for several months as the hens seem to devote dietary nutrients to egg production at the expense of maintaining body fat. In an attempt to validate the energy releasing efficacy of enzymes, a holistic approach to energy metabolism was investigated using a shorter term feeding experiment. Energy utilization was divided into 3 categories, productive energy, maintenance energy and storage energy. Laying hens were fed one of 3 diets, containing 2,880kcal/kg (PC), 2,790kcal/kg (NC) or 2,790kcal/kg with a commercial energy enzyme (NC+E). There were no significant differences in egg production or relative body weight change over the 12 week feeding period. At the end of the experiment, abdominal fat pads were weighed to estimate fat storage. Reducing dietary energy by 90kcal/kg significantly reduced fat pad weight (approximately 40% reduction). Enzyme addition to the NC diet restored the reduction in fat pad to that of the PC fed birds. Although there were no differences in, productive or maintenance energy over the relatively short time frame of the experiment, the differences in energy storage, as indicated by the fat pad weight, validates both the differences in dietary energy and enzyme supplementation. Energy utilization is a complex process in laying hens and a holistic approach can be used to cost effectively evaluate energy releasing enzymes in laying hen diets.

Key Words: energy, laying hen, enzyme

Proteases: The next step in exogenous feed enzymes. B. S. Lumpkins,* Southern Poultry Research Inc., Athens, GA.

In the past 10 years the poultry industry, from the feed aspect, has seen massive changes in how diets are formulated. These changes have been
due to the rising cost of feed ingredients making low cost formulation a much more complex task for nutritionists. The rising feed cost has opened the door to the production, research and use of new products to help alleviate these costs. Exogenous enzymes (i.e., phytase and non-starch polysaccharide enzymes) have demonstrated great potential in improving digestibility of feed ingredients while aiding in lowering feed cost. Furthermore, supplementing diets with enzymes has proven to be effective in decreasing anti-nutritional effects that are seen with the addition of alternative feed ingredients. Currently, protein has become one of the more costly components in broiler diets and has focused research efforts in the direction of improving protein digestibility. Proteolytic enzymes are crucial in digestion to breakdown protein into the amino acids, which the broiler can then utilize. Proteases are by no means a new enzyme and have been around for years. These enzymes have mainly been used in non-agricultural and detergent industry sectors, but the time has come to reap the benefits in poultry feeds. The majority of proteases in the past have been plant derived. The current production of proteases is being improved by using fungal and bacterial means, which has allowed for an increase in production yield while at the same time decreasing manufacturing cost. The improvements in protease production has allowed for a more stable and consistent product, which are extremely important considerations for nutritionists. Another thought to keep in mind when using proteases is that the amino acid availability or uplift among different ingredients is variable. Even though there is a difference in amino acid uplift between feed ingredients, the fact still remains that an exogenous protease will still provide some benefit to protein digestibility and it is up to commercial poultry producers to evaluate the cost effectiveness.

**Key Words:** alternative ingredients, protease, digestibility, protein, enzymes

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178  **Does the use of multiple enzymes improve efficacy?**  A. Batal,* HavePharma Inc., Peachtree City, GA.

The use of exogenous enzymes in non-ruminant diets have the potential to reduce the effect of anti-nutritional factors, render nutrients more available for digestion and absorption, increase energy value of feed ingredients and allow for greater flexibility in feed formulation, thus reducing formulation costs and modulating or stabilizing gut microflora. With the practical use of phytase in poultry diets and due to certain economic conditions, nutritionists are tempted to incorporate more than one type of enzyme in the diets, assuming that independent enzyme effects may be additive. Unfortunately there is limited information in this field and the competition for similar substrate may reduce the benefits provided by single enzymes. While some single enzymes are proposed to promote single effects on a particular chemical component of the diet nutritionist can combine several enzymes to cope with more than one substrate. However, it is clear that enzymes are specific (maintain a given enzyme:substrate ratio) and if similar enzymes are competing for a similar substrate the action of those enzymes would not be additive. While we may have a good understanding of the use of one enzyme alone, the database for the combined use of different enzymes is limited. Nevertheless, knowing that phytases and non-starch polysaccharide enzymes target different substrates releasing nutrients like phosphorus and starch, and are effective in different regions of the gastro-intestinal tract, their indirect benefits may overlap, thus, the combined effect may be complimentary but not directly additive. One also needs to make sure to take into account the compatibility between enzymes to obtain optimal use. Due to lack of precision in identifying the action of some given enzymes, the effect of one of the enzymes should be fixed while the benefits of the other should be reduced. However, this assumption would impact the cost advantages requiring the knowledge and experience of each nutritionist to decide the correct commercial enzyme recommendations when various enzymes are used in combination.

**Key Words:** supplemental enzymes, nutrient utilization, gut microflora, digestive physiology

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179  **Feed enzymes to optimize the gut ecosystem for peak performance and profitability.**  P. R. Ferket,* North Carolina State University, Raleigh.

Enzyme supplementation of feed has progressed during the past 20 years from rare application to standard practice as enzyme production and feed application technologies advanced. The economic incentive for the use of enzymes in feed has become more apparent as the cost of phosphorus, energy and protein increased. Enzymes are now routinely used to reduce feed formula costs by improving nutrient digestibility and utilization, and allowing for greater dietary inclusion of grain coproducts that contain anti-nutritional factors. However, dietary enzyme supplementation also has a profound effect on the gut ecosystem, thereby affecting its microflora, digestive physiology, and enteric disease resistance. In general, supplemental enzymes enhances foregut digestibility of dietary components that favor the bird, leaving digestive residue as fermentation substrates for symbiotic microflora in the hindgut that competitively exclude pro-inflammatory pathogens. Whereas dietary supplementation of phytase improves nutrient digestibility and retention, NSP-degrading enzymes (endoxylanase and complementary enzymes blends) also increases the variety of non-starch oligosaccharides that serve as substrate for a more diverse and symbiotic microflora in the hindgut. Factors that influence the enzymes effects on gut ecology include feed formulation, feed form, and age of the birds. In addition to optimizing dietary nutrient utilization, strategic use of supplemental enzymes can also promote a more stable gut ecosystem that favors enteric health, peak performance and profitability.

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180  **Influence of feed enzymes on enteric disease.**  A. P. McElroy,* Virginia Tech, Blacksburg.

Intestinal responses to enteric pathogens, the host-pathogen interaction, and the ability to minimize the impact of these on growth and performance in commercial poultry are important areas of research. While for years dietary enzymes have been used to improve nutrient availability and bird performance, less research has been done to investigate modulation of intestinal health and gut integrity by dietary enzymes to improve intestinal response during a disease challenge in relation to its ability to function optimally for immune defense, digestion, absorption, secretion and transport. With increased pressure for reduced antibiotic usage in feed, the role of diets in disease status becomes more important. Results are mixed regarding the benefits of enzyme usage for performance and intestinal absorptive capacity during intestinal disease challenges, predominantly coccidial challenges. While research has clearly demonstrated an influence of dietary enzymes on intestinal microbial populations, which has a substantial effect on intestinal health, less evident impacts of enzymes on intestinal immune responses and direct disease susceptibility are more recent. Dietary enzyme influence on the innate immune system was indicated in a trial evaluating the effect of dietary enzymes on intestinal responses to live coccidia vaccination. A vaccination x dietary enzyme interaction on the number of...
intestinal goblet cells was observed, which could subsequently alter mucin presence and defense to pathogens. Alterations in lymphocyte numbers and mucosal antibodies have also been indicated with enzyme addition to diets. The influence of enzymes on nutrient availability may also have a direct effect on disease status as indicated by increased necrotic enteritis-associated mortality with the inclusion of dietary phytase during a natural exposure of broilers to C. perfringens. This is a complex area of research as the effects of enzymes on enteric disease status involve many other factors influencing the intestinal environment including dietary ingredients and form, pathogen challenge, availability of nutrients for both the host and microbial population, and inclusion of other dietary supplements.

**Key Words:** enzymes, intestinal health, disease

181  **Macroeconomic and feed enzymes: Thinking outside the box.** R. D. Walker,* Performance Plus International Inc., Naperville, IL.

The purpose of this presentation is to analyze the feed enzyme industry from a macroeconomic prospective, to better understand the economics forces that have shaped the past, control the present and predict the future of the feed enzyme industry. In 1925 Clickner and Follwell reported improvements in performance using an enzyme product produced from Aspergillus orizae. The development and application of feed enzymes has followed a very predictable pattern governed by technology and microeconomics. A lag in enzyme production technology created a price benefit ratio too high for commercial application of feed enzymes. Biotechnology provided tools that altered the supply of feed enzymes. The development phase is characterized by large capital investments in technology yielding an explosion of data, with a large number of companies entering the supply chain. Balancing macroeconomic forces of supply demand, cost benefit, commodification and product differentiation determine product price, production and use. A commodity is a class of goods without qualitative differentiation. The M&M theory states that arbitrage causes close substitutes to have the same price. Price of a commodity will stabilize at the average production cost. In the maturity phase, product manufacturers invest large amounts of capital to slow commodification of their products using product differentiation. Product differentiation can be technical or perceptional. In the final phase inefficient manufactures exit the market, with product supply controlled by a few very large companies. Some antinutritional feed enzyme products, such as betaglacans and phytase are in the late development stage. The feed enzyme industry is in the early stage of discovery and innovation with large numbers of new feed enzyme products likely to enter the market in the future to address nutritional applications associated with increased use of food, feed and industrial by products. Supply, price, commodification and product differentiation should continue to follow a predictable pattern.

**Key Words:** macroeconomics, feed, enzymes, commodification, cost