Enzyme supplemented poultry diets: Benefits so far – a review

1Elijah I. Ohimain and 2Ruth T. S. Ofongo

1Agricultural and Veterinary Microbiology Research Unit, Biological Sciences Department, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria
2Department of Animal Science, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria

Availability of good quality feed on a sustainable basis at stable prices is a major challenge for poultry farming, hence alternative feedstock are constantly being sourced. The use of supplemented feedstock particularly cereal by-products is challenging due to the presence of non-starch polysaccharides (NSPs). This review presents opportunities in the use of enzymes to enhance the digestibility of supplemented poultry diets. At 20% inclusion, cereal by-products including wheat offal, rice offal, brewers dried grain and corn offal have been successfully used for the replacement of grains but with the application of enzymes especially xylanase, cellulase, glucanase and phytase. These enzymes reduced anti-nutrients, improve digestibility and utilization of nitrogen and phosphorus and caused a reduction of detrimental microbes such as coliforms and enhanced beneficial microbes including lactobacillus and bifidobacteria. The use of enzymes in poultry feed formulation also improved performance, feed conversion ratio and reduced waste generation. The study concluded by suggesting that enzymes which are not produced by monogastric animals can be supplemented to alleviate the anti – nutrition effects of NSP.

Key words: Bifidobacteria, coliform, digestibility, feed enzymes, lactobacillus, non-starch polysaccharide

INTRODUCTION

Availability of good quality feed on a sustainable basis at stable prices may not necessarily mean enhanced nutrient uptake and well being of the poultry flocks. As a result use of certain feed additives aimed at enhanced performance may also be directed to the well being of the bird. The advent of enzyme supplementation of poultry diets was as a result of the negative effect of wheat and barley based diets on performance, nutrient digestibility and increased cases of dirty eggs in the European poultry industry. The important effects of enzyme supplementation include: improved digestibility of nutrients, reduced small intestine fermentation and increased caecal fermentation (Choc et al., 1999a, b).

According to Bedford (2000a, b); increased microbial activity in the caecum is likely as a result of poorly absorbed products of enzymatic degradation entering the caecum where they stimulate bacterial fermentation. Such fermentation activities in the caecum will bring about release of short chain fatty acids - SCFA- (Pinchasov and Elmaliah, 1994; Marounek et al., 1996; Jorgensen et al., 1996; Marounek et al., 1999; Jamroz et al., 1998; Marounek et al., 1999; Jamroz et al., 2002), alter the pH (Ofongo et al., 2012) of this section of the gut and also release energy which might contribute to the M.E. (metabolisable energy) intake of the bird (Jorgensen et al., 1996). Feeding of fibre to poultry has generally been discouraged primarily because of the negative effects fibre exerts on performance and nutrient utilization. Inclusion of high fibre ingredients is usually limited because of the poor metabolisable energy content. With the use of enzymes tailored at degrading specific constituents of dietary fibre, this could confer several benefits to poultry.

Enzyme use could result in the following;

- Generation of specific low molecular weight carbohydrates in vivo, which in turn produce specific health outcomes in birds.
- De-activation of the anti-nutritive effect of NSP, such as arabinoxylans and β-glucans present in dietary fibre.
- De-activation of other nutrients other than NSP and phytate.
- Degradation of non-conventional feed resources to yield metabolisable energy.

Before discussing the benefits of enzyme supplemented diets, it is pertinent to mention a few of the negative effects of NSP (soluble and insoluble) since they are the main target in enzyme supplemented diets. However, it is proper to state that the aim of this review is not just to present the challenge of anti-nutritive factors in poultry feeds but to emphasize key benefits of enzyme supplemented diets. Also to highlight some potential benefits which suggest additional health advantage that appears implicit but is pertinent.

Anti-nutritive effects of NSPs

The anti-nutritive effects of different NSPs generally do not differ, only in their degree. Of core importance is to distinguish between soluble and insoluble NSPs. The anti – nutritive effect of wheat and rye – which contain soluble pentosans (arabinoxylans), has been reported by Choc and Annison (1992b) and Antoniou and Marquardt (1982). As documented by the authors, the anti – nutritive effects of arabinoyxylans present in these grains is related to increased digesta viscosity. Meaning they store large amounts of water, thus having the ability to swell. The implication of this is a more viscous and sticky digesta, delayed digestion and absorption of nutrients, prolonged intestinal transit time, inconsistency in faeces and sometimes even symptoms of diarrhea are observed (Bedford and Classen, 1992; Choc and
Annison, 1992a; Bedford, 1995; Langhout et al., 1997; Simon, 1998; Silverside and Bedford, 1999). While insoluble NSP increase faecal dry matter, this is not the case with soluble NSP such as pectins (Zander et al. 1988; Hadorn and Wenk 1996). As a result, the kind of NSP present in the diet determines faecal dry matter content. In view of this it may be a vital sign to a poultry farmer when sticky droppings with low dry matter are observed within the flock to pay attention to the type of diet in use and have a rethink on the ingredients that constitute the diet on one hand. On the other hand, think about supplementing such diet with enzymes to alleviate potential problems associated with sticky droppings and other performance problems that may arise. The problem of high digesta viscosity elicited by soluble NSP causes reduced passage rate of digesta in the small intestine i.e. reduced transit time from mouth to cloaca (Almirall and Esteve-garcia, 1994; Dänicke et al., 1997). Furthermore is the lesser mixing of digestive enzymes with their specific substrates and reduction of enzyme activity (Choc and Annison, 1992b; Almirall et al., 1995). In line with some authors; (Peterson and Aman, 1989; Almirall et al., 1995; Bedford and Morgan, 1996) the cage effect elicited by insoluble NSP cannot be over emphasized. Their presence as indigestible cell wall structures encloses other nutrients affecting the digestion and absorption of otherwise highly digestible nutrients such as fat and protein. So far, it is evident that while insoluble NSP elicit their anti – nutritive effect by reducing nutrient concentration in the diet, soluble NSP on the other hand increase digesta viscosity developing a gel – like environment.

The net effect of this is reduced nutrient digestion in the small intestine by reduction in the mixing capacity between digesta and enzymes secreted by the small intestine and pancreas (Ward, 1996). Digestion and absorption of nutrients takes place in the liquid phase of digesta. Action of digestive enzymes-feed interaction, absorption and exchange of nutrients take place at this liquid phase. The viscosity of this liquid phase is influenced by the water solubility; size and structure of the NSP and the absolute amount present (Choc and Kocher, unpublished data). Viscosity measures and rate of gastric emptying is also confined to this phase. Soluble NSP reduce the rate of nutrient absorption from the small intestine through its effect on luminal viscosity (Choc and Annison, 1992; Bach Knudsen et al., 1993). The slow passage rate of digesta decreases feed intake, thereby reducing nutrient intake which culminates in declined nutrient availability. Published works of some authors has shown that besides digesta and nutrient availability, NSP also affects tissues of the digestive tract and small intestine fermentation of microbial populations. Smits et al. (1997) reported an enlarged small intestine and hind gut mass after the addition of the viscosity increasing carboxymethylcellulose (CMC) in broilers diet. According to Choc et al. (1996) and Simon, (1998); all these negative effects bring about lower energy intakes that are below the animal’s requirements depending on the NSP content. Consequently inducing decrease in animal performance and gut health.

Effect of exogenous enzymes on nutrient digestion and absorption

Several studies with enzyme supplemented diets have yielded varied results depending on the NSP component of the diet in question. However, it must be mentioned that some of the varied results may be due to several factors encountered by the respective authors. But of core importance is the fact that NSP hydrolyzing enzymes do hydrolyze NSPs to varied degree and several results have indicated a reduction of the negative effect of NSP (either soluble or insoluble) on nutrient digestion and absorption, bird performance, FCR, etc. The report of Choc and Annison, (1992a) indicated that supplementation of wheat pentosans (NSP) into a control diet influenced pre - cecal digestibility of starch and nitrogen. However, the starch and protein digestibility in the study decreased by about 15% and 18%, and that of fat by about 26%. The explanation for the decreased utilization was observed in increased digesta viscosity and the lower mixing of digesta with digestive enzymes (Antoniou et al., 1981; Fengler et al., 1988). Often than not, the benefit of enzyme supplemented diets is more evident in cases where the problem of viscosity is paramount. This is not to say that supplementation of diets with less or no problem of viscosity does not yield good result but rather, the benefits of enzyme supplementation are apparent in terms of weight gain and FCR in such diets than with viscosity reduction (Ofongo et al., 2011).

The viscosity of NSP depends on their solubility and molecular weights. Solubility of NSP is dependent on the chemical structure of the NSP and their association with the rest of the cell wall components. However, viscosity is not specific to the sugar composition or linkage types present in the NSP. Furthermore, the physical effect of viscosity on nutrient absorption also appears to be similar regardless of the source of NSP. Elevated levels of soluble NSP in the diet increases digesta viscosity, thereby leading to changes in the physiology and ecosystem of the gut as previously reported (Angkanaporn et al., 1994; Choc et al., 1996). Soluble NSP lower the oxygen tension in the small intestine thereby providing a relatively suitable environment for the establishment of fermentative microflora. The rate of diffusion of substrates and digestive enzymes is subsequently decreased thereby hindering their effective interaction at the mucosal surface (Ikegami et al., 1990). The interaction between soluble NSP and the glycoalyx of the intestinal brush border results in thickening the rate-limiting unstirred water layer of the mucosa. This process results in the reduction of the efficiency of nutrient absorption through the intestinal wall (Johnson and Gee, 1981). It is at this junction that the benefit of enzyme supplemented diets is more evident where viscosity is in question.

The viscous property of NSP is a major factor in the anti-nutritive effect of NSP in monogastric diets. This is supported by the wide spread use of enzymes in monogastric diets. A large increase in fermentation in the small intestine of broilers by adding soluble NSP in the diet has been observed (Choc et al., 1996). It was thought initially that the increased production of VFA would increase the energy content of the feed. But due to drastic changes in the gut ecosystem, the net effect was decreased nutrient digestion accompanied by poor bird performance. Use of glycanase overcame this problem. The enzymes cleave the large molecules of NSP into smaller polymers, thereby reducing the thickness of the gut content and increasing the nutritive value of the feed (Bedford et al., 1991; Choc and Annison, 1992). Research has shown that viscosity is due to soluble pectins or β-glucans that even in
small amounts markedly increase intestinal viscosity (Annison and Choct, 1991; Bedford and Morgan, 1996). Inclusion of certain NSP to poultry diets reduces the digestion of starch, protein and lipids as mentioned earlier. However, this is mainly associated with viscous sugars that impair the diffusion and transport of lipase, oils and bile-salts micelles within the gastrointestinal chime (Smits and Annison, 1996). Moreover, viscosity may hinder the interaction between substrates in the small intestine and lipase or bile salts and impair transportation of hydrolytic products to the epithelial surface. It has been suggested that β-glucans found in barley and oats create complex bonds with digestive enzymes thereby decreasing their activities (Ikeda and Kusano, 1983). Digestibility of fat is highly affected by the presence of NSP in a diet. Reason for this could be the essential nature of the enzyme lipase in fat (Krogdahl & Sell, 1989) digestion. In the digestion of fat, the enzyme activity constitutes the most important limiting factor. Lipases are built up in the pancreas and secreted into the distal duodenum. By the process of continuous peristaltic movements in the small intestine, a mixing of digesta and pancreatic enzymes is produced (Sklan et al., 1978). It is understood that with higher digesta viscosity, this mixing is negatively impaired (Smulikowska, 1998). However with age, secretion of lipases into the duodenal lumen rises slower than other pancreatic enzymes (Noy & Sklan, 1995).

This could be an eye opener to the age-dependent varying effect of anti nutritive effect of NSP (Veldmann and Vahl, 1994; Viveros et al., 1994). The ability of certain NSP to bind bile salts, lipids and cholesterol has been mentioned. This property of NSP influences lipid metabolism in the intestine. According to Simon (1998) this property is more pronounced when fat from animal source is included in the diet. The continuous “drain” of bile acids and lipids by sequestration, (Ike et al., 1989; Iekami et al., 1990) and increased elimination as faecal acidic and neutral sterols, ultimately influence the absorption of lipids and cholesterol in the small intestine. These effects can lead to major changes in the digestive and absorptive dynamics of the gut, with a consequent poor overall efficiency in nutrient assimilation by the animal. These findings further illustrate why improved fat digestion and absorption may be obtained in certain studies with enzymes and which may not be the case in other studies. Another important factor affected by enzyme supplementation is dry matter. Dry-matter digestibility (DMD) in animals ranges from 50 to 80%; the remainder of the dry matter (DM) is lost via the excreta. In the poultry industry, this represents 9 000–22 000 t of high-N manure per million birds annually (Choct, 1997).

In densely populated parts of the world, such as Asia and Europe, excretion of large amounts of organic matter (OM), especially that containing high levels of nitrogen and phosphorus, presents serious environmental problems. In recent years, enzymes have been widely used in monogastric diets to increase nutrient digestibilities and to decrease nutrient waste in the excreta. The effect of enzyme supplementation on DMD in pigs and poultry depends on the type of diet and the type of animal: increases in DMD range from 0.9 (Schutte et al. 1995) to 17% (Annison and Choct, 1993) in poultry and from 0 (Taverner and Campbell, 1988) to 5.2% (Schmitz, 1995) in pigs. Choct (1997); compared the efficacy of a glycanase product in wheat known to have low metabolisable energy and normal wheat in broiler diets. In that study, enzyme supplementation improved DMD by 17%, apparent metabolisable energy (AME) by 24%, and feed-conversion rate (FCR) by 31%, which coincided with a 50% reduction in digesta viscosity. Invariably, better nutrient digestion and absorption in the animal will culminate in lesser environmental problems due to high levels of nutrient waste (nitrogen and phosphorus) in excreta of poultry and pigs.

### Reduced excreta moisture

The problem of wet excreta is an enormous snag in the poultry industry, especially in the case of laying hens, where increased percentages of dirty eggs are associated with wet droppings as previously stated. In many countries, dirty eggs are unsuitable for sale as second-grade eggs and therefore represent a substantial net loss for the industry. Wet droppings may increase the production of gases (that is, ammonia and hydrogen sulfide) and fly and rodent populations in pig and poultry sheds. These can affect the well-being of the animals by increasing stress and lowering air quality, and they can affect the health of the staff that works in the shed (Donham, 1995). A reduction in the moisture content of poultry excreta is often noted when glycanases are included in the diet. In a trial reported by Choct and Annison (1992), the authors added an equivalent of 4% soluble NSPs to a sorghum-based broiler diet. Bird performance was significantly depressed and the excreta moisture increased from 47.4% (in birds fed the basal diet) to 64.5%. On supplementing the NSP-enriched diet with three different commercial glycanase products performance was improved, but their effectiveness in reducing the moisture levels of the excreta differed from 10 to 29%. This supports the view that different glycanases have similar performance enhancement effects in monogastric animals but the site of the breakdown of the NSPs in the gut and the molecular sizes of the released products differ. These important differences determine the efficacy of an enzyme in reducing excreta moisture. Over de polymerization of NSPs may yield high amounts of osmotically active oligomers in the gut, which in turn increase the moisture content of the excreta (Choct and Annison, 1992). Bruau et al. (1993) examined the effects of adding enzymes to broiler diets containing different varieties of barley and reported reductions of as much as 50% in the incidence of sticky and watery droppings. The severity of diarrhea in young pigs fed barley-based diets has been reported to be largely overcome by the use of β-glucanase (Inborr and Ogle, 1988).

### Gut microflora activity

Results from recent studies demonstrated that addition of soluble NSP in broiler chicken diets significantly elevated fermentation in the small intestine. However, subsequent in vivo de polymerisation of the soluble NSP using glycanases almost totally overcame this problem. Normally, facultative anaerobes make up nearly the entire cecal microflora of the chicken (Salanitro et al., 1977). Soluble NSP increase the residence time of digesta in the intestine (Van der klis and Van Voorst, 1993), thus bringing about a decrease in oxygen tension and favour development of anaerobic microflora. It is clear that proliferation of some anaerobic organisms can lead to production of toxins (Simon, 1998). Intestinal bacteria are
known to produce enzymes (cholyl taurin hydrolase) which deconjugate bile salts which are essential for digestion of fat (Simona, 1998). In the light of fat digestion, modulation of gut microflora by enzyme supplementation may eventually enhance fat digestion. Soluble fibre from cereals (especially wheat and barley) had an anti-nutritional effect on the GIT, leading to decreased feed conversion and increased moisture and organic matter in faeces. The quality of the litter was also reduced (Choct and Annison, 1992). The use of dietary exogenous polysaccharidases that hydrolyse polysaccharides to reduce the anti-nutritive effect of soluble NSP has been reported (Bedford and Schulze, 1998). These enzymes reduce the viscosity of the intestinal contents, while the oligosaccharides produced may act as prebiotics. In chickens, exogenous enzyme addition to diets has been shown to reduce susceptibility to infections with Salmonella (Al-Rawashdeh et al., 2000; Fernandez et al., 2000, 2002). It is noteworthy to mention that these mechanisms through which soluble NSP elicit their anti – nutritive action are all interrelated. They are all dependent on the polymeric nature of the NSP. Once the NSP polymers are cleaved into smaller fragments, their anti-nutritive activity is largely eliminated.

The significance of gut microflora to the nutrition of chickens cannot be overemphasized. Excessive fermentation in the small intestine may interfere with the normal physiological process of nutrient digestion. As often noted, adding antibiotics to poultry diets that have highly soluble NSPs markedly improved bird performance (Misir and Marquardt 1978a). Elevated levels of intact soluble NSP detrimentally increased the activity of fermentative microorganisms in the small intestine (Choct et al. 1996). Xylanase supplementation largely eliminated fermentation in the small intestine and improved the performance of the birds. A sudden change in the gut ecology (from an aerobic or facultative anaerobic environment to a strictly anaerobic one) may induce gastrointestinal stress and severely affect the normal physiological processes. According to Morgan and Bedford (1995) coccidiosis problems could be prevented by using enzymes. Birds fed a wheat-based diet with and without glycanase supplementation showed vastly different responses to coccidiosis challenge. Growth was depressed by 52.5% in the control group but by only 30.5% in the enzyme group, which also had a much better lesion score.

An increase in digesta passage rate and a reduction in excreta moisture are often noted when glycansases are added to poultry diets, which may be detrimental to the life cycle of the organism. To further add; in a recent study, ofongo et al. 2012 recorded a general shift in the gut microflora of broilers fed enzyme supplemented maize -soybean diet containing 200g/kg of diet wheat offal. This was emphasized by Ohimian and Ofongo (2013). Results from that study showed that coliforms and E. coli were consistently higher (P<0.05) in the control (maize – soy bean meal diet) than feeds supplemented with wheat offal with or without enzyme supplementation in the crop, ileum and caecum. The population of coliform and E. coli were lowest in the diet containing wheat offal and Roxazyme G2 G. Their results also showed that E. coli accounted for nearly 100% of total Coliform in the gut of the birds used for the study. The overall pattern of the results indicated that the wheat offal in the poultry diet stimulated Lactobacillus growth which was further enhanced by the addition of enzyme. The stimulation of Lactobacillus by the diet containing wheat offal with or without enzyme coincided with reduction in Coliform and E. coli population, which suggests the efficacy of diet composition and enzyme supplementation in controlling pathogenic organisms in broiler chickens.

**Modification of gut physiology**

Poultry has a comparatively short digestive tract with a small hind gut and a caecum in comparison to the whole digestive tract (Labier & Leclercq, 1994). Therefore the absorptive surface in the small intestine plays an important role, especially in broilers. In conjunction with the above described influences of NSP and their viscosity effect on nutrient digestibility, morphological alterations in the digestive tract have been observed. Extension and elevated weight of the whole intestine, with heightened ceca and pancreas have been reported (Savory, 1992; Van der klies and Van voorst, 1993; Veldmann and Vahl, 1994; Viveros et al., 1994; Almirall et al., 1995; Jørgensen et al., 1996). Other effects are, shortened and thickened microvillus (Best et al., 1999; Jaroni et al., 1999b). Conversely, Rolls et al. (1978) did not detect an increased epithelial regeneration rate in connection with the application of wheat bran into a NSP poor diet, neither with conventional animals nor with abacterial animals, which indicates that the NSP content of the diet is not per se responsible for morphological alterations. The increased intestine weight was ascribed to morphological changes of mucosal of the intestinal wall, namely the increased proliferation of enterocytes and globlet cells (Viveros et al., 1994; Best et al., 1999; Langhout et al., 1999).

The higher rate of globlet cells formation was adduced to an increased formation of mucin and a higher loss of carbohydrates and proteins, of which mucin exists in great parts. Since the unstirred water layer that consists of water and mucin serves as a protective film between digesta and enterocytes (Moran, 1985), such enlargement were thought to be caused by mucin production. Dänicke et al. (2000) corroborate that with a soluble NSP rich diet for broilers, significant higher protein synthesis rates in tissues of the small intestine was recorded. The authors suggested a higher nitrogen secretion into the intestinal lumen and consequently higher endogenous nitrogen losses. In order to meet the need for regeneration of epithelial cells of the digestive tract entail increased protein and energy demand by the animal for this purpose. Therefore available proteins are not utilized for accretion of protein in the case of broilers or egg production in laying hens (Simon, 1998).

**Least cost formulation by means of Addition of agro – industrial by products**

The nutritive value of cereal grains for poultry varies greatly, and no suitable assays are currently available for rapid in-mill testing. For instance, the variability in the AME of wheat for poultry can be as great as 4 MJ/kg DM (Sibbon and Slinger 1962; Rogel et al. 1987). This problem can be largely overcome by using glycansases to bring the AME of different wheats to comparable levels (Choct et al. 1995). In a recent trial, enzyme supplementation increased the AME of wheat from 13.7 MJ/kg DM to 14.5 MJ/kg DM and reduced...
High levels of dietary fibre and as such has negative impact on soybean and, particularly, grain byproducts contain relative levels of insoluble fibres through enzyme supplementation. Solid state fermentation with Aspergillus niger and Trichoderma viride enzymes supplementation allows the wide range of ingredients to be used in a diet for a desired outcome. This gives the producer a great deal of flexibility in formulating a nutritionally balanced, least-cost diet. An increased precision in least cost feed formulation, hence a more uniform performance of the birds. Enzymes also allow a wide range of ingredients to be used in a diet with a desired outcome. This gives the producer a great deal of flexibility to formulate a nutritionally balanced least-cost diet.

Benefits in laying hens

Generally, growing chicks and broilers are more sensitive to wheat pentosans than laying hens; hence wheat is prevalent in the diet of commercial layering hen, nearly without any negative effects being observed. There have generally been no restrictions imposed on its dietary inclusion rate. Barley, rye, triticate and oats are other feed alternatives utilized in feeding laying hens in Europe. But these grains in spite of their suitability have their individual and respective short falls in terms of nutrient availability and nutrient digestion and absorption in laying hens (MacIsaac, 2002; Coon, 2001a,b; Jeroch et al., 1999; Jeroch, 1993; Chot and Annison, 1992a; Jeroch and Peter, 1987; Ruiz et al., 1987; Englert and Cummings, 1985; Ward, 1982; Misir and Marquardt, 1978a, b; Moran et al., 1969; Casier and Soenen, 1967; Wieringa, 1967). According to a study carried out by Simons and Versteegh (1993) addition of phytase to layer diets, increased egg production, positive effects on egg weight and tibia ash were also noted. Generally it is expected that egg quality and problems of wet vent and dirty eggs are better addressed by enzyme supplemented diets for laying hens. Several authors have worked with enzyme supplemented diets for laying hens and obtained varied results as reviewed by Pianka (2007).

Hidden or Unseen potential benefits

It is now well recognized that ingredients such as maize, soybean and, particularly, grain byproducts contain relatively high levels of dietary fibre and as such has negative impact on feed digestibility and performance. This allows for the option of using enzyme to improve growth and feed: gain (Ofongo et al., 2011; Cowieson, 2005) or, alternatively, to use it in diets with lowered levels of energy and protein/amino acids, with higher by-product levels, to maintain performance with lower net feed costs. Breaking down the gel form characteristic of soluble fibres through enzyme supplementation allows the birds’ digestive enzyme to function more efficiently. This improves starch, protein, fat, amino acids and energy digestibility. Coccidiosis control, change in gut microflora (Ofongo et al 2012) and possible elimination of certain diseases are another hidden benefit of enzyme supplemented poultry diet. Ohimian and Ofongo 2013 reported that the stimulation of Lactobacillus by diet containing wheat offal with or without enzyme coincided with the reduction in Coliform and E. coli population. Results from the study suggest the efficacy of diet composition and enzyme supplementation in controlling pathogenic organisms in broiler chickens. An increase in digesta passage rate and reduction in excreta moisture are often noted when glycansases are added to poultry diets, which may be detrimental to the life cycle of micro organism. Enzyme supplementation largely eliminates fermentation in the small intestine and improves nutrient digestibility and the well-being of birds. With An increased precision in least cost feed formulation, hence a more uniform performance of birds can be obtained.

Conclusion

Based on the age, type of diet and ingredient available to compound feed; enzymes can be supplemented to quantitatively supplement endogenous digestive enzymes (Proteases, lipases and Amylases) of mono gastric animals. Enzymes which are not produced by mono gastric animals can be supplemented to alleviate the potential and obvious anti – nutrition effects of NSP that can be present in various feed ingredients (β-glucanases, Pentosanases and Phytases). Notwithstanding, the outcome of enzyme supplementation which is improved performance has other upshots of benefits apart from least cost formulation of feed to shifting the type and population of gut microflora present in the gut.

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