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# Application of Xylanases and $\beta$ -Glucanase to Improve Nutrient Utilization in Poultry Fed Cereal Base Diets: Used of Enzymes in Poultry Diet

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## Abstract

The  $\beta$ -glucanases and xylanases have been used as feed additives for many years and their ability to improve the performance of poultry has been demonstrated in numerous publications. Starch, proteins, and lipids easily degraded in the bird's digestive systems, whereas the major parts of soluble and insoluble non-starch polysaccharides remain intact because of the lack of suitable enzymes. The positive nutritional effects achieved by the dietary supplementation of exogenous enzymes are proposed to be caused by several mechanisms. First, it has been shown that the anti-nutritive effects of viscous cereals such as barley, wheat, rye, oats, and triticale are associated with raised intestinal viscosity caused by soluble  $\beta$ -glucans and arabinoxylans present in those cereals. These problems are overcome by dietary supplementation of  $\beta$ -glucanases and xylanases. It is assumed that the ability of  $\beta$ -glucanases and xylanases to degrade plant cell walls leads to release of nutrients from grain endosperm. Another mechanism that has a positive influence on the nutritive value is the prebiotic effect achieved via the oligosaccharides produce and release. They formed during the degradation of cell wall carbohydrates by supplemental enzymes. In the gastro intestinal tract, the oligosaccharides derived from plant cell wall digestion that is resisting to the digestive enzymes, reach to the large intestine and support from proliferation of the beneficial microorganism. In conclusion, due to the complex structure of cereal grains, it has been shown that appropriate combinations of the different enzyme can obtain improved performance.

**Keywords:** Cereal; Exogenous enzyme; Poultry; Viscosity

## Overview

Enzymes are produced by living organisms as natural catalysts, which accelerate biochemical reactions in living organisms, including single-celled organisms, plants, insects

and animals. So far, over 3000 different enzymes have been discovered. The enzymes are protein-based and form amino acid chains with a peptide bond. Enzymes, by attaching to the substrate, accelerate or facilitate the reactions and reduce the activation energy to start the reaction. As a result, the amount of reactions progresses increased. The activity of the enzymes depended to its three-dimensional form and the position of the amino acids within the molecule, which produces catalytic properties of the enzyme. Conditions that lead to significant changes in the enzymes' structure often lead to reduced activity. As a result, enzymes are very sensitive to the environmental condition in which they function and at optimum temperatures and pH they have the best performance [1].

## The Role of Enzymes in Poultry Nutrition

In the process of poultry production, the feed will include the highest cost, and the profitability of the unit will depend on the relative cost and nutritional value of food. Often limiting factor in setting diets is the ability of the bird to digest different parts of the food, especially the raw fiber. Despite the current studies, the potential nutritional value of food at animal level has not reached its full potential. Therefore, the main reason for the use of enzymes in poultry nutrition is to improve the nutritional value of food. So that by adding the enzyme to the feed, the digestive process is improved and thus the nutritional efficiency increases. For the most part, the use of enzymes is justified in the feeding of poultry [2].

- Enhancing the availability of starch, proteins, and minerals enclosed by cell walls and not available for endogenous enzymes, or by complex anti-nutritional agents the internal enzymes are not able to digest them,
- Disseminating the anti-nutritional factors found in feed components, these materials, which are not digested primarily by internal enzymes, can disrupt the natural process of digestion and reduce the use of nutrients by the bird,

- Breaking certain chemical bonds that are not digestible by the internal enzymes, thus giving more nutrients to the bird,
- Reducing the variation in nutritional value of an oral substance and increasing the correctness of the formulation of the diet and
- Contributing to the endogenous enzymes of young birds, since in young birds the levels of endogenous enzymes are inadequate [2].

## Worldwide Use of Enzymes

Current estimates of the use of enzymes in poultry diets indicate that roughly 65 percent of cereal-based poultry diets use a type of cell wall degrading enzymatic product [3]. The use of enzymes in the feeding of industrial poultry is not a new issue and many studies have been carried out [4-8]. But However, how enzymes act, and the interaction between the animal, enzyme, host microflora, and the components of the feed are still not completely clear [4].

Geographically, the use of cell wall decomposing enzymes is more concentrated in regions where cereals containing sticky materials are introduced as main sources of energy in poultry rations (Europe, Canada, Australia, and New Zealand). This may not be true for regions where the price of corn is equal to products such as wheat (such as USA, South America, and Southeast Asia). For this reason, degrading enzymes are mainly produced by European countries [2].

## Non-starch polysaccharides (NSP)

Starch is a unique polysaccharide found in many foods. Starch in various sources of food and even in a foodstuff is different depending plant varieties, region climatic and crop conditions are different. Also, starch granules vary in size, shape and composition, depending on the type and variety of plants, and even the age of endosperm cells [9].

Non-starch polysaccharides are a heterogeneous group of compounds possesses unique physicochemical properties that vary in degrees of water dissolution, size, and structure and are not digested by the gastrointestinal tract of birds. For this reason, their nutritional effects in the poultry are diverse and, in some cases, extensive [10]. In recent years, much attention has been paid to fiber compounds of poultry diets. This attention has increased after recognizing soluble non-starch polysaccharides that have anti-nutritional effects on the digestion and absorption of nutrients [2].

The main factor affecting the nutritional value of cereals is the presence of polysaccharides such as cellulose, lignin, hemicellulose, pentosans and beta-glucans in their chemical composition [11]. These carbohydrates are referred to as non-starch polysaccharides plus lignin, which in most cases are equivalent to the old term "raw" fiber [12]. Usually in the poultry diet, the amount of lignin is very low, cellulose is the most abundant polymer in the plant series and forms the main building of the cell wall [13]. It is a polymeric compound of glucose in which glucose molecules are bonded with  $\beta$  (4-1)

bonds, which can reach up to 10,000 units [14]. Hemicellulose polysaccharide is a cell wall that is largely associated with cellulose. Hemicelluloses are mainly composed of glucose, galactose, mannose, xylose, and arabinose and probably uranic acid compounds [13].

The most important of these are the Xylans and the most abundant of which are the cereal arabinoxylan. One of other weakly digestible polysaccharide is  $\beta$ -glucan, which, although found in most cereals, is more abundant in barley and rye [12].

Most non-starch polysaccharides are found in the cell wall and there are alone or attached to proteins or lignin. In fact, the solubility of non-starch polysaccharides is the main anti-nutritional property of them. Depending on their connection with other compounds, it is very different. Most non-starch polysaccharides create a sticky and viscose solution that has a negative effect on digestibility and also the interaction between substrates and endogenous enzymes. Some non-starch polysaccharides, such as pectin, have a three-dimensional structure and can be formed a complex compound with some metallic ionic [12].

Different feed ingredients are not only different in terms of the amount of soluble and insoluble non-starch polysaccharides, but also, they have difference in terms of the physical and chemical composition of the non-starch polysaccharides. It is believed that non-starch polysaccharides can be used as anti-nutritional agents and have a strong impact on the digestion and absorption of other nutrients. The effect of non-starch polysaccharides in some food products such as barley, rye, wheat and triticale in the poultry diet is observed in poor growth and very wet and sticky stool production. Although many compounds are present in the non-starch polysaccharide group, it is important to use two types of cereals in the feeding of poultry. These groups include  $\beta$ -glucan in barley and rye and arabinoxylans in wheat and triticale [12]. The NSP content of cereals is very wide vaudeville. The factors affecting this diversity are mainly variety and cultivation region. In a study done on 13 wheat varieties produced in Germany, the mean soluble and total pentosanes in wheat were obtained in the range of 0.5 to 1.6 and 3.5 to 6.5 percent, respectively [15].

## Negative Effects of NSP in Poultry Nutrition

Usually the negative effects of soluble non-starch polysaccharides are more closely related to their polymers and sticky nature, which depends on the size and molecular structure of the polymer. Due to the viscose nature of these polysaccharides, their effects on the gastrointestinal tract and their interactions with intestinal microorganisms, caused morphological and physiological changes in the gastrointestinal [2] tract and resulted to produce changes in the nutrients digestion and absorption rate [16,17].

## Effect of NSP on Poultry Performance

The researchers' findings confirm the negative effect of soluble non-starch polysaccharides on the performance of broiler chicken. The digestibility of non-starch polysaccharides is limited due to the lack of digestive enzymes in the poultry gastrointestinal tract. These compounds reduce the availability of nutrients for digestion and absorption due to increased GIT content viscosity [18-21].

It is believed under this conditions will increase the size of the gastrointestinal mucosal layer and prevent the activity of gastrointestinal enzymes by interfering with the intrusion of digestive enzymes into the digestive tract, delaying the mixing of feed components with enzymes and bile salts, preventing enzyme bonding with substrate and reducing the reaction between enzyme and substrate, reducing going on digested components toward absorption positions on the intestinal mucosal layer, finally decreases absorption of nutrients [22-26]. Increased in the relative weight of gastrointestinal organs is one of other sign observed with increased dietary non-starch polysaccharides concentration. Increasing the amount of non-starch polysaccharides in the diet caused an increase in the relative weight of digestive organs and pancreas. This increase done in response to changes in the environment of the gastrointestinal tract is influenced by non-starch polysaccharides and increased stimulation of its secretion activity. In addition, the amount of protein used increases to improve the gastrointestinal mucus layer, thereby also affecting the growth performance of the body [4].

## Dietary Supplementation by Exogenous Enzymes

In recent years, the addition of exogenous enzyme to poultry diet has expanded. It is estimated that about 65% of poultry diets contain enzyme [3]. Exogenous enzymes contain Xylanase are added to the diet to improve the growth and feed efficiency of broiler chickens fed wheat-based diets [27]. There is a lot of research on the anti-nutritional properties of cell wall carbohydrates in cereals (such as rye, wheat, and triticale mainly containing arabinoxylan; barley and oats mainly containing  $\beta$ -glucan) and methods that their negative effects can be reduced [4,28-34].

One of the limitations of non-ruminant animals in digestive processes and intake of food products is the lack of production of enzymes that affect the digestion of cell wall carbohydrates in the gastrointestinal tract. A large part of the cellular carbohydrates of feedstuff such as wheat, barley, rye and triticale are soluble and insoluble beta-glucan and arabinoxylan [35,36]. The non-soluble section increased small intestine contains viscosity and prevent nutrient digestibility, finally reduced bird's performance.

The amount of cell wall carbohydrates that found in these cereals can vary considerably depending on the species, variety, weather conditions of the cultivated region, and agronomic condition. This, in turn, implies that the nutritional value of food can be very different. The use of additive

enzymes such as xylanase for arabinoxylan and  $\beta$ -glucanase to degrade  $\beta$ -glucan can reduce this diversity and difference in feedstuff nutritional value and improve feed performance and stability in bird's response to diets [2]. Enzyme supplements are mainly used to eliminate the anti-nutritional effects of feedstuffs such as barley, wheat, oat and triticale in the poultry diet [31-34,37].

Many researchers have studied the beneficial effects of the addition of exogenous enzymes to the rich non-starch polysaccharide diets [36,38,39]. These enzymes are able to reduce the intestinal content viscosity by decomposing non-starch polysaccharides and thus increased the digestibility and absorption of nutrients [40]. Studies have shown that the adverse effects of soluble arabinoxylan can be resolved by their hydrolysis by Xylanase activity [41].

The addition enzyme supplements contained Xylanase to wheat-based diet of broiler chicks results in the decomposition of arabinoxylan into low molecular weight compounds, reducing the intestinal contain viscosity and hence improving digestion and absorption of nutrients [30,42,43]. Peterson and Amman reported that the addition of enzymes containing  $\beta$ -glucanase and pentosanes to the diet of broiler chickens containing triticale improved growth and feed efficiency significantly [44]. Frezin et al. confirmed enhancement digestibility in cereal-based diets with using enzyme supplementation [45].

Bedford et al. reported that adding arabinoxylanase enzymes to rye-based broiler diets significantly improved the growth rate and feed conversion ratio [46]. Adding incremental levels of enzymatic activity of  $\beta$ -glucanase and arabinoxylanase (0.19, 0.22, 0.44 and 0.88 g/kg) to wheat and rye-based diet increased the weight of broilers up to 27% and improved feed efficiency by up to 10% [44]. Its reported that the addition of exogenous enzymes to wheat-based diets increased the apparent metabolizable energy by 24% and increased feed efficiency by 25% in the broiler chickens with 3 to 4-week ages [47].

## The Enzyme Action Mechanism

Many discussions have been made on that how exogenous carbohydrates enzymes do improved poultry performance [48]. They were reported that exogenous enzyme supplementation (xylanase and  $\beta$ -glucanase), significantly affects broiler growth performance, and reduces anti-nutrient effects of high levels (40%) of triticale in broiler chickens' grower diet. The poor growth performance of birds fed grower diet with high (40%) level of triticale may be related to lower nutrient digestibility, or higher anti-nutrient factors in triticale as compared to corn.

Increasing the production yield with under the used of exogenous enzymes in the poultry diet is influenced by far more than the nutritional value of sugars released from the plant cell wall. In fact, the main substrates that are decomposed by these enzymes are anti-nutritional substances or substances that reduce digestive processes and absorption [14]. Anti-nutritional effects of sticky non-starch

polysaccharides that reduce digestibility of nutrients can be adjusted by adding exogenous degradable carbohydrates to the diet [49-53].

## Reducing the Viscosity of the GIT Contents

Many studies have been done on the gastrointestinal tract content viscosity and its effects on the digestion and absorption of nutrients [19,36,46,54,55]. In the endosperm cell wall of many cereals there are structural carbohydrates (arabinoxylan in wheat, rye and triticale, and  $\beta$ -glucan in barley and oats) that have high molecular weight and are soluble in the small intestine of bird [20,29,35,36]. Due to this property, the contents of the intestine become a special soluble, that preventing the free movement of other materials. The anti-nutritional effects of arabinoxylan related to its polymeric nature and adhesion properties. The viscosity of the intestinal contents increases quadratic by increasing the amount of soluble non-starch polysaccharides [56].

Enzymes are capable of decomposing sticky polymers (soluble-NSP), so supplemented viscosity cereal based diets by them can be benefit [48,57]. Research confirms that the dietary supplementation of enzymes through the decomposition of  $\beta$ -glucan and arabinoxylan increases the nutrient value of barley, rye triticale and wheat in the poultry diet and reduces the adhesion of the GIT contain [29,46,58,59]. Reported, ileum chyme viscosity significantly increased with increase in the dietary triticale level to 30 and 40%. Enzyme supplementation to grower diet caused a reduction in the pancreas relative weights and ileum chyme viscosity [48]. By adding xylanase enzyme supplements to the broiler chickens diets, the GIT contain viscosity reduced and increased the digestibility of nutrients (starch, protein and fat) and metabolizable energy [42,60].

Significant improvement in the performance of birds fed with barley or rye-based diet supplemented by  $\beta$ -glucanase or argininosilanas due to not only the complete hydrolysis of polysaccharides and the absorption of free sugars, but mainly because of the conversion of polysaccharides to small polymers and decreased viscosity of GIT contains [2]. Since digestion is a dynamic process and relies on the release of enzymes, substrates and crops, no doubt, any interference in the free movement of molecules reduces the overall efficiency of this process. Laboratory studies have shown in a solution with high viscosity reduces the release of sugars and salts [56]. The relationship between intestinal contain viscosity, the molecular weight of non-starch polysaccharides and the performance of bird fed with rye was well illustrated [46].

Several studies have shown that the greatest negative effect of intestinal contents viscosity done on the rate of digestion and the absorption of lipids among different nutrients [19,61,62]. This loss of digestibility and absorption is greater for saturated fat. The fat digestibility in the birds fed rye base diet supplemented with animal fat was lower than the supplemented with vegetable oil [63].

Decrease in lipid digestibility due to the increased intestinal contain viscosity is not only due to a reduction of diffusion but also follow digesting and absorbing fats, it is essential that the lipid particles be introduced into the micelles. This requires the company to emulsify and mix the fat and water phase of the intestine to produce sustainable micelles structures. It is obvious that by increasing the viscosity of the aqueous phase, the formation of micelles greatly reduced. Several studies have confirmed that reducing viscosity through the dietary supplementation with appropriate enzymes increases fat digestibility more than other substances [19,52,54,55,64,65].

## Destruction of cell wall capsule

One of the limitations of poultry in feed digestion is the lack of production of enzymes affect on fiber digestion. Therefore, the cell walls of the cereal block the digestive enzymes and nutrients contained in the cells and cause the stop or delay nutrients digestion in the small intestine. By adding an enzyme with an external source, it is possible to break down the cell wall and improve the nutrient utilization [2,13].

Oligosaccharides formed during the degradation of storage and cell wall carbohydrates by supplemental enzymes. The oligosaccharides derived from cell wall digestion resist the attack of digestive enzymes, thus being able to reach the colon [66].

Research on mice shown with increasing fermentation in the colon the intro-glucagon concentration increased, which in turn reduces the concentration of gastrin significantly. Gastric emptying performed slowly, but its movements increased [67].

In birds, the intro-glucagon signal may also increase gizzard activity per unit of nutrient mass. As a result, the gizzard crushing effects are more than the enzyme's hydrolysis action responsible for cell wall decomposition. Therefore, the hypothesis of cell wall destruction, although not affected directly of exogenous enzyme, may play a significant role through the indirect mechanism. The final result of the use of enzymes is that the contents of the cell are more exposed to endogenous enzymatic activity [13].

## Changed Intestinal Microflora

Supplementary enzymes that used for degrading NSP, caused intestinal microbial flora changing in the ileum and cecum [4]. Exogenous enzymes improved nutrient digestibility by eliminating some of digestion and absorption constraints thus reduced the amount of microbial fermentable substances in the hindgut [68]. Reducing the small intestine contents viscosity due to addition of the exogenous enzyme not only increase the digestion rate of nutrients but also reduce substrate for intestinal microorganism's growth [2]. Some researchers have considered continuous changes in the population of the digestive microorganisms in this regard [69].

Another mechanism that has a positive influence on the microflora is the prebiotic effect achieved via the oligosaccharides produce and release. They formed during the degradation of cell wall carbohydrates by supplemental



enzymes. In the gastro intestinal tract, the oligosaccharides derived from plant cell wall digestion that is resisting to the digestive enzymes, reach to the large intestine and support from proliferation of the beneficial microorganism [4]. Reported beneficial effects of Bifidobacterium on human health include the following three aspects: suppressing the activity of putrefactive bacteria and preventing the formation of products such as toxic amines; repressing the proliferation of pathogenic bacteria due to the production of short-chain organic acids leading to decreased pH in the gastro-intestinal tract [70].

### Factors affecting the response of carbohydrates

Some of the factors that may have opposite effects with carbohydrate responses are as follows.

- High quality grains require little enzymatic supplementation, thus, they do not show significant responses compared to those that provide a large amount of substrates for the enzyme.
- As the age of the birds increases, the population of gut microflora increases [50]. Because of the secretion of carbohydrate enzymes by microbes, the viscosity of the intestinal contents decreases with age [13]. Fortunately, the response to the enzyme decreases as the birds age rises [54,55].
- Any factor that changes the gut microflora can influence the results obtained from dietary enzyme supplementation. These cross-effects may be neutral, negative or positive [71].

### Conclusion

Dietary supplementation of the enzyme in poultry industry has evolved in recent years from a trail to more precisely targeted science based on the increase in knowledge of the antinutritional components of feedstuffs employed. The most common application and the most thoroughly documented is the use of  $\beta$ -glucanase preparation in barley and pentosanases in wheat, rye, and triticale containing poultry diets.

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