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A Review on Maize (*Zea mays*) Nutritive Value and Exogenous Enzymes Needed for Optimal Digestibility in Non-Ruminants Diets, such as Poultry

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Abstract. Maize also known as corn is a popular cereal grain used primarily as an energy source in the diets of non-ruminants, including poultry mainly for its readily bioavailable digestible energy (DE). Additionally, maize also provides crude protein, amino acids and phosphorus to these animal species. However, there are often differences observed in the DE value of corn in these animals, especially the young chicks and piglets because they are deficient in the enzymes that degrade some nutrient components; however, with improvements as the chicks or piglets mature. These observations were seen to be linked more to the digestion of nutrients in the small intestine and the hindgut of the animals. Digestion in the hindgut depends on age, maturity and the digestive capacity of the animal. These are also linked to the fibrous components of corn implicated in reducing its nutritive values. It has been shown that one of the means of removing some of the drawbacks in dietary corn or corn-based diets is by the use of exogenous enzymes. To this point therefore, the enzymes required as additives to corn-based diets as to improve its nutritive status and value include amylase, trypsin, protease and phytase, respectively.

Key words: Maize, Nutritive Value, Nutrients' Digestibility, Enzymes and Poultry

Introduction

Globally, corn also known as maize is the most widely used cereal grain in the diets of non-ruminant animals. Corn is usually used primarily as an energy source in diets because of its high available digestible energy (Lampe et al., 2004; NRC, 2012). Furthermore, since maize often constitutes about 70% of the diet it also contributes to the crude protein (CP) and amino acids (AAs) requirements of the animals. This is more so as corn is relatively uniform cereal grain with only slightly variations in its energy, CP and AA contents (Lampe et al., 2004; NRC, 2012). To this end, feed formulators do not perturb about frequent analyses of corn in diet formulation. However, at present farmers are experiencing variation in performance indices of swine and poultry in corn-based diets suggesting feeding-value variability in corn. Starch is the major energy source in corn and is usually found in the endosperm of the corn kernel. Furthermore, the majority of the corn starch is amylopectin which is why is readily made bioavailable to the animal (Lampe et al., 2004; NRC, 2012). However, it contains insoluble fibers, such as hemicellulose and cellulose; these fibers on average constitutes about 9 – 15% of its dry weight (NRC, 2012). It is the variability in content of these fibers that is mainly responsible for variation in the feeding value of corn and hence the need for exogenous enzyme supplementation. Phytic acid is another anti-nutritional value of corn (NRC, 2012; Noy & Sklan, 1995). Therefore, the objectives of this paper are to shed light on the types of fibers present in corn which also warrants the kind of enzymes required to increase the nutritive value of corn for the swine and poultry industries, respectively.

Factors Influencing Variability in the Nutritive Value of Corn

The observed variability in nutritive values of corn as evidenced by variations in animal performance indices in corn-based diets is related to their fiber types and possibly phytic-acids contents of corn as a dietary ingredient (Table 1).

Table 1. DE, CP, Lysine, NDF, ADF and P contents of barley, corn and wheat

Item	Barley	Corn	Wheat
DE (kcal/kg)	3,050; 3,100	3,525; 3550	3,365; 3250
CP (%)	11.3; 10.6	8.3; 8.5	13.5; 12.9
Lysine (%)	0.41; 0.39	0.26; 0.26	0.34; 0.37
NDF (%)	18.0; 17.8	9.6; 12.0	13.5; 10.8
ADF (%)	6.2; 7.1	2.8; 3.4	4.0; 3.5
P (%)	0.36; 0.35	0.28; 0.25	0.36; 0.32

Source: NRC (2012 and Patience, Thacker and de Lange (1995)

Note: DE = digestible energy; CP = Crude protein; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; and P = Phosphorus

Table 1 compared the nutritive values of three cereal grains: barley, corn and wheat based on two references (NRC, 2012; Patience, Thacker & de Lange, 1995), respectively. Corn has the highest DE contents and lowest levels of fibers, namely NDF and ADF yet low nutritive values are sometimes experienced in birds fed corn-based diets. This observation as stated previously might not be unconnected with its fibers' contents (NDF and ADF). The study of Fairbairn et al. (1999) demonstrated that NDF and ADF fractions have negative effects on the utilization of DE in cereal grains as well as the digestibility of other nutrients. In the light of this, Moeser et al. (2002) who studied the performance of pigs fed conventional corn versus a corn whose fibers were removed found that the diet with removed fibers significantly improved animal performance compared to the conventional corn with intact fibers. Certain fibers in feed ingredients, including NDF and ADF are considered as anti-nutritional factors because non-ruminants lack the enzymes for effective fiber digestibility; and apart from the fibers not being digested also prevent the digestibility of other nutrients. Fiber also dilute the energy content of diets (Fairbairn et al., 1999; Moeser et al., 2002; Green et al., 1987).

The study of Mahagna et al. (1995) showed that metabolizable energy of corn differed in net energy from the first week post-hatch to the third week by between 200 – 250 kcal/kg. Again, the study of Collins, Moran and Stilborn (1998) demonstrated that age of bird was an essential factor when assigning an available energy value to maize. Some of the major reasons found to be responsible for these observations were related to the age of the bird and the fact that starch digestion is not complete in the small intestine but continues to the hindgut leading to the finding that ileal and fecal DE values are not the same. This has also been confirmed in the pig studies (Dritz et al., 1996; Green et al., 1987). Furthermore, the study of Noy and Sklan (1995) showed low ileal digestibility of starch and fat in young broiler chicks fed maize-based diet. Digestibility of starch in chicks from 4 to 21 days of age up to the end of the small intestine was as low as 82% with no evidence of any increase as the birds get older. This therefore supports the fact that a portion of maize starch is reaching the hindgut where it undergoes fermentation via microbes resident there with poor energetic utilizations. This is further supported by the finding that microscopic examination of the ileal digesta contained large maize endosperm particles that were not digested (Moeser et al., 2002; Mahagna et al., 1995; Collins, Moran & Stilborn, 1998). The study of Persia and Lilburn (1998) that investigated apparent metabolizable energy (AME) and starch digestibility in the small intestine of turkey poults found a significant difference in the AME for wheat and corn when measured with the small intestine versus colon contents. Their data findings showed a 5.21% of undigested starch entering the colon from corn versus 2.67% from wheat. Pack et al. (1998) widely reported most of the studies with maize in the area of starch availability and concluded that not only is starch not completely digested in the small intestine but also there can be a significant amount of protein and in particular AAs entering the hindgut depending on age of bird and corn sample. They thus demonstrated that AA digestibility is significantly lower when measured with ileal digesta compared with fecal determinations. The reason for these differences is majorly due to the contribution by the hindgut digestion of starch; which of course is not effectively utilized by the animal coupled with the error involved with the determination of AA digestibility values when a correction is made for endogenous losses counterparts. There are also bodies of significant reports indicating that overall digestion is low in the chick to around 10 days and then increases to a plateau around 4 weeks of age. This has also been confirmed in swine studies (Dritz et al., 1996; Grieshop, Reese & Fahey, 2001). These point to the fact that values used for available energy for the young chick show significant opportunity for improvements by means of altering maize composition or the employment of specific exogenous enzymes. To this point, Noy and Sklan (1995) demonstrated that amylase, trypsin and lipase are low at 4 days of age but at 21 days of age they increase by 100-, 50- and 20-fold, respectively. They inferred that only 82-89% of fatty acids and starch are digested in the small intestine; whereas nitrogen digestion is also not complete in the small intestine; it increased from about 78% at 4 days to 92% at 21 days of age, respectively. These data therefore form the bedrock of the kinds of exogenous enzymes that are dietary essentials for optimum digestion and nutrient absorption in corn-based diets for poultry. Additionally, these data are also related to the dietary fibrous components found in corn (Moeser et al., 2002; Grieshop, Reese & Fahey, 2001).

The digestive phenomenon of enzymes on polysaccharides and other factors influencing starch degradation have been widely reported (Planchot et al., 1995). Similarly, there are various data showing enhancing efficiencies in the feeding value of the coarse cereals by supplementing diets with exogenous enzymes. The enzymes degrade the non-starch polysaccharides (NSPs) present in the cereals and thereby significantly improved their available energy content. Corn with low NSPs does not respond much to those enzymes. Nevertheless, in recent times it has been shown that a mixture of enzymes containing amylase, xylanase and protease is effective and very efficient in enhancing the nutritive value of maize-based diets (Pack et al., 1998). Their data demonstrated a 2-5% improvement in available energy with enzyme supplementation of corn-based diets. Furthermore, more uniform broiler weights at marketing and reduced morbidity/mortality rates have also been documented with enzyme-supplemented diets. The reasons attributed to these were possible removal of anti-nutritional elements present in the feed ingredients, in addition to more effective nutrient digestibility in the small intestine and thus an influence on gut microbial activity. Yan et al. (1998) reported reduced incidences of morbidity and mortality as one of their consistent observations when phytase was added to maize-based diets for broilers. Maize-based diets nutritive values have been improved by the addition of phytase. Although phytase inclusion aided overall improvements, the use of phytase is mostly associated with improvement in phytate-phosphorus availability. Simons et al. (1990) demonstrated an improvement in dietary phosphorus availability for poultry of approximately 65% with microbial phytase supplementation of diets. A marked improvement in phytate degradation with laying hens from 8 to 50% when phytase was added to the laying hen diets was demonstrated by the studies of Van Der Klis et al. (1990).

Conclusions

Corn is primarily used in the diets of non-ruminants for energy supply. However, it also provides some CP, AA and phosphorus. Addition of enzymes to corn diets enhances more of the utilizations of these nutrients and thus better support animal performance. Enzymes of importance in corn-based diets are amylase, xylanase, protease and phytase, respectively.

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