Use of Exogenous Enzyme in Animal Feed

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Abstract: The constant population increase and the continued need for feed of animal have originated rise in demand for livestock products and continuous research on the use of additives for growth. In last years, the addition of exogenous enzymes has become a good solution for improving animal performance, and it is most widely studied and reported disciplines in animal science showing rapid growth worldwide in the industry. Nowadays, consumer and producers increase knowledge concern to the use of secure growth promoters and antibiotics in livestock production attend these reasons; many researchers have been investigated the use of exogenous enzymes in ruminant and non-ruminant animal production. The aim of this paper is to review about exogenous enzymes add and their use on different animal livestock species in most recent years.


Keywords: Animal feed, enzyme, nutrition

The intensive and rapid growth on world population are caused on increased demands of animal origin. Meat and meat end-products consumption (including beef, pork, goat, mutton and poultry) has increased gradually, by almost 60% between 1990 and 2009; from 175,665 thousand to 278,863 thousand tons, driven in part by a growing world population (Henchion \textit{et al}., 2014).

The need of methods for animal rapid growth has been derived in investigation for an increase the livestock production with the human food safety and animal welfare requirements. On this topic, animal nutritional researchers are in constant investment about improvements breeding strategies, based on improvement genomics (Rothschild and Plastow, 2014), or applied growth promoters, as well as the possible alternative strategies for their use in livestock feeding; nevertheless, the use of chemical substances like β-agonist whose increase lean meat to fat ratio and improve feed conversion efficiency it is actually illegal since the 90’s decade (Cayetano \textit{et al}., 2013; Johnson \textit{et al}., 2014). For these reasons, many researchers were investigated the use of other additives for improving efficiency on animal livestock (Cedillo \textit{et al}., 2014; Gado \textit{et al}., 2014; Salem \textit{et al}., 2014; Zhao and Kim, 2015), natural antioxidants (Rossi \textit{et al}., 2014) and exogenous enzymes (Salem \textit{et al}., 2013, 2015; Valdes \textit{et al}., 2015).

The popular attention on the use of exogenous enzyme it is due to their capacity to increase the efficiency of digestion by help break down anti-nutritional factors (e.g. fiber, phytate and non-starch polysaccharide (NSP)) (Adeola and Cowieson, 2011; Alsersy \textit{et al}., 2015), or do improve the digestibility of many ingredients, which remains low because of a lack of the enzymes needed for breaking down the complex cell wall structure that encapsulates nutrients presents in plant based feed.

The use of dietary exogenous enzymes on livestock production could be a promising strategy for improve animal digestibility and feed efficiency; however, many articles have been published every year in enzyme and animal nutrition disciplines, with counterpoised results, reveled new challenges, and opportunities for this topic research. The purpose of this review article summarizes current research regarding exogenous enzymes and their use on different animal livestock species for a show a general understanding on this topic.

Types of Enzymes Utilized in Animal Feed

Since the late 1980, feed enzymes have played a major part in helping to improve the efficiency of livestock products. The use of exogenous enzymes, specifically non-starch polysaccharidase and phytase, is almost ubiquitous in poultry and common place in pigs feeds because the inclusion of feed of plant origins, which compounds with low digestibility, considered anti nutritional factors such as NSP (Schedle \textit{et al}., 2012) and phytic acid (Abudabos, 2012). However, recently many researchers have directed their work on other species like ruminants, actually exists many types of enzymes utilized in animal feed; most popular are
shown in Table 1. Farm animals include diverse species; each of them possesses different physiological systems and forms to digest their food, the use of specific enzymes is explained below.

<table>
<thead>
<tr>
<th>Table 1. Distinct Type of Enzymes and Action Mode</th>
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<tbody>
<tr>
<td><strong>Type</strong></td>
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<tr>
<td>---</td>
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<tr>
<td>Xylanases</td>
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<tr>
<td>β-glucanase</td>
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<tr>
<td>Vegetal cell degrading enzymes</td>
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<tr>
<td></td>
</tr>
<tr>
<td>Protein degrading</td>
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<tr>
<td>Phosphatases</td>
</tr>
</tbody>
</table>

**Application of Exogenous Enzymes in Animal Farm.**

**Poultry**

Nevertheless enzymes have been used extensively in poultry diets for performance in different species like turkeys, duck, and laying hens, broilers are received much more attention on research about enzyme addition because they cannot digest adequately NSP and subsequently the ingestion of high levels of soluble NSP leads to increased digest viscosity and reduced nutrient digestibility and absorption (Hajati, 2010), the works are focusing on diverse proposes like develop performance and nutrient digestibility when added to poultry diets containing cereals, improving indicators like body weight gain (27.9 gr/day -control- vs 32.2 gr/day-enzyme add) in broiler supplemented whit Endofeed® (Xylanase and β-glycanase) (García et al., 2008), dietary apparent metabolizable energy from 3588 to 3752 Kcal kg⁻¹ with β-mannanase supplementation (Kong et al., 2011) and decreases on digests viscosity, increased nutrient retention, and consequently improved the performance of broilers fed supplemented with xylanase (Esmaeilipour et al., 2011).

Related to adding of phytase results from recent studies have shown increased digestibility on total phosphorus from 35.81 to 15.87% (Nourmohammadi et al., 2012), decreased tibia breaking strength around 10.2 kg less (28.8-18.6 kg) than the breaking strength at 28 days for birds fed with the standard diet (Shaw et al., 2010) and act synergistically with other enzymes for the availability of protein as a result of phytase addition to poultry diets. However, Francesch and Geraert (2009) obtained a decrease from 3.4% an average in the feed gain ratio, although reduction on feed intake in broilers supplemented with xylanase and phytase. The authors conclude that impairment could be attributed to the dietary energy and crude protein dilution applied or to the negative effect of the phytate on apparent metabolizable energy, ileal protein and amino acid digestibility, and endogenous amino acid flow.

It is important to mention than the enzyme application on broiler feed implicates considered other factors than enzyme type and diets. Figueiredo et al. (2012) realized an experiment whit 1-day-old chicks feed wheat-based diet supplemented with a commercial xylanase for 28 days. Significant differences in body weight emerged at 21–28 days of age, suggesting that the response to xylanase supplementation occurs primarily during the latter stages of broiler growth, showing that the age of broiler is an important factor for good results. Other factors less considered, is the size of particle of feed. Jia and Slominski (2010) compared flax seeds diets (whole, grinding and pellet) in broilers supplemented with cellulase, mannanase, pectinase, xylanase and glucanase.

Pelleting showed more pronounced and beneficial effects on growth performance, particularly when whole seeds were used, indicating a potential for using whole flaxseed in the pelleted diets. Enzyme addition resulted in an increase on the total tract fat digestibility by 3 to 6%, which was reflected in an improved feed conversion ratio by 1 to 3%, regardless of the processing method used; the authors conclude that physical rupture of the seed and disruption of cell wall structure via diet pelleting, and the addition of NSP-degrading enzyme offers
practical solutions to improve the nutritive value of flaxseed in poultry feed.

Other works about exogenous enzyme addition on poultry performance (Table 2), mentioned the improvements in different indicators, with the use of exogenous enzymes. Only a few papers are reference to egg. Wen et al. (2011) proved phytase, xylanase, cellulase, α-amylase and acidic protease on egg production, nutrient retention, digestive enzyme activities and pancreatic enzyme. Poultry fed diets supplemented with enzymes tended to have higher lipase and protease activity in duodenal and jejunal digest, but did not affect productive performance of laying hens in the late phase of egg production. Similar results were founded by Kashani et al. (2014), who not observe any effect on egg quality parameters with addition of phytase on laying hens.

**Pigs**

Regarding of pig exogenous enzymes have been applied on diets for different proposes; like diminish the manure odor emissions measured in European odor units (OuE) in the barley diet from 5,543.2 - 4,426.1 OuE/m$^3$ (72 h) and oats from 2,366.2 - 1,993.0 OuE/m$^3$ (72 h) (O’Shea et al., 2010); improvement in bone development. Varley et al. (2011) founded a linear increase in bone ash (P<0.01), bone calcium (P<0.01) and bone phosphorous (P<0.05) concentrations at 33 kg body weight in pigs feed with phytase, and improvement on nutritive value of vegetable feedstuffs contained a considerable amount of NSP (De Lange et al., 2010). Wang et al. (2008) observed improvement in daily gain of growing pigs fed the rough rice-based diet supplemented with enzymes showing increased by 10.1% (P<0.05) and feed: gain improved by 9.4% (P<0.05) compared to the control group.

However, unlike the poultry industry in pig, it is livestock has been more cautious in accepting feed enzymes because the pig response is less consistent compared with the poultry. In pigs, passage through the digestive tract is much slower than poultry; time that food stays on a small intestine allow nutrient better absorption (Bedford and Partridge, 2010) which diminish the observable effects for enzyme added.

Previous research has found that carbohydrates in wheat, particularly starch and the non-digestible carbohydrate components such as NSP, influence energy digestibility (Kim et al., 2008). Supplementation of pig diets with NSP-degrading enzymes improved the utilization of these compounds, but not all works are consistent (Table 3).

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Diet</th>
<th>type of poultry</th>
<th>Improvement over control</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lipase and phospholipase</td>
<td>Sunflower seeds</td>
<td>Broiler</td>
<td>Increase on BWG</td>
<td>Brenes et al. (2008)</td>
</tr>
<tr>
<td>Multicarbohydrase</td>
<td>Wheat – soy bean meal</td>
<td>Broilers</td>
<td>Growth improved , health promoter</td>
<td>Jia et al. (2009)</td>
</tr>
<tr>
<td>β-mannanase</td>
<td>Guar meal</td>
<td>Laying hens</td>
<td>Increased FCR</td>
<td>Mohammad and Torki (2010)</td>
</tr>
<tr>
<td>β-mannanase</td>
<td>Corn-soybean meal</td>
<td>Broilers</td>
<td>Improve CTTAD</td>
<td>Kong et al. (2011)</td>
</tr>
<tr>
<td>xylanases</td>
<td>Corn- wheat</td>
<td>Laying hens</td>
<td>Improve the digestion of xylans and arabinoxylans</td>
<td>Cufadar et al. (2010)</td>
</tr>
<tr>
<td>multi-enzyme</td>
<td>Multi ingredient diet</td>
<td>Broiler</td>
<td>Improved relative growth, energy efficiency and protein efficiency</td>
<td>Hajati (2010)</td>
</tr>
<tr>
<td>β-mannanase</td>
<td>Corn-soybean meal</td>
<td>Broiler</td>
<td>Increase CTTAD</td>
<td>Li et al. (2010)</td>
</tr>
<tr>
<td>Natuzyme®</td>
<td>Multi ingredient diet</td>
<td>Broiler</td>
<td>Improved the feed conversion ratio</td>
<td>Khalaji et al. (2011)</td>
</tr>
<tr>
<td>Protease</td>
<td>Corn–soybean</td>
<td>Broiler</td>
<td>Improve content in protein digestibility</td>
<td>Angel et al. (2011)</td>
</tr>
<tr>
<td>Microbial phytase</td>
<td>Corn-soybean meal</td>
<td>Broiler</td>
<td>Increased ileal digestibility of nutrients, increasing on mineral contents in tibia ash</td>
<td>Nourmohammadi et al. (2012)</td>
</tr>
<tr>
<td>β-mannanase</td>
<td>Whole</td>
<td>Broiler</td>
<td>Improved BWG and feed conversion ratio</td>
<td>Zangiabadi and Torki. (2010)</td>
</tr>
<tr>
<td>Thermotolerant xylanase</td>
<td>Wheat and soybean meal</td>
<td>Broiler</td>
<td>Improved performance</td>
<td>Masey et al. (2012)</td>
</tr>
<tr>
<td>xylanase, β-glucanase, and phytase</td>
<td>Corn-soybean</td>
<td>Broilers</td>
<td>Reduction of phytate</td>
<td>Francesch and Geraert (2009)</td>
</tr>
<tr>
<td>Protease</td>
<td>Corn, soybean</td>
<td>Poultry</td>
<td>Increase protein digestibility</td>
<td>Yan et al. (2012)</td>
</tr>
<tr>
<td>Natuzyme®</td>
<td>Sorghum–Wheat</td>
<td>Broilers</td>
<td>Improve IDE 1.5%– 2.9%</td>
<td>Sultan et al. (2012)</td>
</tr>
<tr>
<td>Phytase</td>
<td>Yellow corn and soybean</td>
<td>Laying hens</td>
<td>Increasing release of organic phosphorous</td>
<td>Abudabos (2012)</td>
</tr>
</tbody>
</table>

Ileal digestible energy (IDE), coefficient of total tract apparent digestibility (CTTAD), body weight gain (BWG), feed conversion ratio (FCR).
Woyengo et al. (2008) were conducted an experiment with the addition of xylanase and phytase on wheat based diets, but there were no dietary effects on growth performance. Phytase increased the apparent total tract digestibility of phosphorus and calcium by 51 and 11% at 20 kg of body weight (BW) or by 54 and 10% at 60 kg of BW, respectively, but increasing the level of phytase and the apparent ileal digestibility (AID) of phosphorus and calcium by 21 and 12%. The addition of xylanase increased AID of lysine, leucine, phenylalanine, threonine, glycine, and serine. Phytase improves digestibility of phosphorus and xylanase enhances amino acid digestibility, but no interaction between the two enzymes was noted. The authors, concluded that phytase supplementation to wheat based diets for growing pigs improved phosphorus, and calcium digestibility, but they cannot influence on grow performance.

Adeola and Cowieson in 2011, reviewed investigation work about NSP-degrading enzyme addition on growth swine, and report variable responses on body weight gain (BWG). The differences could be explained for type and quantity of cereal grains used the extent of deficiency of limiting nutrient, and the extent to which the enzyme increased digestible nutrient content.

Enzyme supplementation on pigs’ diets depends of the survivor of the enzyme in digestive tract, age of swine or the synergism between different enzyme types (Emiola et al., 2009a), for example; the gastrointestinal tract of a piglet is a complex environment. Opposite adult pigs, the piglet digestive system is immature and is more susceptible to suffer affections and quickly alters in digestive and immune. The weaning of piglets usually takes place between 3 and 4 week of life, when the majority of nutrients are ingested with milk. Poor digestion of solid feed by piglets weaned at 21-28 of age is especially obvious in the first 2-3 weeks after weaning inappropriate choice of feed ingredients at this time can be produced diarrhea (Bedford and Partridge, 2010).

In this case, works realized with addition of exogenous enzymes founded good responses in the treatments applied. Tapingkae and Yachail (2008) diminished the incidence of diarrhea in weanling piglets from the 3-4 week post weaning, with a diet based on local ingredients and multi-enzyme treatments. In the same way, Zhou et al. (2011) proved the inclusion of enzymolitic soy bean (ESBM) on piglet diets; the inclusion of ESBM at 5 to 15% increased the digestibility of crude protein (CP) by 5 to 16%, and ESBM at 15% increased the digestible energy (DE), calcium and phosphorus compared with the control diet. The results suggest that ESBM can be a better protein source in improving growth performance, nutrient digestibility and immune function of weaned piglets. Owusu-Asiedu et al. (2010) measured the effect of xylanase in piglet’s wheat-barley based-diets. On average, piglets grew 525 g/day, consumed 845 g/day, and exhibited mean feed conversion ratio (FCR) of 1.59. Weight gain and feed intake did not differ among treatments; however, FCR for the overall period was better for pigs fed diets supplemented with 200 g/MT enzyme compared with those fed the control diet.

Table 3. Different Works of Enzymes Addition on Pig Diets.

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Diet</th>
<th>Age of swine</th>
<th>Observation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrases phytase</td>
<td>Corn, wheat-middling, soybean, canola</td>
<td>Weanling-finisher</td>
<td>Improved ADG in pigs whit 10-kg of body weight but not in pig with 23-kg , improving phosphorus digestibility in pigs of all ages</td>
<td>Olukosi et al. (2007)</td>
</tr>
<tr>
<td>Non-starch polysaccharides (NSP)enzymes</td>
<td>Rough rice</td>
<td>Growing Pigs</td>
<td>Improved performance of pig reduced viscosity and increased digestive activity in the small intestine.</td>
<td>Wang et al. (2008)</td>
</tr>
<tr>
<td>β-glucanase</td>
<td>Barley-oat</td>
<td>Finishing Pigs</td>
<td>Increased manure ammonia on oat diets, not influence on the oat-based diets.</td>
<td>O’Shea et al. (2010)</td>
</tr>
<tr>
<td>Phytase</td>
<td>Wheat-barley-soya</td>
<td>Weanling</td>
<td>Improved Ca and P digestibility feed conversion ratio and bone mineralization at 33 kg BWG.</td>
<td>Varley et al. (2011)</td>
</tr>
<tr>
<td>Carbohydrase</td>
<td>Palm kernel meal</td>
<td>Growing Pigs</td>
<td>Improve the growth performance and energy and nutrient digestibility’s</td>
<td>Ao et al. (2011)</td>
</tr>
<tr>
<td>Easyme Mixer®, Hemicell-W®, Porzyme 93010®</td>
<td>Dried distillers grains</td>
<td>Nursery</td>
<td>Not improve growth performance</td>
<td>Jones et al. (2011)</td>
</tr>
<tr>
<td>Axtra® XB,</td>
<td>Mixed grains</td>
<td>Fattening pigs</td>
<td>Not improve growth performance</td>
<td>Kiarie et al. (2012)</td>
</tr>
<tr>
<td>Multicarbohydrase</td>
<td>Distillers dried grains</td>
<td>Finishing Pigs</td>
<td>Improved growth performance and apparent total tract digestibility</td>
<td>Emiola et al. (2009b)</td>
</tr>
</tbody>
</table>

Body weight gain (BWG); Average Daily Gain (ADG)
The variability in the responses founded in diverse woks implicated the needs for more research into the mode of action, survivor, degree of breakdown and mixed types of exogenous enzymes in a digestive tract, for pig growth improvement.

**Ruminants**

Cellulose and hemicellulose are quantitatively the most important structural carbohydrates present in ruminant diets (Khattab et al., 2013; Kholif et al., 2014). Rumen microorganisms produce enzymes that catalyze their hydrolysis, but the complex network formed by structural carbohydrates and lignin can reduce their digestibility and restricts efficient utilization. Fiber degradation in the rumen is not optimal, since the fiber fraction recovered from feces is fermentable (Gallardo et al., 2010).

The use of exogenous fibrolytic enzymes holds promise as a means of increasing forage utilization and improving different parameters in ruminal species. Several studies have reported increases in enhancing in different responses (Khattab et al., 2011). Togtokhbayar et al. (2015) tested xylanase and cellulose in vitro ruminal degradation, all enzymes tested still increased the degradability of substrate acid detergent fiber and the production of acetate, propionate and total volatile fatty acids (VFA). Gado et al. (2009) proved the commercial enzyme complex ZADO® in dairy cows, founded increases on milk and milk protein production 12.8–15.7 and 0.45–0.57 kg/day respectively. Pinos-Rodriguez et al. (2008) improving ruminal disappearance rates of dry matter (DM) in lambs. Carréon et al. (2010) increased potentially disappearance fractions and total disappearance of DM and starch on steers.

Although studies showed improved animal performance with enzyme treatment, others not show effects, like Phakachoed et al. (2012) reported that dry matter intake, ruminal pH, in sacco ruminal disappearance of feedstuff (rice straw), and hemicellulose degradability were unaffected by xylanase treatment. Their inconsistent response is due to a lack of standardization of methodology used to assay enzyme activity of ruminant feed enzymes. The resulting enzymatic activity on ruminal environment is affected by conditions like the substrate used, temperature, and pH.

These inconsistencies might be attributable to different factors like mode of application or the portion of the diet to which the enzyme was added. The methods of the enzyme mixture application are possible responsible for inconstancies responses (Khattab et al., 2011). Quantities of doses are an important factor for a different responses (Phakachoed et al., 2012) reported that dose response was an enzyme dependent for most variables, for example, increase a similar result were found by Avellaneda et al. (2009) who not observe effects on dry matter intake, nitrogen balance, ruminal degradation, total tract digestion, ruminal fermentation, as well as ruminal protozoal count with exogenous fibrolytic enzyme treatment. Seed fiber disappears in proportion to the increase in enzyme concentration.

Nevertheless, the inconsistencies of the results obtained with exogenous enzyme addition ruminal species, recent investment is applied for prove other non-conventional feedstuffs. Awawdeh and Obeidat (2011) improve nutrient digestibility and increases on feed intake and growth on lamb performance feed with olive by product derived of olive oil production (residue obtained after the pressure extraction of oil from the entire olive fruit and contains skin, crushed pulp, stone wall and kernel). Salem et al. (2013) applied enzyme on crossbred steers diet in order to evaluated the effects of exogenous enzyme (ENZ) addition on nutrient intake, digestion, ruminal fermentation and feed conversion in beef steers. The magnitude of improvement in digestibility varied among nutrients, with the highest improvement occurring in digestibility of NDF and ADF (21.8% and 26.7%, respectively). Addition of ENZ also increased (P<0.05) concentrations of rumen ammonia N and total short chain fatty acids (SCFA) before and 3 h post-feeding.

Enzyme addition did not affect (P=0.1) DM intake, whereas it increased (P<0.05) total tract apparent digestibility of all nutrients. The magnitude of improvement in digestibility varied among nutrients, with the highest improvement occurring in digestibility of NDF and ADF (21.8% and 26.7%, respectively). Addition of ENZ also increased (P<0.05) concentrations of rumen ammonia N and total short chain fatty acids (SCFA) before and 3 h post-feeding. Allantoin concentration total purine derivates were increased (P=0.04) with enzyme addition while uric acid was not affected (P=0.05). Live-weight gain was also higher (P<0.01) in steers supplemented with ENZ. In conclusion, adding the exogenous enzyme product increased live-weight gain by 16% due to increased nutrient digestibility.

Another research about the employ of exogenous enzyme for improving nutrient digestibility is applied in the region with forages with low levels of nutrients like tree and shrub. Salem et al. (2012) proved the effect of sun-drying an enzyme adds in leaves of desert shrubs showed that there are beneficial impacts of sun-drying and/or dietary exogenous enzyme addition for sheep fed leaves. The authors attributed the best response to the enzyme preparation may have stimulated and/or increased
total viable rumen bacterial numbers because rumen microbial nitrogen synthesis was increased; which may be due, at least in part, to increased fiber digestion and an improved capacity of rumen bacteria to digest feed and degrade secondary metabolites present in the diet (Kholif and Aziz, 2014).

Alsersy et al. (2015) reported the effects of feeding Atriplex halimus (AH) silage treated with two developed enzyme cocktails to sheep on feed intake, nutrient digestibility and ruminal fermentation. Ensiling AH with enzymes reduced its contents of neutral detergent fiber and acid detergent fiber. The dry matter intake of AH of AH silage treated with ZAD1® and barley (D2), AH silage treated with ZAD2® and barley (D3) and AH silage treated with a combination of ZAD1® and ZAD2® (1:1) and barley (D4) decreased (P < 0.001) as compared to AH silage and barley (D1). However, enzyme-treated diets had greater total digestible nutrients intake (P < 0.001) as compared to D1. The nutrients digestibility for D2, D3 and D4 were higher than those for D1 (P < 0.001), and were higher for D3 as compared to both D2 and D4. Sheep fed on D3 had highest (P < 0.001) ruminal total volatile fatty acids concentration.

However, not only fibrolytic enzymes are applied in ruminal feed, phytase and their role like an additive are less studied. In no-ruminant animals like a pig or poultry, phytate is not fully utilized, and this resulting excretion of phosphorus contributes to phosphorus pollution. In contrast, the rumen is a source of highly active phytase, and thus ruminants can use phytate as a source of phosphorus (Bedford and Partridge, 2010). Buendia et al. (2010) proved the inclusion of phytase in sorghum diets on lamb digestion and pollutants excretions, and conclude that the enzymes not modified in vitro kinetic characteristics of diets and did not diminish the negative impact on the environment.

Inclusion of exogenous enzymes in ruminants needed more investigation of the mode and level of application on ruminant diets. However, there is evidence that fibrolytic enzymes only enhance for stomach digestion and fermentation of fiber.

Other Species: Aquaculture.

Nevertheless, the aquaculture it is not considered in livestock products fish farming is the fastest-growing sector of world food production (Soler-Villa et al., 2009). In recent years, aquaculture has been relatively slow adopting feed enzyme technology. Normally, research in carnivorous fish nutrition focuses on the replacement of the fish meal with plant-based protein ingredients in order to support the globally expanding aquaculture (Dalsgaard et al., 2011).

The looking for replacing a fish meal by cheaper and more sustainable protein sources is essential for reducing the cost of fish feeds. In order to develop sustainable, economical, and viable aquaculture production; alternate sources of high-quality proteins must be identified to replace unavailable high-cost fish meal. Various plant protein sources such as soybean, corn gluten, cotton seed and canola, are major candidates for the substitution of the fish meal in fish diets due to availability and low cost (Soler-Villa et al., 2009). However, carnivore fish such as trout and salmon have a high protein requirement and do not have the capacity to utilize energy from complex fibrous carbohydrates, for these reason exogenous enzymes are frequently used to increase the nutritive value of feed ingredients of plant origin and improve growth performance.

Denstadli et al. (2011) tested the pretreatment with carbohydrates in three different diets (sunflower, soybean meal and whole) in rainbow trout Oncorhynchus mykiss diets concluding than the enzyme add has significant effects on reductions in total NSP in vitro, but the released substrates did not contribute to an improvement in fish performance under the current experimental conditions. Contrary to these authors, Imanpoor and Bagheri (2012) proved soy bean meal diet with the addition of phosphorous and microbial phytase in Persian sturgeon Acipenser persicus founded that the soy bean meal could be partly an alternative protein source if phosphorous supplied for fish by incorporation with microbial phytase or phosphorous.

Future research on exogenous enzymes in fish feed could focus on effects of enzymes on amino-acid availability, because in fish feed, it is normally used high protein content stuffs like a fish meal (FM) for the favorable amino acid profile (Shina et al., 2011). Inclusions of proteases which can promote the release of amino-acids or diminish the protease inhibitors presents in fish diets could be a good response in fish growth.

Conclusion

The inclusions of exogenous enzyme in animal feed are a vast area of research, and promise turn is a good solution for the use of safe additives in animal nutrition. Mostly of investments were demonstrated good responses in the increases of nutrient digestibility, health and improved animal performance. However, before the inclusion of enzymes in any diet, it is necessary considered many factors than can affect the response in animal growth, at this point it is clear the need to continue to clarify the mode of action in the different pathways in animal digests, for the purpose to development new products or methods specifically to improve feed digestion through the exogenous enzyme addition.
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