

◀Review▶

Using Enzymes and Organic Acids in Broiler Diets

Muhammad S. Anjum^{1,2} and Abdul S. Chaudhry¹

¹ School of Agriculture, Food and Rural Development, Newcastle University,
Newcastle upon Tyne, NE1 7RU, United Kingdom

² Dr M S Anjum is a visiting scientist from Azad Jammu and Kashmir University, Rawlakot, Azad Kashmir

Broiler industry has been bridging the gap between the supply and demand of high quality protein foods such as meat for the ever increasing human population worldwide. However, the overall expenditure on broiler diets remains between 60–80 percent of the total cost of broiler production. Therefore, the broiler industry has been striving to reduce the cost of production through improved feed utilisation by the broilers. For this purpose, exogenous enzymes have been claimed to improve the utilization of feeds by maximising the conversion of dietary nutrients into broiler meat, for example. Enzymes not only help in formulating more balanced diets for broilers by increasing the choice of ingredients such as cereals and other agro-industrial by-products but also by increasing their efficiency of utilisation by enhancing the digestibility of fibrous materials. The enzymes can also be beneficial as growth promoters instead of antibiotics which are banned in the European Union. Enzymes have been tried alone and in combinations with other additives such as organic acids to maintain health and production of broilers. Although the role of enzymes in improving feed utilisation, growth, meat quality and economics has been well reported, their quality, consistency and reproducibility have been questioned by many researchers. This article reviews the role of enzymes alongside organic acids in broiler diets and their future potential to maintain bird health and efficient broiler production which has desirable impacts on the environment.

Key words: broilers, diets, exogenous enzymes, organic acids

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Introduction

Enzymes are biological catalysts that perform some essential functions in living organisms. They are naturally present in living organisms and can be mass produced through the aerobic or anaerobic cultures of bacteria and fungi. The enzymes have been used for the last 50 years but their use in animal feeds has received more attention in the last 20 years (Partridge and Wyatt, 1995). In fact, it has become a common practice to supplement poultry diets with enzymes to improve the nutritional value of feeds and the gut microflora of birds. Enzymes, even in small quantities, can initiate or accelerate the rate of chemical reactions that transform dietary substrates into products of biological significance for broiler growth and production (Taylor-Pickard, 2008).

The dry matter digestibility (DMD) of broiler diets can vary from 50 to 80% depending upon the type of a diet, its composition and bird age. In broilers, different enzymes play an imperative role in the utilization of different nutrients i.e. amylase can digest starch, protease can digest

protein and lipase can digest fats. However, broilers lack enzymes that digest fibrous components or cell wall fractions of diets such as those that contain cereal grains. The structure of these fibre fractions repels the infusion of endogenous enzymes or inhibits their binding with other nutrients that broilers could otherwise metabolise. Therefore, high inclusion of cereal grains may result in poor growth, less efficient digestive organs, increased activity of harmful gut microbes, undesirable sticky droppings, poor feed conversion ratio and carcass downgrades of broiler birds. Such negative effects are usually associated with the presence of high levels of non-starch polysaccharides (NPS) in cereal grains such as wheat and corn or their by-products. Enzymes can overcome these problems by increasing the digestibility and reducing the amount of excreta in broilers. Thus, enzymes not only enhance the performance of birds but also help in reducing the environmental pollution by decreasing the excreta and moisture contents (Choct, 2006). However, the extent of such benefits depended on the nature of the dietary components, processing, particle size and the compatibility of different enzymes with the dietary substrates (Acamovic, 2001).

Although numerous research articles and reviews have been published on various aspects of enzyme use in the poultry industry (Bedford, 1996; Choct, 2006; Kamyab

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Correspondence: A.S. Chaudhry, School of Agriculture, Food and Rural Development, Newcastle University, Newcastle upon Tyne, NE1 7RU, United Kingdom. (E-mail: a.s.chaudhry@ncl.ac.uk)

and Houshmand, 2006; Aksu *et al.*, 2007; Brzoska and Steck, 2007), it is still unclear how these enzymes could remain effective in improving feed utilisation in the foreseeable future. Also, it is essential to find enzymes which are consistently effective in enhancing the utilisation of cereal grains in poultry diets (Scott *et al.*, 1998, 2001; Acamovic, 2001; Meng *et al.*, 2006). It would help if the enzymes could also be used as alternatives to antibiotics after the implementation of European wide ban on the in-feed use of antibiotics as growth promoters. Therefore, this paper reviews various aspects of different enzyme use alone or in combination with organic acids in poultry diets by comparing and contrasting their efficiency in utilising high fibrous diets to reduce nutrient wastage and improve bird health, growth and production.

History of Enzyme Use

The history of enzyme use is somewhat ambiguous but one point is clear that the French scientist Louis Pasteur was the pioneer for some of the developments in enzyme industry. While the digestion of meat by stomach secretions and the conversion of starch to sugars by plant extracts and saliva were known in the late 18th century, the mechanisms by which these conversions occurred were not known at that time. In the 19th century, Louis Pasteur concluded that the conversion of sugars by yeast to alcohol was catalyzed by a vital force in the yeast cells called “ferments”, which were believed to function only in living organisms (Aleksander *et al.*, 2009).

The modern enzyme technology began in 1874 when the Danish chemist Christian Hansen extracted and purified rennet from dried calves' stomach with saline solution. Other enzymes have been used by man in the form of microorganisms in brewing, baking and production of alcohol and even cheese. In fact, some enzyme complexes were isolated from the fermented malt by Payen and Persoz in 1833. These complexes were used to convert gelatinised starch into maltose and termed as “diastase”. Further developments continued during the following decades by Schwann, Liebig, Pasteur and Kuhne. However, Liebig disputed with Pasteur by claiming that fermentation resulted from a chemical process and the yeast was not a viable substance as it was degraded during fermentation. The dispute finally ended in 1897 when the Buchner brothers demonstrated that cell free yeast extract could convert glucose into ethanol and carbon dioxide as did the viable yeast cells. This implied that the conversion was not attributed to yeast cells directly, but to their enzymes. In 1878, a German physiologist William Kuhne used the term *enzyme* for the first time. Similarly, Eduard Buchner in 1897 named the enzyme that fermented sucrose as *Zymase*. From hereafter enzymes were usually named by their reactions with different substrates where the suffix-ase is added to the name of a substrate or the type of reaction.

Recently, hundreds of enzymes have been investigated for various chemical reactions depending upon the sub-

strate and the end products. In poultry diets the maximum focus has been on the digestive enzymes due to their ability to improve the utilisation of dietary nutrients, reduce nutrient wastage and consequently to reduce the poultry production costs.

Using Enzymes in Broiler Diets

It is possible to use enzymes to improve the nutritional value of broiler diets and consequently to facilitate the growth of beneficial gut microflora of broiler birds. Digestive enzymes typically hydrolyse the dietary components and so are classified as hydrolases (Taylor-Pickard, 2008). Different forms and types of enzymes have been used in various poultry diets primarily to enhance their utilisation and ultimately to improve the health and production of broilers as summarised in Table 1. Obviously the success of using single or mixed enzymes in a diet depended upon the quality and suitability of these enzymes for bird health and production and the method of their delivery in poultry diets as described in the following section.

Enzyme Preparation and their Mixing Methods in Diets

Enzymes (single or mixture) are usually mixed in diets according to the manufacturer's guidelines which are regulated by the feed legislations. These guidelines are usually based upon the outcomes of initial tests which are conducted under very controlled conditions by the manufacturers of these enzymes. Many methods have been used to mix enzymes with dietary ingredients in poultry diets and some of these methods are listed as follows:

- Enzyme powders are added to pre-mixes before their mixing with other ingredients as coarse mixtures.
- Enzyme powders or granules are mixed directly with a coarse feed or pellets formed.
- Enzymes as liquid are either mixed with other ingredients, or directly added to the drinking water. Enzymes in drinking water are preferred due to their easy feeding and maximum utilization but immediate use of this water is necessary to retain enzyme activity and utility.
- Adding enzymes as liquid after pelleting avoids the problems associated with pelleting at high temperature. However, this has the disadvantage that the enzyme is coated on the surface of the pellets with no intimate contact with the internal components of the pellets. This may reduce the pre-ingestion action of the enzyme when compared with the application of the enzyme before pellet formation. However, it is claimed that the enzymes applied as liquids to the surface of pellets can exert superior benefits on the nutritional value of the diet and bird performance (Ziggers, 2000).
- The method of inserting genes is preferred but it involves more technological input for inserting foreign genes into the relevant plant DNA to enable it to synthesise novel enzymes such as phytases

Table 1. Examples of enzyme supplementation and the effects on broiler performance

Type of enzyme	Substrate	Purpose or Effect	Author and Year
Protease, Glycosylase	Meals	Nutritional quality of meals and cost saving	Lim and Tan, 2006
Xylanase, amylase, protease, phytase	Corn	Nutrient retention	Olukosi <i>et al.</i> , 2007
Protease and xylanase	Wheat cultivars	Nutrient availability and digestibility	Rafuse <i>et al.</i> , 2005
α -Amylase, β -glucanase and xylanase	Corn + Soybean	Digestibility and lysine flow	Rutherford <i>et al.</i> , 2007
Xylanases, α -amylase and β -glucanase	Cereals	AME, AA digestibility	Lim and Tan, 2006
Xylanase	Wheat	Growth performance	Ponte <i>et al.</i> , 2004
Phytase	Phytate	Enhanced phosphate use	Taylor-Pickard, 2008
Microbial phytase		Phytate degradation	Selle and Ravindran, 2007
Phytase, xylanase	Wheat	Phosphorus digestion, Physiological	Afsharmanesh <i>et al.</i> , 2004
Processing + Phytase	Cereals	and Immunological response	Hassan <i>et al.</i> , 2005
Hemicellulase	Grains	Reduced viscosity and enhanced digestibility	Taylor-Pickard, 2008
Pentosanase	Pentosans	Reduced viscosity etc	Taylor-Pickard, 2008
β -glucanase	β - glucans	Reduced viscosity and enhanced digestibility	Taylor-Pickard, 2008
β -glucanase	Barley	Increased ME	Eila <i>et al.</i> , 2006
Pectinase	Pectin	Reduced viscosity	Taylor-Pickard, 2008
Polygalacturonase and pectin methyl esterase	Lupin	Degrade pectin and reduce viscosity	Ali <i>et al.</i> , 2005
Pectinase, cellulase and hemicellulase	Corn, soybean	Performance and digestion	Tahir <i>et al.</i> , 2006
α -Galactosidase	mannans, galactans	Enhanced digestibility	Taylor-Pickard, 2008
α Glactosidase		Calorie utilization	Waldroup, 2006
Glactanase, mannanase (Ronozyme)	Maize, soybean	Enhanced Nutritive value	Centeno <i>et al.</i> , 2006
Cellulase, cellobiase	Cell wall	Cellulose digestion	Taylor-Pickard, 2008
Cellulase	Corn, soybean	Increased AME	Lim and Tan, 2006
Cellulase, xylanase, glucanase, pectinase, mannanase and pectinase	Canola	Improved energy utilization from oil seeds	Meng <i>et al.</i> , 2006
Cellulase, hemicellulase	Corn, soybean	Synergistic effect	Tahir <i>et al.</i> , 2006

(Acamovic, 2001).

- Adding enzymes in combination with acidifiers, probiotics, growth promoters, symbiotic, amino acids and antibiotics has also been reported
- Combination of enzymes with a solution of glucose has also been suggested

Using Enzymes in Cereal Based Diets

Recently the enzyme research for improved feed efficiency and animal performance has been very popular (Annison and Choct, 1991, 1993; Morgan and Bedford, 1995; Zhang *et al.*, 2005; Kamyab and Houshmand, 2006; Maisonnier-Grenier *et al.*, 2006; Sayyazadeh *et al.*, 2006; Aksu *et al.*, 2007; Danicke *et al.*, 2007; Fabijanska *et al.*, 2007; Gruzaukas *et al.*, 2007). The reason behind this

increased interest in enzyme use is that it allows the maximum (70–80%) inclusion of cereal grains in poultry rations by increasing their digestion in poultry birds. Choct (2006) reported a vital role of enzymes in maximizing the digestion of different nutrients, i.e. amylase digests starch, protease digests protein, and lipase digests fats. However, poultry birds such as broilers lack enzymes that digest the fibrous fractions of cereal grains. The structure of this fibre fraction repels the infusion of endogenous enzymes by binding the nutrients within the fraction that birds could otherwise metabolise. So the high inclusion of cereal grains in poultry diets can retard digestive organs, increase unwanted gut microbial activity, reduce feed conversion and inhibit growth and carcass quality. The presence of high fibre contents and high levels of NSP in

cereals such as wheat and maize are known to affect nutrient digestion in birds. Enzymes can overcome these problems by increasing the digestibility and lowering the amount of excreta in birds. They not only enhance the overall performance of birds but also help in reducing the environmental pollution by decreasing the excreta and moisture contents (Choct, 2006).

The increase in dry matter digestibility for diets containing enzymes could range from 0.9 to 17% (Annison and Choct, 1993) for broilers. Furthermore the digestibility of cereals was improved by reducing the impact of anti-nutrients in these diets. Amongst cereals, wheat, barley, and maize attracted the greater attention of poultry industry because of their easy availability and lower cost than other ingredients (Dibner and Buttin, 2002; Maisonnier-Grenier *et al.*, 2006; Danicke *et al.*, 2007; Fabijanska *et al.*, 2007; Anjum *et al.*, 2009). Many trials have reported the beneficial effects of enzymes on the overall performance, feed utilization and slaughter characteristics of poultry birds consuming wheat, barley or maize based diets (Esteve-Garcia *et al.*, 1997; Ouhida *et al.*, 2000; Scott *et al.*, 2001; Steinfeldt, 2001; Svihubs and Gullord, 2002; Kim *et al.*, 2003; Cowieson *et al.*, 2006; Esonu *et al.*, 2006; Ravindran *et al.*, 2007; Taylor-Pickard 2008). Other ingredients can also be tested for their use in combination with enzymes to improve poultry production and reduce pressure on more costly feed ingredients. However, the need to reduce the cost of broiler production by improving feed utilisation and reducing nutrient wastage still remains. This need may be satisfied by optimising the activity of most appropriate enzymes in poultry diets which may also help improve the efficiency of broiler production.

Using Enzymes for Broiler Health

The role of enzymes in poultry health has been suggested (Jackson *et al.*, 2003; Ali *et al.*, 2005; Orda *et al.*, 2006; Rosin *et al.*, 2007) where better bird performance and low mortality was related to better immunity, health and longevity of these birds. However, Rosin *et al.*, (2007) did not find much effect of enzyme supplementation on microbial populations in the ileum of broilers where the effect on gut bacteria depended on the nature of carbohydrates and the enzyme. While increased dietary lupins in broiler diets significantly decreased colony forming units (CFU) of *E. coli* and *Lactobacillus*, the enzyme addition reduced CFU of *E. coli* and increased *Lactobacillus* in faecal contents from these broilers (Orda *et al.*, 2006).

Better nutrition and management can help reduce the incidence of pododermatitis in poultry (Nagaraj *et al.*, 2007). Indeed, enzyme (Allzyme Vegpro, Alltech Ltd) supplementation of corn-soybean meal based broiler diets showed reduction in pododermatitis in older broiler chickens. Wet excreta could be a big problem for the broiler industry where it may increase the production of ammonia and hydrogen sulphide and fly and rodent populations in

broiler sheds. This can be stressful for the birds and relevant staff due to the poor air quality at these farms. The moisture content in poultry excreta can be reduced by using glycanase in poultry diets. Choct *et al.*, (1995) reported improved broiler production in response to the supplementation of the NSP-enriched sorghum based diet with three different commercial glycanase formulations, which also reduced the moisture in excreta by 10 to 29%. Chesson *et al.*, (2002) observed reductions of up to 50% in sticky and watery droppings from birds consuming enzyme containing barley based diets. Morgan and Bedford (1995) reported that coccidiosis problems could be prevented by using glycanase enzymes in wheat based diet for broilers. Similarly beta-mannanase group of feed enzymes reduced lesion scores in birds receiving oral inclusion of *Eimeria sp.* and *Clostridium perfringens* and so acted as alternative to antibiotics (Jackson *et al.*, 2003). Hassan *et al.* (2005) also supported the health benefits of using dietary phytase for broilers having improved haematocrit and haemoglobin contents.

It is evident from the above research findings that further studies are needed to test the suitability and amounts of enzymes for their effect on preventing the disease and hence improving the performance of broilers in various situations.

Using Enzymes to Improve Meat Quality

Many researches (Bedford, 2000; Ponte *et al.*, 2004; Buchanan *et al.*, 2007; Gruzuaukas *et al.*, 2007) have shown that the use of enzymes in broiler diets can enhance meat production. However, the information on the meat quality of birds consuming enzyme based diets is not always conclusive. Therefore, a more coordinated approach to study the impact of enzymes on broiler meat quality is required (Bedford, 2000).

It has been found that the addition of 20 or 40 mg of Synthetic Soybean Isoflavin (ISF)/kg diet significantly increased the pH and 40 or 80 mg of ISF/kg diet increased the lightness of meat colour (Jiang *et al.*, 2007). The results revealed that dietary ISF could improve the growth performance and meat quality by decreasing peroxidation and improving antioxidants in male broilers. This aspect needs further attention in order to improve the meat quality for its more acceptable colour and extended shelf life. Gruzuaukas *et al.* (2007) found that the Rovabio enzyme (Adisseo, France) with combinations of organic acids and probiotics had no effect on the sensory properties of broiler drumsticks but significantly increased the hardness of their breast meat. More research work is needed to improve the meat quality through improved hardness of Desi (indigenous breeds) chicken meat in Asiatic region where masses usually prefer Desi chicken meat because of its aroma, flavour and taste. Similarly, some consumer groups in America and Western World prefer organic broilers which may be reared better on diets containing enzymes. Buchanan *et al.* (2007) found improved utilisation of diets containing high amounts of

NSP in the presence of enzymes when these diets were offered to the organic chickens. Decreasing energy contents of organic broilers diets was successful for up to 7% with enzymes. This aspect could help decrease the overall feed cost which otherwise can restrict the expansion of organic broiler production.

The use of alfalfa in diets for monogastric animals is limited by its high fibre content. However it is well known that alfalfa is a natural source of xanthophylls which could induce a desirable orange-yellow colour to the broiler meat. Ponte *et al.* (2004) reported that the addition of cellulase and xylanase not only improved the nutritive value of alfalfa based diets but also the skin pigment of the broiler consuming these diets. This aspect of meat colour could be of interest to people who prefer organic chickens with a more desirable skin colour by using natural rather than synthetic products. Some sensory tests to compare the use of synthetic versus natural colours by involving enzymes on broiler meat may be helpful in the future.

Using Enzymes to Improve Slaughter Characteristics and Hormone-enzyme Profiles

Several studies examined the relationship between the enzyme use and slaughter yield and hormones in broilers (Sarvestani *et al.*, 2006; Sartori *et al.*, 2007; Saki *et al.*, 2008). However, these studies were unable to show the clear advantages of using enzymes to modify slaughter aspects in broilers. Sarvestani *et al.* (2006) reported increases in the weights of breast, thigh, abdominal fat, heart and liver of broilers fed 0.75 kg/ton Biozyme (BioZYME Inc, USA) in a pellet diet. Other studies showed increased weights of liver, proventriculus, gizzard and abdominal fat in birds consuming rapeseed based diets with NSP degrading enzymes. Conversely, Saki *et al.* (2008) did not observe any effect of various levels of rapeseed meal and enzyme supplementation on the concentration of thyroxine and triiodothyronine in broilers. Also, Sayyazadeh *et al.* (2006) and Sartori *et al.* (2007) did not observe any effects of enzymes and symbiotic inclusion in the diet on the carcass yields, cuts, abdominal fat and the size but the weight of the intestine. However, breast meat yield was increased in broilers consuming Versazyme (BRI Inc, USA) containing diets (Wang *et al.*, 2006).

The birds consuming low phosphorus and high phytase diets had significantly higher thymus weights but not the weights of thyroid gland, spleen and bursa (Wang *et al.*, 2006). The shank weight and tibia length were higher in broilers consuming no phytase and high phosphorus diet than those consuming high phytase and low phosphorus diets. At 6 weeks of age, plasma calcium, total protein and alkaline phosphatase in broilers consuming diets with 500 FU phytase were significantly higher than the control group. The broilers consuming diets with 750 FU phytase had significantly high plasma lipids and low cholesterol but low plasma acid phosphate than the control birds. In contrast, the xylanase fed broilers had smaller pancreas,

liver, intestine, proventriculus and no change in their serum levels of triiodothyronine, thyroxine, and glucagon except for insulin. The variable impacts of dietary enzymes on bird slaughter characteristics suggest that further studies are needed to find the most suitable enzyme to improve the efficiency of diets and subsequently the slaughter features of these birds.

Using Enzymes and Organic Acids

Table 2 presents many organic acids that could play a vital role in the process of digestion in broilers. They are produced by beneficial microbes, e.g. *Lactobacillus*, which live naturally in digestive tract and so their natural or synthetic forms can play an important role in the poultry diets. Organic acids are mixed with the feed to create an acidified pH which provides a favourable environment in the digestive tract of broilers for the effective digestion of dietary nutrients such as proteins. They act as growth promoters and feed preservatives in poultry where they can also maintain the feed hygiene. More recently, the supplementation of organic acids as feed additives to replace antibiotics has gained momentum due to European ban on the use of antibiotics as growth promoters for poultry and other farm animals. Organic acids and antibiotics improve protein and energy digestibility by reducing the microbial competition with the host for nutrients, endogenous nitrogen losses and ammonia production in addition to their other beneficial effects for broilers (Dibner and Buttin, 2002). Therefore, feeding of organic acids alone or with enzymes and other feed additives has recently achieved more attention and interest of animal nutritionists. Future studies may be able to identify the most suitable organic acids for their use alongside different enzymes in poultry diets.

Researchers (Brzoska and Steck, 2007; Viola and Vieira, 2007) have reported the beneficial effects of organic acids such as fumaric versus lactic acid as alternatives to some feed additives and antibiotics on the performance, carcass quality and intestinal morphology of broilers. While feed intake and feed conversion ratios were not affected, the live weight gain, carcass weight and yields of thigh, breast, neck, liver and internal edible organs were improved with organic acid supplementation at 4 g/kg feed (Aksu *et al.*, 2007). In another experiment, Zhang *et al.* (2005) reported that the birds fed on 1 g/ton Avigro (essential oils plus fumaric, citric and malic acids, Brown & Gillmer Ltd Ireland) or 300 g/ton of Repaxol (essential oils from oregano, cinnamon, thyme, and capsicum; SODA Ingredients, USA) had better feed conversion than the control birds.

Positive effects of feeding organic acids to chickens were also reported by many researchers (Alcicek *et al.*, 2004; Luckstadt, *et al.*, 2004; Jozefiak *et al.*, 2007). Conversely 0 to 0.3% of Genex (propionic acid, ammonium propionate and formic acid; Optivite Ltd, UK) plus salts in broiler diets did not show any effect on bird live weight gain, carcass, edible organs and intestinal pH during 6

Table 2. Some commonly used organic acids in poultry diets or water

Type of acid	Chemical Formula	Amount of acid/kg feed	Functions/Benefits	Author and Year
Tartaric acid	COOHCH(OH)CH(OH)COOH	3 g	Gut morphology and growth	Viola and Vieira, 2007
Propionic acid	CH ₃ CH ₂ COOH		Gut microbes	Dibner and Buttin, 2002
Mixed organic acids		1-2 g	Improved weight and carcass	Aksu <i>et al.</i> , 2007; Samanta <i>et al.</i> , 2008; Owens <i>et al.</i> , 2008
Acids and salts	Genex	2 g	Low intestinal and G- bacteria	Gunal <i>et al.</i> , 2006.
Malic acid	COOHCH ₂ CH(OH)COOH	3 g 0 to 1.5 g	Intestinal morphology Low E. coli & pH high pancreatic fluid and digestion	Viola and Vieira, 2007 Dibner and Buttin, 2002; Moharrery and Mahzonieh, 2005
Lactic acid Lactic acid + organic acid	CH ₃ CH(OH)COOH	3 g	Gut morphology Low bacteria, fungi, pathogens & ammonia	Viola and Vieira, 2007; Dibner and Buttin, 2002
Fumaric acid	HO ₂ CCH=CHCO ₂ H	3 g	Gut morphology, weight and carcass	Viola and Vieira, 2007; Brzoska and Steck, 2007
Formic acid	HCOOH	3 g unclear	Gut morphology, weight & carcass	Viola and Vieira, 2007; Brzoska and Steck, 2007
Euroguard mixture	Mixed	unclear	2% Gain; FCR down by 6%	Gruzauskas <i>et al.</i> , 2007
Organic acids combinations	Mixed (propionic, formic, lactic)	80 to 250 mg	Low Campylobacter	Berrang <i>et al.</i> , 2006
Organic acid + beta-glucanase	Lactic acid	3 g	Low microbe load, no poisoning or meat spoilage More weight, FCR, Low caecal pH	Aksit <i>et al.</i> , 2006 Jozefiak <i>et al.</i> , 2007
Citric acid	CHO ₂ CH ₂ C(OH)(COOH) CH ₂ COOH	3 g	Intestinal morphology	Viola and Vieira, 2007; Moharrery and Mahzonieh, 2005;
Butyric acid	CH ₃ CH ₂ CH ₂ COOH		Low pH and high digestion	Viola and Vieira, 2007; Moharrery and Mahzonieh, 2005; Dibner and Buttin, 2002
Ascorbic acid	C ₆ H ₈ O ₆		Better efficiency	Viola and Vieira, 2007
Acetic acid	CH ₃ COOH	3 g	Gut morphology, Low pH and high digestibility	Viola and Vieira, 2007; Moharrery and Mahzonieh, 2005

weeks of a study. However, Gunal *et al.* (2006) reported that Genex supplementation increased body weight gain, feed intake, carcass and feed efficiency than other groups. The body weight of broiler chicken increased by 2% and feed conversion decreased by 6% as compared to other groups by organic acid feeding (Gruzauskas *et al.*, 2007). Luckstadt *et al.* (2004) supported the use of organic acids to preserve and protect feed from microbial and fungal destruction. It was concluded that organic acids showed variable effects on the performance of broilers.

Choct (2001) reported the wide use of organic acids in Europe to inhibit pathogens like Salmonella in both raw materials and feed. The lower pH caused by the organic acids can protect the animal from infection especially at their younger ages. However, the effectiveness of organic

acids in broiler diets may also depend on the composition of the diet and its buffering capacity.

Clearly, the role of organic acids alone or with other acids or enzymes or probiotics or other oils and spices in poultry diets has been emphasised by many researchers. However, there is still a need to conduct more research in order to establish the suitability of adding such combinations in broiler diets to reduce infections and enhance feed utilisation and broiler production.

Using Enzymes and Probiotics in Broiler Diets

Probiotics or other growth promoters have been used to stabilise the normal intestinal functions, by decreasing the ill effects of enteric pathogens by acting as antibiotics. They can also be used as additives in combination with

enzymes. Such uses can improve the bird performance even under unhygienic conditions during early stages of their growth.

The effect of enzymes, organic acids and probiotics on the growth, feed conversion ratio, mortality and sensory attributes of broiler meat has been reported (Gruzauskas *et al.*, 2007). Sartori *et al.* (2007) reported the use of symbiotic with enzymes to improve the performance of broiler chickens at 42 days of age. In another trial rumen microbial fibrolytic enzyme genes in probiotic (*Lactobacillus reuteri*) not only acquired the capacity to breakdown soluble carboxymethyl cellulose, beta-glucans, or xylans but also showed high adhesion efficiency to mucin and resistance to bile salt and acids (Liu JeRuei *et al.*, 2005). They also observed the positive effect of probiotic and enzyme supplementation on the performance of broilers. The dry matter retention and humoral immune response were highest in probiotic plus enzyme fed birds.

Future studies should test the role of enzymes as probiotics alone or with other known probiotics in improving broiler health during various stages of their growth and production. Such uses of enzymes may also help improve the quality of broiler meat for human consumption.

Conclusion

Enzymes can help improve the utilisation of cereal based diets and consequently optimise the efficiency of broiler production by decreasing the feed costs. Using exogenous enzymes in diets can also improve the growth performance and meat quality of chickens. However, the selection of a correct type and amount of an enzyme and its method of mixing with diets would be essential to achieve the objectives of a successful broiler production system. Nevertheless, the consistency of a target enzyme would remain an issue in achieving the reproducibility of the beneficial impacts of enzyme based diets on broiler production. Combining appropriate type and amount of enzymes with different organic acids or prebiotics in poultry diets can also help maintain the feed hygiene and bird health in different situations. Here, the success of finding a correct enzyme and organic acid alone or together in broiler diets will depend on the continuous supply of these products with reliable quality, shelf life and consistency. Therefore, further research would need more coordinated approach between researchers and poultry industry to find the most suitable combinations of these products in broiler diets. Such an approach may optimise bird health and production to ensure more desirable meat from these birds while minimising the impacts of broiler production on the environment.

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