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THE APPLICATION OF ENZYMES TO ANIMAL FEEDS

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ABSTRACT

Humans have made use of enzymes, often unknowingly throughout history. Cheese making and the use of malted barley in brewing are examples of the harnessing of the power of enzymes. Modern enzyme technology really started in 1874 following the first documented production of a refined enzyme that was prepared from the contents of calves' stomachs. Today, enzymes are widely used in many industries, continuing and extending many processes which have been used since the drawn of history. The first commercial use of feed enzymes in farm animal nutrition dates back to 1984 in Finland, where opportunities existed to improve significantly the nutritional quality of barley-based rations by inclusion of enzymes derived from the brewing industry. The years since then have seen an exponential increase in the usage of many enzyme types in ration for poultry and, to a lesser extent pigs. Significant recent interest has also been shown by the ruminant sector. Enzymes are added to animal feed to increase its digestibility, to remove anti-nutritional factors, to improve the availability of components and for environmental reasons. Associated benefits are reduction in variability of animal response, decrease or elimination of wet, sticky droppings, use of cheap feedstuffs, enabling reformulation of feeds, for example, to decrease the amount of energy or phosphorus added to a ration.

Key Words: Enzymes, Animal Feeds, Ruminant, Pigs, Poultry

INTRODUCTION

Supplemental enzymes found only limited practical use in animal nutrition before the early 1990s. The main reason was an unfavourable relationship between enzyme costs and their real benefits. However, due to the advance in biotechnology leading to lower production costs, economical use of feed enzyme is now possible (Broz and Beardsworth, 2002). Economically, the cost of the manufacture and use of feed enzymes is usually repaid in enabling cheaper feeds to be fed and in increasing nutrient digestibility (Henuk and Dingle, 2002). The purpose of this paper is to review the history of enzymes, their classification and practical applications in animal feeds.

What are enzymes?

Throughout the great diversity of living matter there runs a basically similar pattern of chemical changes, by which food is converted into energy and into the structural materials for growth and reproduction, while waste products and toxic substances are eliminated. The rate at which these changes take place, and the nature of

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the products formed, are controlled by the properties of catalysts produced by living systems; these catalysts are called 'enzymes' (Moss, 1968).

The term "enzyme" was proposed by Kühne in 1878 to avoid the use of names "unorganized" and "organized" ferments being used by Pasteur and Leibeig. Emil Fisher developed the concept of enzyme specificity in 1894. His studies on synthetic substrates produced the famous "lock and key" analogy of enzyme substrate interaction. This close stereospecific fit between enzyme and substrate has continued to influence thinking on the enzyme substrate complex to the present day (Sears and Walsh, 1993).

In other words, enzymes are biological catalysts and all enzymes are proteins (Palmer, 1981; Sears and Walsh, 1993). Perhaps the best definition of an enzyme was proposed by Underkofler *et al.* (1958): "Enzymes are biocatalysts, produced by living cells to bring about specific biochemical reaction generally forming parts of the metabolic process of the cells. Enzymes are highly specific in their action on substrates and often many different enzymes are required to bring about by concerted action, a sequence of metabolic reactions performed by the living cell. All enzymes which have been purified are protein in nature, and may or may not posses a non-protein prosthetic group."

Enzyme classification

There is a long tradition of giving enzymes names ending in "-ase". The only major exceptions to this are the proteolytic enzymes, whose names usually end with "-in", e.g. trypsin (Palmer, 1981). Enzymes are classified into six different groups depending on the type of reaction catalyzed (Table 1). Each classification is then further subdivided until enzymes are identified by a chemically meaningful six figure code (Palmer, 1981). Enzymes are also classified as "endo" or "exo" enzymes which refers to the way the enzyme attacks the substrate molecule. Endo enzymes attack the substrate at the interior bonds, while exo enzymes approach the substrate from one or the other end or the molecule (Search and Walsh, 1993).

A brief history of enzymes and their industrial applications

Humans have made use of enzymes, often unknowingly throughout history. Cheese making and the use of malted barley in brewing are examples of the harnessing of the power of enzymes (Sheppy, 2001). The early history of the study of enzymes is largely involved with two biological processes, the digestion of food by animals and fermentation of sugar to alcohol by yeast (Moss, 1968). Until the 19th century, it was considered that processes such as the souring of milk and the fermentation of sugar to alcohol could only take place through the action of living organisms (Palmer, 1981). The first clear recognition of enzyme action is generally taken to be the discovery by Payen and Persoz in 1833 that a substance could be precipitated by alcohol from malt extract which was capable of converting starch into sugar. They called the active principle diastase, from the Greek word for separation, (now known as amylase), because of its ability to separate soluble dextrins from insoluble starch grains, they also observed that it was destroyed by heat (Moss, 1968; Palmer, 1981; Sears and Walsh, 1993).

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Table 1. The six main classes of enzymes (after Palmer, 1981).

First digit	Enzyme class	Type of reaction catalyzed
1	Oxidoreductases	Oxidation/reduction reactions
2	Transferases	Transfer of an atom or group between two molecules (excluding reactions in other classes)
3	Hydrolases	Hydrolysis reactions
4	Lyases	Removal of a group from substrate (not by hydrolysis)
5	Isomerases	Isomerisation reactions
6	Ligases	The synthetic joining of two molecules, coupled with the breakdown of a pyrophosphate bond in a nucleoside triphosphate

That enzyme, rennet, is still used today in cheese manufacture (Sheppy, 2001). In 1884, Jokichi Takamine was awarded a patent in the US for the first industrial application for an enzyme called "Taka-Diastase." This particular diastatic enzyme was derived from a mold, *Aspergillus oryzae*, which was grown on rice. The name, "Takamine," is present throughout the literature and has become synonymous with enzyme products and application in both the pharmaceutical and industrial enzyme products (Search and Walsh, 1993).

The first commercial use of feed enzymes in farm animal nutrition dates back to 1984 in Finland, where opportunities existed to improve significantly the nutritional quality of barley-based rations by inclusion of enzymes derived from the brewing industry. The years since then have seen an exponential increase in the usage of many enzyme types in ration for poultry and, to a lesser extent pigs. Significant recent interest has also been shown by the ruminant sector (Bedford and Partridge, 2001). Officer (2000) also reported that between the late 1980s and mid 1990s, enzyme products changed with the formulation of feed enzyme supplements specifically for animal diets. Over this period, feed enzyme supplementation has increased dramatically all over the world, but predominantly in pig and poultry diets. Also in recent years, renewed research interest into the potential value of feed enzymes has occurred in the field s of ruminant nutrition and aquaculture.

Today, enzymes are widely used in many industries, continuing and extending many processes which have been used since the drawn of history (Palmer, 1981; Search and Walsh, 1993; Sheppy, 2001; Thorpe and Beal, 2001). The use of enzymes in industry continues to expand due the following five distinct advantages of enzymes relative to chemical and mechanical processing methods.

They are: (1) enzymes are of natural origin and are non-toxic; (2) enzymes have specific activities; (3) enzymes work best under mild conditions, i.e., moderate temperatures, and broad pH range. High temperature, pressure, or high acidity which may require special equipment are not needed; (4) enzymes work rapidly at relatively low concentrations. The rate of reaction can be readily controlled by adjusting temperature, pH, and concentration of enzyme; (5) enzymes are easily inactivated when the reaction has reached the desired point (Search and Walsh, 1993).

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Why use enzymes in animal feeds?

Table 2. Some of the companies now producing enzymes (after Hotten, 1992; Dingle, 1995).

Company name (country)	Example of brand name	Substrate	Enzyme
Alko	Finase	Phytin in plants	Phytase
Alltech Biotechnology (Limited	Allzyme	Protein in cereal	Protease
(USA)	Superzyme	Starch	Amylase
Bicon India (India)	Endofeed	Cellulose	Cellulase
Bioferm Limited (Canada)	-	β-glucans	β-glucanase
Boerhigher (Germany)	Superzyme	β-glucannase	β-glucanase
CelticSea (Ireland)	Irgazyme	Pectin	Pectinase
Ciba-Geigy Corporation	Avizyme SX	β-glucans	β-glucanase
Finnfeeds International (Finland)	Selfeed	Specific feeds	-
GHEN (Japan)	Natuphos	Phytin in plants	Phytase
Gist-Brocades(The Netherlands)	Grindazym GV feed	Cellulose	Cellulase
Grindsted Products (Denmark)	Kenzyme W	Pentosans in wheat	Pentosanase
Kemin Industries (USA)	Driselase	Carbohydrate	Carbohydrase
Kyowa Hakko, Kogyo Co. Ltd.	ZY	Cellulose	Cellulase
(Japan)	Cellulase TV	Starch	Cellulase
Lohmann (Germany)	Bio-feed	β-glucans	β-glucanase
Miles Chemical Co. (USA)	AD – 30,000	Starch	Cellulase
Novo Nordisk (Denmark)	Enerzyme	Xylan	Xylanase
Pfizer Limited (USA)	Roxazyme G	Cellulose	Cellulase
Quest International	Rhozyme	Starch	Amylase
Roche Products (Switzerland)	Onazuka ss.	Cellulose	Cellulase
Rhone-Poulenc (Switzerland)			
Yakult Biochemicals Co. (Japan)			

In many animal production systems feed is the biggest single cost and profitability can depend on the relative cost and nutritive value of the feeds available. Thus, the principal rationale for the use of enzyme technology in feeding of domestic animals is to improve the nutritive value of feedstuffs (Sheppy, 2001). A wide variety of carbohydrase, protease, phytase and lipase enzymes find use in animal feeds. They are added to animal feed to increase its digestibility, to remove anti-nutritional factors, to improve the availability of components and for environmental reasons (McCleary, 2001). Associated benefits are reduction in variability of animal response, decrease or elimination of wet, sticky droppings, use of cheap feedstuffs, enabling reformulation of feeds, for example, to decrease the amount of energy or phosphorus added to a ration.

In general, there are eight main reasons for using enzymes in animal feed: (1) to break down anti-nutritional factors that are present in many feed ingredients; these substances, many of which are not susceptible to digestion by the animal's endogenous enzymes, can interfere with normal digestion, causing poor performance and digestive upsets (e.g. β-gluconases, xylanases); (2) to release starch, protein and minerals that are enclosed within fibre-rich cell walls and therefore not as accessible to the animal's own digestive enzymes (e.g. cellulase); (3) to break down specific chemical bonds in raw materials that are not usually broken down by the animal's own enzymes, thus releasing more nutrients (e.g. phytases); (4) to supplement the enzymes produced by young animals where, because of the immaturity of their own digestive system, endogenous enzyme production may be inadequate (e.g. amylases, proteases, lipases); (5) to reduce the variability in nutritive value between feedstuffs (e.g. energy and CP contents of feedstuffs); (6) to improve the accuracy of feed formulations; (7) to reduce the incidence of wet litter in poultry production; and (8) to decrease environmental pollution (Officer, 2000; Sheppy, 2001; McCleary, 2001; Thorpe and Beal, 2001; Ravindran, 2001; Kies *et al.*, 2001; Williams, 2001; Schöner and Hoppe, 2002; Broz and Beardsworth, 2002).

In practice, enzymes have found widespread application in those countries where animal diets are based principally upon wheat, barley, oats, triticale or rye. The rapid commercial uptake of this new technology in recent years has resulted from extensive research, yielding a greater understanding of the anti-nutritive properties of these cereals and of the enzyme types and dosages required to reduce their negative effects. This in turn has stimulated the commercial availability of a number of feed enzyme products that can offer consistent and economic benefits to the user (Hotten, 1992; Dingle, 1995 – Table 2).

CONCLUSION

1) The first commercial use of feed enzymes in farm animal nutrition dates back to 1984 in Finland.
2) Enzymes are classified into six different groups depending on the type of reaction catalyzed. They also classified as "endo" or "exo" enzymes which refers to the way the enzyme attacks the substrate molecule.
3) Enzymes are added to animal feed to increase its digestibility, to remove anti-nutritional factors, to improve the availability of components and for environmental reasons. Associated benefits are reduction in variability of animal response, decrease or elimination of wet, sticky droppings, use of cheap feedstuffs, enabling reformulation of feeds, for example, to decrease the amount of energy or phosphorus added to a ration.

REFERENCES

Bedford, M.R. and G.G. Partridge. 2001. *Enzymes in Farm Animal Nutrition.* CAB International, Wallingford, UK.

Broz, J. and P. Beardsworth. 2002. Recent trends and future developments in the use of feed enzymes in poultry nutrition. In: *Poultry Feedstuffs: Supply, Composition, and Nutritive Value*, pp. 345–361. Edited by J.M. McNab and K.N. Boorman. CAB International. Wallingford, UK.

Dingle, J.G. 1995. The use of enzymes for better performance of poultry. In: *Proceedings of the Queensland Poultry Science Symposium*, 4(14): 1-10. Edited by J.G. Dingle. The University of Queensland. Gatton, Queensland, Australia.

Henuk, Y.L. and J.G. Dingle 2002. Poultry wastes: current problems and solutions. In: *Global Perspective in Livestock Waste Management: Proceedings of the 4th International Livestock Waste Management Symposium* and *Technology Expo*, pp. 101-111. 19-23 May 2002, Penang, Malaysia. Edited by H.K. Ong, I.

ISBN 979-97243-9-2

Zulkifli, T.P. Tee and J.B. Liang. Malaysian Society of Animal Production, Penang, Malaysia.

Hotten, P. 1992. Enzymes as a feed additive. *Feed Mix*, May: 9-10, 12.

Kies, A.K., K.H.F. Van Hemert, and W.C. Sauer, 2001. Effect of phytase on protein and amino acid digestibility and energy utilisation. *World's Poultry Science Journal*, 57: 110-126.

McClearly, B.V. 2001. Analysis of feed enzymes. In: *Enzymes in Farm Animal Nutrition*, pp. 85-207. Edited by M.R. Bedford and G.G. Partridge. CAB International. Wallingford, UK.

Moss, D.W. 1968. *Enzymes*. Oliver & Boyd, London, UK.

Officer, D.I. 2000. Feed enzymes. In: *Farm Animal Metabolism and Nutrition*, pp. 405-426. Edited by J.P.F. D'Mello. CABI Publishing. Wallingford, UK.

Palmer, T. 1981. *Understanding Enzymes*. Ellis Horwood Ltd., Chichester, UK.

Ravindran, V. 2001. Potential of microbial phytases to release nutrients. *Asian Poultry Magazine*, July/August: 32,35-38.

Search, A. and G. Walsh. 1993. Industrial enzyme applications: using these concepts to match animal, enzyme and substrate in feed industry applications. In: *Proceedings of Alltech's 9th Annual Symposium on Biotechnology in the Feed Industry*, pp. 373-394. Edited by T.P. Lyons. Alltech Technical Publications, Kentucky, USA.

Schöner, F.J. and P.P. Hoppe. 2002. The effects of phytase in poultry nutrition. In: *Poultry Feedstuffs: Supply, Composition, and Nutritive Value*, pp. 363–373. Edited by J.M. McNab and K.N. Boorman. CAB International. Wallingford, UK.

Sheppy, C. 2001. The current feed enzyme market and likely trends. In: Enzymes in Farm Animal Nutrition, pp. 1-10. Edited by M.R. Bedford and G.G. Partridge. CAB Publishing. Wallingford, UK.

Thorpe, J. and J.D. Beal. 2001. Vegetable protein meals and the effects of enzymes. In: *Enzymes in Farm Animal Nutrition*, pp. 125-143. Edited by M.R. Bedford and G.G. Partridge. CAB International. Wallingford, UK.

Underkofler, L.A., R.R. Barton, and S.S. Rennert. 1958. Micro-biological process report. Production of microbial enzymes and their applications. *Applied Microbiology*, 6(3): 212-220.

Williams, W.P. 2001. Economic implications of phytase use in layer nutrition. In: *Proceedings of Alltech's 17th Annual Symposium on Science and Technology in the Feed Industry*, pp. 235-239. Edited by T.P. Lyons and K.A. Jacques. Nottingham University Press. Nottingham, UK.