

Poultry Research Foundation

50th Anniversary Seminar

13th February, 2008

Edited by

Peter H. Selle

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Preface

The Poultry Research Foundation was one of the original Foundations established within the University of Sydney. The purpose of the Foundation is to provide an interface between the relevant industries in Australia and the University of Sydney.

As part of the Foundation's link with industry, it has hosted workshops, seminars and symposia since its inception. In 1989 the annual Foundation Symposium became the Australian Poultry Science Symposium as a joint meeting with the Australian Branch of the World's Poultry Science Association. An indication of the success of the Symposium is that it now features prominently in the international calendar of Poultry Science meetings. This year the Symposium is making way for the World Poultry Science Congress which is being held in Brisbane in June. However, as 2008 is the 50th year of the Foundation, a one day Conference was held at Camden to allow past and present members of the Foundation and members of industry to celebrate the achievements of the Foundation and speculate on future developments in poultry research. This booklet records the proceedings of the Conference.

The Foundation has made a major contribution to the development of the Australian poultry and stockfeed industries during the past five decades. This has been achieved through research programs directed at obtaining a better understanding of the metabolism and nutrition of poultry. Much of the research has concentrated on feed composition and nutrient requirements reflecting the fact that feed accounts for about 60% of the total cost of poultry production. This approach has helped improve the production, efficiency and profitability of the commercial egg and broiler meat industries.

The success of the Foundation has ultimately depended on the efforts of numerous people but in particular a number of individuals have given many years of service including: Chairmen (now known as Presidents) Mr. John Darling (1959-1969), Mr. Val Parkinson (1969-1981) and Dr. Balkar Bains (1981-1988) and the Directors: Professor Terry Robinson (1959-1977 and 1982-1983), Professor Frank Annison (1977-1981 and 1984-1991) and Professor David Fraser (1992-2000). None of the success would have occurred without the energy and imaginative insight of distinguished research directors from the Department of Animal Husbandry, later to become the Department of Animal Science including: Dr. Harold McNary (1959-1965), Associate Professor Charles Payne (1967-1977) and Associate Professor Derick Balnave (1978-2001). In addition, Professor Wayne Bryden commenced as a PhD student in the Foundation Unit in 1976 and spent the following 25 years working within the Department and the Unit. Throughout the history of the Foundation, technical, administrative and academic staff have been pivotal to the day-to-day running of the Unit. Mrs. Joy Gill has tirelessly contributed to the success of the Foundation over the last 34 years along with Mrs. Melinda Hayter who has been with the unit for 20 years. During part of that period, Mrs. Noelene West was Secretary of the Foundation Unit at Camden (1987-2003), with Mrs. Deirdre Pudney, Secretary in the Sydney office (1978-2001); they were both instrumental in the organisation of Foundation activities. Also the more recent contributions of Dr. Wendy Muir and Dr. Jeff Downing should be mentioned. All of these individuals have contributed greatly to the success of the Foundation.

Over the past fifty years more than 70 students have completed postgraduate degrees or diplomas in the Foundation's research facilities at Camden. The research effort of postgraduate students has been augmented over the years by industry funded Research Fellows. In developing the program for the Conference past and present members of the Foundation were invited to provide a commentary on their research and/or the role of research in the development of the industry. The Foundation is grateful to all the contributors for agreeing to participate in this conference.

Finally, it is appropriate to acknowledge the Committee who arranged this Conference: Linda Browning, Judy O'Keefe, Greg McDonald, Peter Groves and Wayne Bryden. Also, a special thank you is due to Jo-Ann Geist for her excellent administrative support in the production of this booklet and her pivotal role in the organisation of the Conference.

W.L. Bryden
Organising Committee

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Mr. J. Darling
Mr. E. Newton

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***DEPUTY
PRESIDENT*** Ms. Judith O'Keeffe

***DIRECTOR
(ACTING)*** Dr. Peter Groves

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Dr. J.A. Downing, WDA, B.Sc., Ph.D.
Dr. W.I. Muir, B.Sc. Agr., Ph.D.

Honorary Research Fellow

Dr. P.H. Selle, B.V.Sc. Ph.D.

General Staff

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Mrs. M.E. Hayter - Farm
Mrs. J. Geist - Administrative

Postgraduate Students

Mr. M. Sayed MSc. (Poultry
Production)

Mrs. E. Ovelgonne MAg.Sc., D.V.M.



Ms. Linda Browning



Ms. Judy O'Keeffe



Dr. Peter Groves



Dr. Jeff Downing



Dr. Wendy Muir



Dr. Peter Selle



Mrs. Joy Gill



Mrs. Melinda Hayter



Mrs. Jo-Ann Geist



Mr. Mohamed Sayed



Mrs. Elizabeth Ovelgonne

PAST FOUNDATION OFFICERS & STAFF

PRESIDENT (CHAIRMAN)

Mr. J. Darling	1959-1969
Mr. V. T. Parkinson	1969-1981
Dr. B.S. Bains	1981-1998
Mr. E. Newton	1999
Dr. I. Partridge	2000-2005

***DEPUTY PRESIDENT
(DEPUTY CHAIRMAN)***

Mr. A. J. Lockett	1959-1964
Mr. V.T. Parkinson	1965-1969
Mr. S. J. Wilkins	1969-1981
Mr. D. J. Ebbott	1981-1987
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Mr. A. Hartley	1989-1993
Dr. T. Walker	1994-1997
Mr. E. Newton	1998
Dr. I. Partridge	1999
Ms. L. Browning	2000
Mr. D. Damjanovic	2001-2004
Mr. J. Aspinall	2004-2005

SECRETARY

Mr.C.W. Bridges-Maxwell	1959-1964
Mr. K.E. Beguad	1965-1973
Mr. R.N.Bird	1974-1975
Mr. C. Morbey	1975-1985
Mr. P. J. Hewson	1985-1987

SECRETARIAL STAFF

Mrs. J. Rock	1970-1975
Mrs. P. Grundy	1976
Ms. S. Pyman	1977-1981
Mrs. D. Pudney	1978-2001
Ms. K. Muhleisen	1983-1985
Ms. H. Kershaw	1985-1986
Mrs. N. West	1987-2003

***DIRECTOR AND RESEARCH
DIRECTOR***

Professor T.J. Robinson	1959-1977
Dr. H.W. McNary	1959-1966
A/Professor C.G. Payne	1967-1977
Professor E.F. Annison	1978-1981
A/Professor. D. Balnave	1978-2001
Professor T. J. Robinson	1982-1983
Professor E.F. Annison	1984-1991
Professor D.R. Fraser	1992-2000
A/Professor W.L. Bryden	2001
A/Professor W.M.C.Maxwell	2002
Professor T.A. Scott	2003-2006

RESEARCH FELLOWS

Dr. G. Annison	1987-1990
Dr. T.A. Scott	1988-1989
Dr. A.O. Ajuyah	1993-1995
Dr. I. Gorman	1993-1995
Dr. G. Ravindran	1994-1998
Dr. V. Ravindran	1994-1998
Dr. J.A. Downing	1996-2002
Dr. X. Li	1996-2002
Dr. W. Muir	1997-2001
Dr. R. E. Newman	2001-2003

JUNIOR RESEARCH FELLOWS

Ms. L. Berven	1988-1991
Mrs. N. Usayran El-Khatib	1991-1992
Mr. G.G. Irish	1991-1992
Ms. W. Muir	1992-1996

**HONORARY GOVERNOR
(YEAR APPOINTED)**

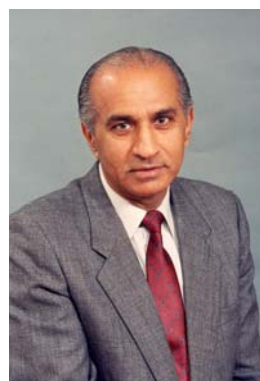
J. Darling	1969
T.J. Robinson	1979
V.T. Parkinson	1981
E.F. Annison	1994
B.S. Bains	1999
D. Balnave	2001
W.L. Bryden	2002
E. Newton	2004



Mr. John Darling



Mr. Val. Parkinson



Dr. Balkar Bains



Mr. Ern Newton



Dr. Ian Partridge



Mr. Syd Wilkins



Mr. David Ebbott



Dr. Tim Walker



Mr. Jim Aspinall



Mr. Charles Morbey



Professor Terry Robinson



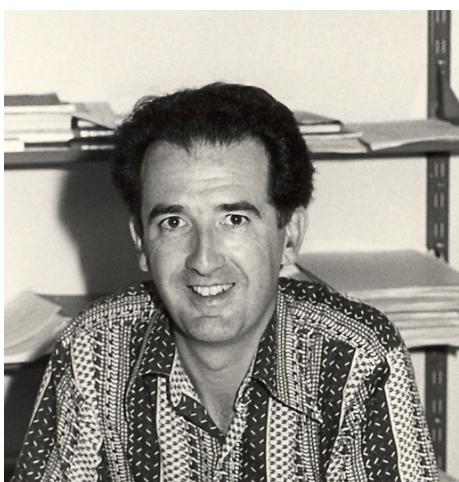
Dr. Harold McNary



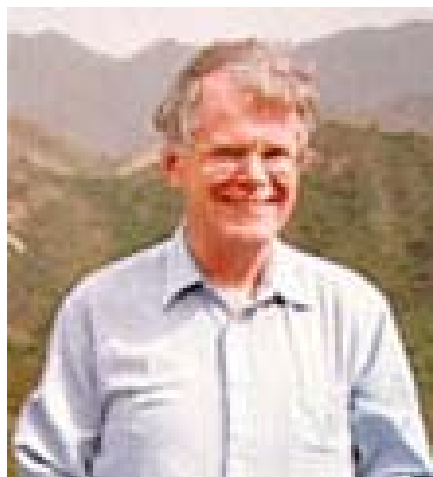
Associate Professor
Charles Payne



Professor Frank Annison



Associate Professor
Derick Balnave



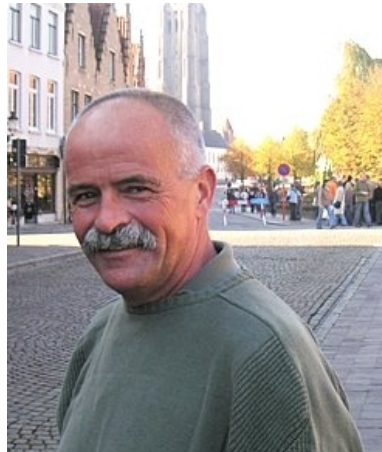
Professor David Fraser



Associate Professor
Wayne Bryden



Associate Professor
Chis Maxwell



Professor Tom Scott



Dr. Geoffrey Annison



Dr. Ravindran



Dr. Xiuhua Li



Noelene West & Deirdre Pudney

POSTGRADUATE DEGREES COMPLETED 1958 - 2008

Student	Ph.D. Thesis Title	Year
E.E. Best	Blood glutathione of the domestic fowl	1966
F.P. Moss	The growth of skeletal muscle in the domestic fowl	1967
W. Kingsley-Smith	The effect of environmental temperature and dietary nutrient concentration on the egg weight of laying strain hens and the growth of broiler chickens	1969
R.G. Packham	Growth studies on the nutrition of the broiler chicken	
N.A. Watson	The nature of egg production in Australian broiler-type hens	1976
J.A. Nell	Molybdenum in the nutrition of the chicken	1979
R. MacAlpine	Energy-protein interrelationships in broiler chicken nutrition	1980
Y. Mollah	Metabolizable energy of poultry diets in relation to cereal carbohydrates and their interactions	1980
W.L. Bryden	Nutritional and hormonal aspects of biotin metabolism in the fowl	1982
G.S. Heard	Utilization of vitamin B ₆ in the domestic fowl	1982
A.M. Rogel	Wheat starch digestion in chickens	1986
A.P. Sinurat	The effect of high ambient temperature on broiler growth and some plasma growth-related hormone profiles	1986
T.A. Scott	The response of sexually-maturing pullets to ambient temperature, diet composition and feeding regimen	1987
I. Yoselewitz	Effects of drinking water containing sodium chloride on shell gland function and egg shell quality	1989
P. Siriwan	Endogenous amino acid secretion in relation to protein digestion in the chicken	1990
L.A. Berven	Studies on vitamin D metabolism and bone abnormalities in growing chickens	1991

M. Choct	The anti-nutritive effect of wheat pentosans in poultry	1991
A.G. Oliva	Sulphur amino acid requirements of broilers at moderate and high temperatures and sodium biocarbonate supplements	1991
G.G. Irish	The nutritive value of soyabean meal and the effect of complementary protein concentrates in broiler retention	1992
I. Gorman	Influence of dietary minerals on the production performance and mineral retentions of broilers at high temperatures	1993
S. Suksupath	Cyclopiazonic acid toxicity in laying hens	1993
N. Usayran El-Khatib	Studies of phosphorus requirements and uterine shell-forming enzymes in the laying hen	1993
N. Wing	The toxicity of <i>Fusarium</i> species in section gibbosum	1993
D. Zhang	Shell gland function and egg shell quality	1993
K. Angkanaporn	Hormoarginine and endogenous amino acid secretions in chickens	1995
W.I. Muir	Novel strategies for improved mucosal immunity in chickens: Application to control Samonellosis	1996
J. Hayat	Application of high dietary arginine: Lysine ratios for heat-stressed broilers	1999
Hew Lap Im	Studies of animo acid digestibility in poultry	1999
S.M. Hosseini	Responses of laying hens to dietary supplementation with single feed additives at thermoneutral and high temperatures	1999
W.J.K. Bakau	Physiological responses of domestic fowl to ergoline mycotoxins	2000
R.E. Newman	Modulation of avian metabolism by dietary fatty acid	2001
P.H. Selle	Phytate and phytase: Consequences for protein and energy utilization by pigs and poultry	2001
J. Chen	Aspects of amino acid and mineral nutrition of broilers and laying hens	2001

Student	Master's Thesis Title	Year
K. bin Ismail	Selection of broilers	1964
J.F. Dillon	An investigation of the importance of vitamin B6 in practical chicken diets	1964
Koentjoko	Studies in the use of rape seed meal in poultry diets	1974
R. Lahore	Energy allowances for layers	1974
W.J. Yule	Australian vegetable proteins in broiler diets	1975
B.V. Luong	A study of peanut meal, rapeseed meal, feather meal and meat meal for laying hens	1976
R.W. Naylor	Studies on the amino acid allowances for layers	1977
R. Brewster	Rearing energy restriction for layers	1979
Y. Derilo	The sulphur amino acid and choline requirements of broiler chickens	1979
M. Daniel	Meal feeding and heat stress responses of laying hens	1980
S.K. Aloa	Importance of fatty acid composition and level of supplementation of fats and oils in broiler diets	1983
L.C. Flood	Measurement of methionine availability and uptake in poultry and the methionine requirements of Australian broiler breeders	1983
I.R. Wallis	Studies on digestability bioassays in the fowl with particular reference to amino acids	1983
Ruo-jun Xu	Full fat soybeans for poultry	1984
N. Suwindra	The effect of intermittent lighting and feeding on broiler performance	1985
T.M. Abdoellah	The responses of egg-laying pullets to self-select feeding at high and low temperature	1989
W.J.K. Bakau	Toxicity of <i>Alternaria</i> and <i>Claviceps</i>	1990
J.A. Jois	The effect of microbiota on the digestibility of amino acids in chickens	1993
C.C. Kyarisiima	Influence of ambient temperature during growth and lay, and nutrient density of layer diets, on the performance of laying hens	1995

M.T. Amba	A study of two <i>Fusarium</i> toxins: fusarochromanone and fumonisins	1996
A.A. Baird	Behavioural immunity in birds	1997
S. Muheereza	Improving egg shell quality at high temperatures	1997
S. Cabahug	Microbial phytase and nutrient availability in broiler diets	1998
C.A. Den Brinker	Biogenic amines in fish products and animal by-products	2000
T.D. Ho	Lipid utilization in poultry	2000
P. Mollett	Aspects of amino acid digestibility in broiler chickens	2001
X. Wang	Sialic acid in porcine milk, saliva and plasma	2001
S.J. Wilkinson	Sialic acid kinetics in a porcine model of the human neonate	2002

PhD's:



Errol Best 1966



Frank Moss 1967



Roger Packham 1973



Nikki Watson 1976



John Nell 1979



Ron MacAlpine 1980



Yasin Mollah 1980



Wayne Bryden 1982



Greg Heard 1982



Anne Rogel 1986



Arnold Sinurat 1986



Tom Scott 1987



Israel Yoselewitz 1989



Perm Sak Siriwan 1990



Leise Berven 1991



Mingan Choct 1991



Geoff Irish 1992



Irene Gorman 1993



Sucheeep Suksupath 1993



Nadia Usayran El-Khatib 1993



Dagong Zhang 1993



Kris Angkanaporn 1995



Wendy Muir 1996



Javed Hayat 1999



Hew Lap Im 1999



Mohamed Hosseini 1999



Bill Bakau 2000



Peter Selle 2001

Masters:



Koentjoko 1974



Rosalie Lahore 1974



Robert Brewster 1979



Yolanda Derilo 1979



Madeleine Daniels 1980



Louise Flood 1983



Ruo-jun Xu 1984



Tuti Abdoellah 1989



Bill Bakau 1990



Jenny Jois 1993



Sam Muheereza 1997



Tam Duc Ho 2000



Stuart Wilkinson 2002

The Establishment and Research Activities of the Poultry Research Foundation – The First Two Decades.

E. F. Annison

Honorary Governor, Poultry Research Foundation, University of Sydney, Camden NSW 2570

The establishment of the Poultry Husbandry Research Foundation (now termed Poultry Research Foundation, PRF) has been dependant on the long term financial support of the poultry industry since its inception, as outlined below. For the first three decades of its existence, the PRF was closely integrated with the Department of Animal Science. The Head of Department, as directed by the constitution of the Foundation, was also Director of the Foundation. The activities of the Department and the Foundation were inextricably linked, to the mutual benefit of both bodies. This situation changed a decade or two ago when the Faculty of Veterinary Science abolished Departments, probably in response to financial stringencies and the Foundation became accountable to a Faculty Committee.

Professor T.J. Robinson, who was appointed to the Foundation Chair of Animal Husbandry at Sydney University in 1955, recognized that the poultry industries in Australia at that time lagged far behind their counterparts in the USA and Europe in terms of productivity and profitability. The overseas industries owed their success to the application of research findings delivered by scientists working in Universities, Colleges of Agriculture and the U.S. Department of Agriculture. In contrast, in Australia very few scientists were committed to poultry research and development. Professor Robinson concluded, after discussion with senior members of the poultry industry, and with C.S.I.R.O.

and State Departments of Agriculture, that the most effective strategy to encourage research relevant to the animal industries would be to create University Foundations which would operate in close partnership with industry. The University would provide staff, buildings and infrastructure, with industry contributing funds for relevant research programs.

The President of the Breeders and Hatcherymans Association Mr. Aub Lockett agreed with Professor Robinson that the urgent needs of the poultry industry for research and development would be met, at least in part, by the proposed Poultry Foundation.

Mr. Lockett's support was crucial in convincing a good proportion of the chicken industry in NSW to provide financial support for the proposed Foundation. This industry support encouraged Professor Robinson to appoint a Research Director to accept responsibility for the planning and construction of a Poultry Unit adjacent to the Shute Building. Dr Harold McNary, an experienced poultry scientist at Purdue University, USA, was appointed in 1958 for five years, with his salary provided by the poultry industry (£1000 p.a.), the Pfizer Corporation (£1000 p.a.) and the Rural Bank (£500 p.a.).

The efforts to establish the PRF were coordinated by a Provisional Council comprising University and industry representatives, and the inaugural

meeting of the Poultry Husbandry Research Foundation took place on 12 May 1959. The industry members present were:

Mr. J. Darling (J. Darling & Son Pty Ltd.). Elected Chairman.

Mr. A.J. Lockett (B&H Association). Elected Deputy Chairman.

Mr. F.A. Giddey (Phillips-Roxane P/L).

Mr. S. Jedlin (Crest Mills Pty Ltd).

Mr W.L. Jones (W.S. Kimpton & Sons).

Mr. E.R. Manson, representing Mr. W. Clancy (Pfizer Corporation).

Mr. T. Matthews, representing Mr. C.R. McKeritan (Rural Bank of NSW).

Mr. D. Nettlefield (Merck Sharp & Dohme).

Mr. R.H. Rule (Aust. Broiler Growers' Association).

Mr. F.C. Sergeant (Steggles P/L).

Mr. J. Traham, representing Mr. V.T. Parkinson (Roche Products Pty Ltd).

Mr. Parkinson and Mr. Clancy were elected governors. Mr. W. Bridges-Maxwell was appointed secretary of both the Poultry Research Foundation, and the Dairy Research Foundation, whose inaugural meeting was held in April 1959. The Poultry Research Foundation is indeed fortunate that Mr. John Darling, the first chairman of the Foundation, is still with us, and is often an honoured guest at Annual Symposium Dinners.

The building program initiated by Dr. McNary was completed in 1962, with the erection of layer and broiler units, and the Environmental Laboratory. The total cost was about £30,000 of which the industry, through the Foundation members subscriptions, contributed about £20,000, the remainder coming from the Commonwealth Government. The building costs, £30,000, represents about \$350,000 in present currency.

Laboratory facilities for the unit were made available in the Shute Building.

Dr. McNary resigned in 1965, and returned to the U.S.A. where, sadly, he died in 1969. In 1968 he was replaced as Research Director of the PRF by Dr. Charles Payne from the University of Nottingham. Charles Payne was an incredibly enthusiastic, dedicated and inventive research scientist, with a practical knowledge of all facets of poultry production. Much of his research in the UK had involved poultry housing, in addition to his commitment to poultry nutrition. At Camden his responsibilities included undergraduate teaching in the Faculties of Agriculture and Veterinary Science and supervision of postgraduate students.

The direct involvement of Charles Payne with the poultry industry was best illustrated by his readiness to travel, at short notice, all over Australia to advise producers experiencing problems with any aspect of poultry production. Most of his weekends were spent in the Shute Building maintaining analytical equipment, the most demanding of which was an early version of the classical Moore and Stein amino acid analyzer. As alluded to by Professor Balnave in a subsequent paper, the establishment of a database of the amino acid content of poultry feed ingredients was of continuing benefit to the industry.

Charles Payne's most outstanding achievement, however, was his success in defining and providing a simple solution to a disease, the Fatty Liver and Kidney Syndrome (FLKS), which sporadically inflicted heavy losses on broiler flocks. A/Prof Payne showed conclusively in a series of feeding trials that the disease was caused by inadequate levels of the vitamin biotin

in the diets fed to broiler flocks afflicted by FLKS. The costs of providing the supplementary biotin to ensure adequate levels of the vitamin in commercial broiler feeds were small, and FLKS was quickly eradicated from the industry.

Charles Payne supervised many postgraduate students, many of whom subsequently pursued successful careers in the poultry industry. Prominent among these, was Dr. Ron MacAlpine, who has represented the Inghams Company on the PRF Council for several decades, and has served on many industry committees responsible for funding research and development. Charles Payne's outstanding qualities were recognized when he was awarded the World's Poultry Science Association's Australian Poultry Award in 1975.

In 1977 Charles Payne died suddenly in the UK after attending a conference in Switzerland. At that time, the poultry unit was heavily committed to research spearheaded by research students. A number of feeding trials were in progress, and overall responsibility for the Unit fell to the senior academic at Camden (the author). The postgraduate students and staff at the Poultry Unit, who were devastated by the loss of their friendly and brilliant leader, responded by working together to complete current research activities. Two PhD students, Wayne Bryden and John Nell, were particularly helpful in coping with the complex issues created by the tragic death of Charles Payne. Wayne Bryden, after completing his PhD, was appointed lecturer in the Department of Animal Science in 1979. He pursued a successful teaching and research career at Camden which culminated in his promotion to Associate Professor, and his appointment as Deputy-Dean of the Veterinary Faculty in 2000. Professor

Bryden was appointed to his current Chair at Queensland University in 2001. John Nell went on to a successful career as a marine biologist with NSW Fisheries Department as well as becoming a Councilor and Mayor for a term of the Port Stephens Council.

The Department of Animal Science and the PRF were most fortunate to be able to fill the vacancy created by the loss of Charles Payne by the appointment in 1978 of Dr. Derick Balnave. Dr. Balnave, of Queens University, Belfast, a distinguished poultry scientist, had migrated to Australia to take up a position with NSW Department of Agriculture at Seven Hills. The untimely death of Charles Payne was partly attributed to his heavy workload, and the University was persuaded of the need for a second appointment in poultry science. This decision led to the appointment of Dr. Bryden as alluded to above. The team of Dr. Balnave, Research Director, and the ever-enthusiastic Dr. Bryden, succeeded in developing the Poultry Unit into the most productive poultry research centre in Australia, as outlined in the following papers.

The research undertaken by Derick Balnave and Wayne Bryden, and their postgraduate students, was largely financed by industry committees representing the broiler and egg producers. These committees understandably gave the highest priority to projects likely to increase profitability in the short term. In contrast, academic research, which is mainly conducted with postgraduate students working for higher degrees, must explore aspects of the basic sciences and contribute to avian biology. These differences in priorities were recognized by industry committees, who recognized that the

training of postgraduate students was essential for the future staff needs of a science-based industry. The research carried out by Foundation staff successfully blended both these objectives. In 1998, Dr. Derick Balnave was awarded the World's Poultry Science Associations' Australian Poultry Award "for a distinguished contribution to poultry research and education" and was further recognised by the senior body by being invited to present the Association's' annual invited lecture for 2003 at the University of Wisconsin, USA.

Animal nutrition and the global developments in poultry production

L. den Hartog

Nutreco R&D and Quality Affairs, The Netherlands

In the last century the world population has increased from nearly 2 billion to approximately 7 billion people nowadays. In 2050 it is expected that there will be an extra 2 billion people on earth. The living standard is improving and there is a positive relationship between living standard and consumption of animal products. Therefore, it is expected that in the upcoming 20 years 50% more food has to be produced on a global level. It is an enormous challenge for the agriculture and food producing sectors to meet the demand of animal products concerning quantity and quality. Innovation and efficiency are important for the future to face these challenges.

Of all meat products the consumption of poultry meat has had and will have the strongest growth rate. In emerging markets production has to grow in order to have enough food at affordable prices. Further, international trade of poultry products, especially poultry meat, will increase. In more developed countries the focus will be on production of added value products. This can result in specific egg concepts and more ready-to-eat or ready-to-heat poultry meat products.

Present trends in animal production include (i) disappearance of antimicrobial growth promoters (AGP), (ii) quality assurance and (iii) health consciousness.

Legislation can differ between countries. Since 1 January 2006 it is to use antimicrobial growth promoters in the diets of animals forbidden in the European Union. Intensive research for alternatives has resulted in products, which can be added to the diets and are based on a variety of underlying mechanisms. These include: (i) inhibition of attachment to the gut wall (prebiotics), (ii) inhibition of proliferation of pathogens (organic and medium chain fatty acids), (iii) competitive exclusion (probiotics) and (iv) immune stimulation (yeast glucans).

The quality of eggs and poultry meat is highly influenced by the quality of the animal feeds. This concerns both the “negative” and “positive” quality attributes, such as safety and product quality, respectively. In particular, safety for consumers and animals is top priority for the animal feed industry. Therefore, quality assurance programs have been introduced. In order to produce high quality products Nutreco has developed Nutrace[®]. The objective is to create added value for customers and the supplier by using one consistent feed-to-food quality approach throughout the company, based on sharing of knowledge, best practices, tools and resources, which all contribute to the transparency of the company and its businesses. This overall approach is built on four standards which are interlinked. These include: (i) certified quality - applying

international standards in all parts of the production chain, (ii) Monitoring - auditing suppliers and constant product and process checking, (iii) Risk Management - dedicated procedures to minimize damage in the event of unforeseen incidents and (iv) Tracking and Tracing - electronic tracking and tracing system which contain all the information from starting materials through processed products.

fair price. Food quality and a customer oriented supply chain production are critical factors for now and for the future.

Due to the fact that most of the risks are related to the use of feed ingredients, risk assessment and management of feed ingredients are receiving much attention. Competitors in the feed market are sometimes even sharing information and best practices to assure quality feed ingredients in order to optimise efficiency, costs and readiness. Another trend is to insure product liability; so downstream partners have the guarantee that in case of feed safety incidents, damage is paid. Despite all these efforts, feed safety is presumed to give only limited competitive advantage.

The European animal feed industry is focusing on other quality attributes, which can create added value. With animal feed and feeding programs, the composition and sensory quality of animal products can be steered in a way that it matches with specific consumer demands. In particular, the health consciousness of the consumer is offering opportunities for marketing animal products. However, a critical factor for successful marketing of added value animal products remains a joint approach by the chain partners.

In conclusion, total quality management throughout the whole production chain is the only way to fulfill the demands of the consumers and to offer them safe, nutritious and attractive poultry meat products for a

Research and Commerce: When they become interdependent

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Introduction

In the past, the great inventions occurred largely due to curiosity. In recent years, however, research has been driven, to a large extent, by commercial imperatives in order to solve a practical problem of the day or for the purpose of making money in the future. Although it is understandable for research programs funded by commercial organisations to have such a focus, the question may be asked whether such an approach is entirely appropriate for the future of science. I will use my own PhD research, conducted during the early 1990s at the Poultry Research Foundation of The University of Sydney, as an example to illustrate the change in the attitude of funding bodies to funding projects, the obsession of the research providers with intellectual property (IP) negotiation and protection, and the plight of the researchers caught in the middle.

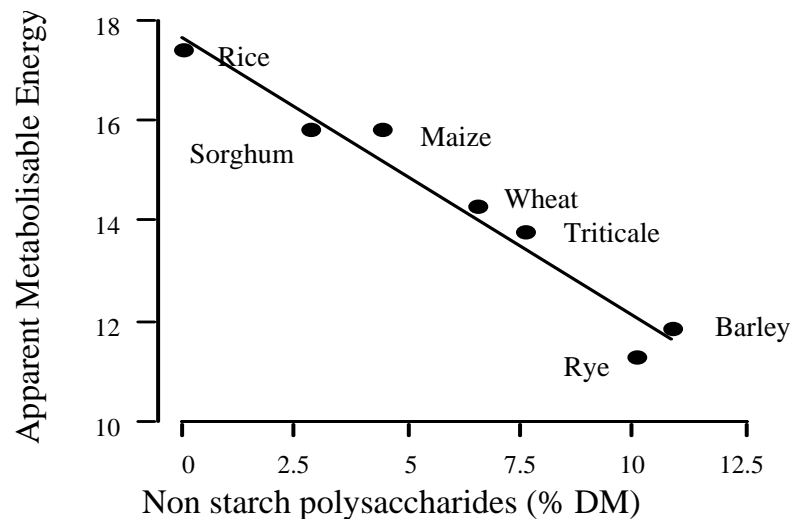
Where has research taken me?

I started my PhD in 1988 at the University of Sydney under the auspices of Dr Geoffrey Annison. I was fortunate to receive a scholarship from the Wheat Research Council and my project was funded by the Australian Chicken Meat Research Council. My PhD project investigated the effect of wheat non-starch polysaccharides (NSP) on broiler performance. Coming from a wool science background, it was difficult to get my head around the complexity of polysaccharide chemistry and the simplicity of working with chickens compared with cattle or sheep at the beginning of my PhD. Nevertheless, with wonderful supervision, good facilities and a total flexibility of project approach, my

project started promptly and within the first 18 months produced enough data to show that pentosan (arabinoxylan), the major component of wheat NSP, was the likely culprit for the depressed growth performance and wet droppings noted in broiler chickens fed wheat based diets. The key discovery of my first ever PhD experiment is shown in Figure 1.

The publication of our first paper (Choct and Annison, 1990) in *British Poultry Science* made a clear link between the nutritive value and NSP level in wheat for broiler chickens. In the following year (Annison, 1991) the nature of the relationship was further clarified, identifying that the soluble fraction of the NSP was the key anti-nutritive component of wheat for broiler chickens. This attracted the attention of companies that were producing enzymes for monogastric animal diets at the time. With funding from these companies, as well as from various funding bodies, including the Chicken Meat Research Council and the Australian Research Council, we continued working on the role of NSP in poultry diets and elucidated the mechanisms of action of the anti-nutritive effect of NSP on bird performance and welfare. This was the start of my interest in working with commercial companies, where my research outcomes are used in practice to solve industry problems. Indeed, the use of NSP-degrading enzymes has become a widespread practice in the world, especially in countries where the main energy source for poultry diets is a viscous grain such as wheat, barley, rye or triticale.

Figure 1. The relationship between apparent metabolisable energy of cereals and their non-starch polysaccharide level in broiler chicken diets (Choct and Annison, 1990).



This story contrasts sharply with the approaches most researchers are taking today. The key differences are: (a) in the past, funding bodies, by and large, were interested in the science of a project, keeping in mind that the research might lead to some practical outcomes; (b) funding bodies and research providers were not obsessed about “project equity” and IP, thus providing a flexible, open approach to research; and (c) the researcher did not have to worry about endless milestone reports and contract variations, focussing solely on the problem at hand.

So, how has the landscape changed over the past fifteen years? Some critics may say that the pendulum certainly swung to the other extreme. Today, funding bodies will not fund research unless commercial benefits are first identified; research providers will take 3-12 months to sign up a long-winded legal contract out of fear of “losing” IP or “exposing” themselves to risks; researchers are expected to be experts on governance, risk management and commercialisation. Where do we find

time to ponder the unknown, read literature and test hypotheses without worrying about legal contracts? My career has taken me from being a curiosity driven researcher to a manager of research over this period of change. Some may say that this is a requirement for being a modern scientist, whereas others may say it is symptomatic of a time where the pure pursuit of science is no longer a good career choice.

It is argued that an over-emphasis on “accountability” has been detrimental to “creativity”. Of course, this is not entirely correct. Accountability is important and it should not be in conflict with creativity. What seems to be the issue here is that the pursuit of accountability has placed enormous pressure on time otherwise available for creative work. Coupled with increases in the speed of communication and the amount of information that one has to deal with, this has become the most formidable challenge for the creative researcher.

Applied vs. “blue sky” research – the implications for the Australian poultry industry

Research that addresses short and medium term production issues is essential for the poultry industry. Dedication of industry experts to the poultry industry through their identification of research problems and their close relationship with researchers has been the strong feature of Australian poultry research. Without the knowledge and dedication of industry people, the success of applied research, in terms of its delivery of benefits to industry, will largely vanish. The challenge, therefore, is how the industry can attract and nurture the next generation of industry experts who will carry on the tradition.

Indeed, the challenge has been made tougher over the past decade or so by the trend towards measuring research value through high-impact journal articles or patents, which, in turn, has forced good researchers to focus on certain areas of basic research, rather than short-term applied work with industry.

Of course, there is a place for both fundamental research and applied practical work in the poultry industry. Fundamental research is important for the poultry industry from a number of perspectives. Firstly, many of the applied areas of research require a basic understanding of physiology, genomics and microbiology. The mapping of the gut microflora is a good example for blue sky research that could bring in dividends for the industry in the long run. The gut harbours more than 640 different species of bacteria, with 90% of these species unidentified organisms and their role and functions uncharacterised (Apajalahti *et al.*, 2004). In order to find viable alternatives to in-feed antibiotics, it is absolutely essential that at least the functions of the majority of these organisms be understood. Secondly, it is usually attractive for good researchers to have a mixture of fundamental and

applied research portfolios, and thus funding some basic research is a good way to entice high calibre scientists into the poultry industry.

The key challenges facing the Australian poultry industry

Increased public demands for a cleaner and greener environment and stricter controls over food safety and quality will continue to significantly impact on livestock industries. Consequently, food production industries must develop new holistic strategies for the management of sustainable production of safe, high quality products as well as addressing issues involving environmental impact and animal welfare. Thus, the focus of future research is: the delivery of solutions to the Australian poultry industry, which faces particular challenges in the areas of increasing productivity and alternative feed resources; novel health products in the face of reduced reliance on antibiotics and chemicals; and improved preparedness against the emerging pathogens and more discerning and demanding consumers.

In addition, with the world’s attention on climate change, the poultry industry should emerge as a low carbon footprint industry that produces high quality food products for the consumer. According to Pimentel and Pimentel (2003), poultry ranks No. 1 amongst meat industries in terms of environmental impact (Table 1).

Conclusion

There is a significant opportunity for the Australian poultry industry to re-enforce itself as a domestically focused, clean and green industry that is environmentally sustainable and free of avian influenza. An added benefit of this will be an increased attractiveness of the poultry industry to environmentally conscious future generations.

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Table 1. Comparison of common livestock industries for their environmental impacts (Pimentel and Pimentel, 2003).

Protein Source	GH Gas Emission	Water Use	Waste Production	Other Impacts	Ranking
Poultry	Less than for other meats when compared in terms of grain	3,500 L/kg meat	Chicken litter is sold as fertiliser or soil conditioner	Dust and odour issues that affect community	1
Beef	In terms of grain, a large emitter of CO ₂ ; a major producer of CH ₄	43,000 L/kg meat	Large amounts of manure cannot be absorbed, resulting in wash-off into rivers	Soil erosion and land degradation due to grazing; deforestation	4
Lamb	In terms of grain, large emitter of CO ₂ ; contributor to CH ₄ emission	51, 000 L/kg meat	Large amounts of manure cannot be absorbed, resulting in wash-off into rivers	Soil erosion and land degradation due to grazing	5
Pork	Less grain required to produce a unit weight but more than poultry	6,000 L/kg meat	Large amounts of manure cannot be absorbed, resulting in wash-off into rivers	Odour issues that affect community	3
Fish	Not applicable	Not applicable	By catch – damages to seabed and unwanted sea animals; intensive fish farming polluting sea and seabed can lead to waters polluted with fish faeces and waste	Species extinction; impact on marine environment; 3 to 4 t cheap fish to produce 1 t of salmon; every kg of salmon → 2.5 to 5 L diesel	2

The Poultry Research Foundation: Outcomes for Industry 1978 - 2001

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Two decisions were made at the start of the period under study, which proved indispensable to the continuing success of the Foundation after the death of Charles Payne. The first was the decision to initiate an annual Foundation Symposium and the second was to secure funding for the construction of controlled temperature housing for the study of the effects of ambient temperature on poultry production and metabolism. Subsequently, in the mid-1990's, funding was secured to replace the commercial poultry sheds, originally built at Camden in the early 1960's, with modern poultry housing for broilers and laying hens. These buildings, opened in February 1997, have provided the Foundation Research Unit at Camden with technically advanced facilities for conducting replicated growth and laying trials for the foreseeable future.

The inaugural annual Poultry Research Foundation Symposium in 1982 has, over time, become a world-recognised international scientific meeting. This was an important extension arm of the Foundation and was the means by which many distinguished overseas poultry scientists and commercial personnel were brought into contact with Foundation members and Australian research scientists. It was also an important avenue for Australian scientists and postgraduate students to present their research findings to poultry industry personnel and their peers in universities and other research centres. The stature of the annual Symposium was further

enhanced in 1988 when the Foundation accepted a proposal from the Australian Branch of the World's Poultry Science Association that the two bodies should join forces and share the management and presentation of the Annual Symposium. This arrangement was an instant success and, the newly-named "Australian Poultry Science Symposium", has continued to this day. The international status achieved by this annual symposium was shown by the comments of the respected journalist William A. Dudley-Cash writing in the US magazine "Feedstuffs" in April 2001 where he stated "one of the most outstanding poultry science symposiums is sponsored by the Poultry Research Foundation of the University of Sydney and the Australian Branch of the World's Poultry Science Association." In subsequent private correspondence to the present author he stated "the Australian Poultry Science Symposium is easily in the top 1% (if not number 1) of all poultry science meetings in the world. The breadth of topics is excellent, the quality of the information is excellent."

The outstanding contributions that Charles Payne made to the poultry industries have been highlighted by an earlier speaker. These included the development of two commercial assays for Foundation members. These were supported by the commercial poultry industries in Australia and proved to be of great benefit to industry for several decades. They were a 'Metabolisable Energy Bioassay' and an 'Amino Acid

Feedstuffs Evaluation' and both of these were continued after his death. Charles Payne provided a summary of the mean determined amino acid values of typical Australian feedstuffs for members of the Foundation prior to his death and during the 1980's and early 1990's this was continued through the production of three more Occasional Bulletins. These were based on the accumulated amino acid determinations from the commercial assays but, with larger numbers of samples, the data were provided with greater detail and precision.

The research output from the Foundation increased rapidly after 1978. During the first 20 years of its existence with a limited staff a total of 25 scientific papers were published in peer-reviewed internationally recognised scientific journals. Between 1980 and 2001 a total of 134 scientific papers were published in such journals. This research was funded primarily by the Egg and Chicken Meat Research Councils (the equivalent of the modern RIRDC) through competitive grants awarded to staff of the Foundation although some projects were funded by the Agricultural Research Council, industry and other sources. The present paper will summarise the research outcomes that, in my opinion, had the greatest impact on commercial practice during the tenure of my appointment at Camden.

Broiler Industry

The present author, along with a number of co-workers, conducted a series of research programs during the period under study designed to examine dietary manipulation as a means of ameliorating the effects of heat stress on broiler chickens. One of the important findings for industry was that no apparent relationship was

observed between broiler growth and either the dietary or retained mineral balances as defined by the two commonly accepted 'dietary electrolyte balance' and 'cation-anion' equations used in dietary formulation. Rather, evidence showed that in terms of broiler growth at high temperatures consideration should be given to dietary metabolisable anions, in particular bicarbonate (Gorman and Balnave, 1994). Specific studies carried out with dietary sodium bicarbonate confirmed its beneficial use in the diet or drinking water, the effects on feed intake and growth being observed at high but not thermoneutral temperatures. It was suggested that broilers have a dietary requirement for bicarbonate at high temperatures. This research program included the first dose-response study to be carried out with sodium bicarbonate (Hayat *et al.*, 1999) and it identified the optimum dietary and drinking water concentrations to be used by the broiler industry in Australia.

Other important outcomes from this research program included the identification of important effects of temperature and dietary electrolytes on amino acid metabolism. In fact, one of the early studies led to the first scientific publication to identify ambient temperature as an important factor affecting amino acid digestibilities in growing broilers (Wallis and Balnave, 1984). Evidence was gained as early as 1990 that amino acid requirements of broilers differed between birds kept at thermoneutral temperatures and birds kept under heat stress (Balnave and Oliva, 1990) and later studies carried out in co-operation with Professor John Brake from North Carolina State University confirmed this conclusion (Balnave and Brake, 2002). This latter review and that by Balnave (2004) summarises the work

with heat-stressed broilers that showed that the optimum dietary arginine:lysine ratio varies with ambient temperature and with dietary electrolytes in the form of sodium chloride and sodium bicarbonate. This research into the effects of temperature on broiler dietary arginine:lysine ratio requirements also contributed to an understanding of the long-standing scientific conflict concerning the relative efficacy of methionine and its hydroxy analogues. In particular, the recommendation was made that the dietary arginine:lysine ratio, dietary salt inclusion levels and ambient temperature should all be considered before the methionine activity source is selected for dietary inclusion (Balnave and Brake, 2004).

The research program initiated by Frank Annison and known locally as the 'Low-ME Wheat' program identified a problem with the starch digestibility of certain wheat cultivars that resulted in a limitation in the availability of dietary metabolisable energy for growing chickens (Mollah *et al.*, 1983). Commercially this was of major significance to the broiler industry. This research program was extended by Geoffrey Annison and Mingan Choct who identified the anti-nutritional component as being the non-starch polysaccharide (mainly pentosans and/or arabinoxylans) component in wheat (Choct and Annison, 1992a). The problem was shown to be associated with decreased digestibilities of starch, protein and lipid due to an increase in gut viscosity (Choct and Annison, 1992b). Dietary supplementation with pentosanases (xylanases) reduced anti-nutritive activity and these studies at Camden can be considered as being extremely important to the subsequent establishment of feed enzyme

technology in poultry diet formulations.

The other research program of major significance to the broiler industry was one conducted over a number of years by Wayne Bryden and his co-workers. This program was designed to examine specific aspects of amino acid metabolism. The most important aspect of this work was the pioneering of a procedure for the measurement of endogenous amino acids using a technique involving the guanidination of proteins (Siriwan *et al.*, 1994). Once perfected this procedure offers a way of measuring true ileal digestibilities of amino acids. The extensive range of studies necessary for the successful development of this research program has been described by Bryden *et al.* (1995). This research program also produced a database of apparent ileal digestibility coefficients for typical Australian feedstuffs derived using growing broilers (Ravindran *et al.*, 1998), a useful resource for commercial nutritionists and an important extension of the earlier occasional bulletins detailing the amino acid concentrations of Australian feedstuffs. Subsequent studies extended the wheat non-starch polysaccharide studies mentioned above to show that exogenous dietary xylanases markedly improved the apparent metabolisable energy and ileal amino acid digestibilities of wheat (Hew *et al.*, 1998). More recent studies have concentrated on the complexities of protein-phytate interactions and their relationship to exogenous phytase and other enzymes (Selle *et al.*, 2003).

Egg Industry

During the period of time under study the present author conducted a number of investigations with laying hens the results of which had ramifications for the commercial industry. The earliest

research programme highlighted the value of including rice pollard as a feed ingredient in conventional Australian layer diets based on wheat, sorghum and meat meal. Replacing wheat with rice pollard was shown to improve egg size and, furthermore, alternating these diets on a four weekly basis was a means of manipulating short-term egg weight responses (Balnave, 1987). Furthermore, research carried out in the controlled-temperature rooms showed rice pollard to have a major effect in reducing losses in egg weight from hens housed at high ambient temperatures.

The controlled-temperature rooms were used extensively by the present author to examine ways of improving the nutrition of laying hens at heat-stress temperatures. Apart from the rice pollard story, three other major outcomes with direct relevance to industry can be identified. These were the fact that optimum production during lay depends not only on the pullet obtaining adequate nutrient intakes during growth but also on the adult hen having an adequate gut capacity to maximise feed consumption when exposed to high temperatures at point-of-lay. Both these needs were achieved by rearing pullets in a cool environment. Self-selection feeding studies with adult hens confirmed the value of feeding low-energy, high-protein diets at high temperatures and the specific conditions under which dietary sodium bicarbonate supplementation improves eggshell quality were identified. Many of the studies leading to these conclusions were described in the review by Balnave and Brake (2005).

A highlight of the research carried out for the Egg Industry was the discovery that saline drinking water containing sodium chloride at concentrations

similar to those found in underground bore water has an adverse effect on eggshell quality and the incidence of eggshell defects. This discovery was subsequently confirmed by work carried out in Germany, Israel, Lebanon and Iran. Basic physiological and biochemical studies, allied to feeding trials and eggshell quality assessment, helped not only to identify the problem but also to determine the biochemical lesion as being related to the supply of bicarbonate rather than calcium for eggshell formation. A reduced activity of carbonic anhydrase in the shell gland mucosa limited the supply of bicarbonate and the dependent calcium to the lumen of the shell gland. Reduced numbers of settable eggs and lower hatchability were observed with breeder hens. The incidence of eggshell defects was significantly greater, and eggshell quality significantly poorer, when similar intakes of sodium chloride were obtained from the drinking water rather than the diet. Effective treatments were preventive rather than remedial in nature and involved the use of ascorbic acid supplements in the diet or drinking water and the use of zinc methionine supplements in the diet. Balnave (1993) reviewed the many studies involved in this research programme and the associated conclusions derived from them.

Summary

Like all successful research programs those described in this paper involve numerous experiments and publications. I have tried to limit the number of references by quoting, where possible, published review papers by the research leaders that outline the development and major conclusions arising from individual programs. Accordingly, a number of the references quoted were published after 2001. It should be appreciated

that I have made a personal choice in describing those outcomes that I feel had major direct outcomes and application for industry. Many other research studies were carried out at Camden during the period under study that were more academic or short-term in nature and which have not been included in this paper. Anyone wishing to know about these or to follow in detail the various programmes mentioned above can access all publications from the Foundation that have been collected in a series of eight volumes held at Camden. These contain all poultry-related publications including refereed papers, conference proceedings and invited papers, produced by Foundation staff, postgraduate students and visiting scientists from the time of the inception of the Foundation to 2003.

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Past Innovations and Future Directions for the Poultry Industry

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It's only 40 years ago that even commercial poultry feeds were prepared according to secret recipes that were the domain of old timers who had many years experience of feeding their chooks at home! Back in those early days, the Australians usually ate chicken only twice a year – at Christmas and Easter. And even then, the bird from the chook pen down the back yard was a dual-purpose Rhode Island Red hen that was suspected of going off the lay or a rooster who had become a handful to control.

Time has certainly moved on from those days and poultry and egg production has become more globalised and the Australian industry has enjoyed the benefits and suffered the consequences of that ongoing trend. Local breeding companies have disappeared in the wake of imported strains of both layers and broilers. Technical extension was once the principal domain of State Departments of Agriculture but now, technical backup comes as product support from commercial interests. Due to the substantial cost of research, much of the latest technical information comes from foreign product suppliers or overseas research institutions that specialise in a unique aspect of poultry research.

Some notable developments (implemented both commercially and for educational purposes) early in the life of the University of Sydney PRF include the re-assessment of vitamin and mineral requirements for poultry (eg biotin and Fatty Liver Kidney

Syndrome in broilers); the characterisation and measurement of metabolisable energy and amino acid levels in Australian raw materials and the impact of environmental temperature on energy requirements and feed/nutrient intake of poultry. The low AME wheat issue was an area that received much attention not all that many years ago.

More recently, the industry has adopted many technical innovations (particularly as the result of ideas and expertise from overseas speakers for the annual PRF Symposium) and the PRF has frequently played a direct or indirect part in adapting overseas findings to local conditions. Some of the major areas of involvement include: The use of digestible amino acids for formulating diets based on 'ideal' protein profiles, adoption of enzymes (xylanase and phytase) as a routine addition to diets, the importance of water quality on shell quality for layers and the use of NIR as a tool for QA and raw material evaluation.

The future issues for the poultry industry where the PRF can potentially play a significant role have recently been identified and include: (i) identification of major factors responsible for variation in broiler flock performance, (ii) enhanced NIR calibrations (based on Premium Grains for Livestock Programme) for energy determination of grains, (iii) evaluation and development of new grain varieties (e.g. peas, millet and triticale) and (iv)

improvement of sorghum utilisation for broilers.

As the industry moves forward, the improvements in performance and efficiency will be facilitated by better husbandry and nutrition of the young chick and through a greater understanding of the complex interactions between genetics, feed/nutrition, bird health and husbandry throughout the whole livestock operation. The major contribution that poultry geneticists have made to the improvements in efficiency cannot be overstated and will no doubt, continue into the future.

Finally, the demands of the market in shaping future directions of the poultry industry, are likely to feature more prominently in the years to come.

Metabolisable Energy/Amino Acid Interaction in Broilers

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Numerous studies have been made of the amino acid requirements of growing broilers with consistent evidence of an optimal relationship between (digestible) amino acids and metabolisable energy (ME). However, there remains disagreement as to how essential amino acid requirements are best interpreted. Do they simply relate to each other ("ideal protein"), total dietary protein, ME or both protein and energy? If essential amino acids requirements are interpreted in balance to lysine what is the relationship between essential and non-essential amino acids, and in turn total amino

acid supply and energy? What is the need for minimum crude protein in today's broiler diets? Interpretation of these issues has remained critical to economic optimisation of broiler growth, feed efficiency and carcass composition over the past 30 years.

A typical response to protein in Australian (Tegel) broilers from 1975 is shown in Table 1. Essential amino acids were kept in balance with protein and lysine for each starter (S) diet (0-35d) and finisher (F) diet (35 – 56d). Starter diets contained 12.6MJ ME/kg and finisher diets 13.0 MJ ME/kg.

Table 1. Live performance and mean food intake, weight gain, FCR and body fat of broilers at 56 days of age in response to protein/lysine (MacAlpine, 1980).

Protein S/F (g/kg)	Total lysine S/F (g/kg)	Food intake (g/bird)	Gain (g/bird)	FCR (food/gain)	Body fat (g/kg)
256/225	13.3/11.3	3744 a	1787 a	2.10 a	135 a
240/213	12.2/10.5	3718 a	1750 a	2.12 a	-
226/200	11.3/9.8	3782 a	1787 a	2.12 a	152 b
212/188	10.5/9.0	3718 a	1681 b	2.21 b	154 b
196/174	9.7/8.3	3573 b	1566 c	2.28 c	-
182/165	9.0/7.5	3296 c	1331 d	2.48 d	162 c

Live performance and whole body composition were sensitive indicators of dietary amino acid requirement. A clear plateau in live performance was evident above the optimal protein intake (226/200g/kg diet). However, body fat was reduced further at the highest protein level.

A recent protein/amino acid response study with imported (Cobb) broiler stock is summarised in Table 2. Again, essential amino acids were kept in balance with lysine and protein for each starter (S), grower (G), finisher (F) and withdrawal (W) diet. ME was constant within each diet phase at 12.7, 12.8, 12.9 and 12.9 MJ/kg for S, G, F and W respectively.

Table 2. Mean live weight, FCR and breast yield of broilers at 42 days of age in response to protein (MacAlpine and Balding, 2006, unpublished).

Protein S/G/F/W	Live weight (g/bird)	FCR (food/gain)	Yield (g/kg live weight)
252/235/221/212	2702 a	1.68 a	200 a
237/219/206/200	2645 b	1.69 a	195 b
223/207/195/190	2575 c	1.73 a	204 a
211/196/189/180	2471 d	1.81 b	193 b

The results similarly demonstrate an economically optimal protein or amino acid/ME profile. However, the response pattern in particular performance parameters for modern broiler breeds was not as sharply defined as in breeds of 30 years ago. In the present study, growth rate increased through to the highest protein regime but this was not evident in FCR. Although not clear in the results of Table 2, current broiler types usually respond to increasing levels of lysine and balanced protein in meat yields. This is explained by the enormous gains in potential protein deposition and meat yield of modern breeds.

Lemme (2007) reviewed recent studies of amino acid-to-energy adjustment in broiler diets and found little evidence to support expression of amino acid requirements per unit of energy. Although feed intake typically increased as dietary energy decreased, several studies concluded that balanced protein should not be reduced in the same proportion to ME. A higher balanced protein/ME ratio was optimal in low energy diets. The inconclusive outcome may have been masked by the small range of relatively high-energy diets in most studies (12.6 – 13.4 MJ/kg) and inconsistent application of an optimal ratio between essential and non-essential amino acids in the “balanced” protein.

Studies of 30 years ago (MacAlpine, 1980) also showed interactions between dietary ME concentration (11.5 and 13.6 MJ/kg) and protein/ME ratio (12.8 to 18.1g protein/MJ ME) in 28 – 56 day growing broilers. ME intake and weight gain were similar for both energy regimes. However, while a protein/ME ratio of 15.9 g/MJ optimised weight gain and food efficiency within both energy regimes at 19°C, more protein was required for optimal performance at high temperature (30 °C) in the low ME diet (18.1g/MJ) than in the high ME diet (15.9g/MJ). This effect was not simply explained by increased protein intake as a similar increase in intake occurred with the high-ME regime without a parallel response in growth. Elevation of essential amino acid levels in plasma at the high protein/ME ratio occurred at 19 °C, but not 30 °C. This suggested that changes in amino acid metabolism, as well as intake, may be important in optimising protein/ME balance at high temperature.

Conclusion

The established relationship between balanced protein (including essential and non-essential amino acids) and dietary energy safely underpins diet formulation strategy under usual practical ME circumstances. However, a fixed relationship should not be relied upon under high and low extremes of dietary ME and under high temperature conditions. Further research appears justified to better

explain the need for non-essential amino acids in balanced protein and to examine amino acid metabolism from low energy diets, particularly at high temperatures.

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Strategies to improve the intestinal immune response in the chicken.

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This paper provides a brief review of the research undertaken in avian intestinal immunity, and in particular the generation of localized immunoglobulin A (IgA), by the author over recent years. Initial studies investigated intestinal immune function and were specifically designed to identify the source/s of precursor cells involved in the generation of an IgA antibody response at the intestinal mucosa. Subsequent work evaluated methods of antigen delivery to the intestinal immune system and manipulation of the local intestinal environment to favour a local IgA response following vaccination.

Intestinal immune function

The function of the mucosal immune system is to provide defense at mucosal sites, which are avenues for the entry of pathogens and other antigens. Mucosal immunity involves the innate and acquired immune systems. Our work has focused on acquired immunity and, in particular, the generation of IgA antibody. IgA is the predominant immunoglobulin isotype found in mucosal secretions, where it is able to bind to an antigen, interfering with its attachment to the epithelial surface.

Many functional aspects of the avian intestinal immune system had been assumed to be similar to the mammalian system, and yet anatomically they are quite different (Muir, 1998; Jeurissen et al., 1994). For a vaccination program to be successful, the antigen needs to be delivered to the site/s containing

appropriate precursor cells. Therefore, studies involving adoptive cell transfer of a lymphocyte single cell suspension into bursectomised chickens assisted in identify the site/s of origin of IgA secreting plasma cells. Not surprisingly cells originating from the Bursa of Fabricius resulted in notable repopulation of the duodenum with IgA-secreting plasma cells. However, cells isolated from both the ileal lymphoid aggregate and caecal tonsils also contributed to duodenal repopulation with IgA secreting plasma cells (Muir et al., 2000). Therefore, it is crucial that antigen be delivered to these sites for the production of IgA antibody at the intestinal surface.

Antigen delivery systems

The oral delivery of native antigen would seem to be the most obvious method for the administration of antigen to the IgA precursor cells along the intestinal tract. However, such a vaccination protocol typically produces a very limited immune response. This low response is due to the susceptibility of antigen to the acid environment of the stomach, extensive proteolytic breakdown of antigen by gastric enzymes and/or the presence of few properties that intrinsically assist in the binding of antigen to the mucosal epithelium (Walker, 1994). Therefore, we investigated other, more novel vaccination procedures for their ability to invoke an antigen-specific IgA-focused immune response in the intestinal lumen. One protocol assessed the response following intraperitoneal injection of antigen. Here, the primary

immunisation consisted of antigen emulsified in a vegetable oil-based adjuvant administered via intraperitoneal injection. This was followed two weeks later by an oral booster of antigen. This immunisation schedule generated significant antigen-specific IgA antibodies at the intestinal surface (Muir et al., 1995). When birds were immunised according to this protocol with killed *S. typhimurium*, they experienced a delayed onset of *S. typhimurium* infection from a live challenge of homologous *S. typhimurium* (Muir et al., 1998).

Due to the practical limitations of intraperitoneal immunisation we investigated alternative methods for the oral delivery of antigen in the chicken. Biodegradable microspheres, where the antigen is dispersed throughout a polymer, which protects it from the environment and will regulate its rate of release (Eldridge et al., 1990), have been used successfully in mammals. However, the immune response in chickens orally immunised with antigen in biodegradable microspheres was limited (Muir, 1996), and not dissimilar to the low responses observed following oral delivery of native antigen. This is in contrast to the ability of orally administered microspheres to effectively deliver antigen to the immune system of rodents (Muir et al., 1994).

Protection of the antigen from the harsh, acidic environment of the gut lumen may also be possible through the use of an antigen carrier diet designed to create an “antigen friendly environment”. Here, dietary ingredients that will temporarily mitigate the destructive intestinal environment are included in a carrier diet which is delivered to coincide with the oral delivery of antigen. A carrier

diet that has shown promise for effective oral delivery of antigen in aquaculture species was evaluated in chickens. Several forms of the diet, that is wet, dry and an extracted solution from the dry diet were assessed, as were several antigens. Interestingly, of all of the diet forms and antigen combinations evaluated, only the extracted solution of the diet was effective in significantly upregulating the local immune response, and, further, it was only effective with one of the antigens tested. This outcome, while exciting, again highlights the need to test each vaccine/antigen/delivery system combination, as the immune system may respond differently following only minor variations to the vaccination protocol. It also reiterates the possibility of a between-species variation in the immune response to the same vaccination protocol, as previously mentioned with the microsphere technology.

Mucosal adjuvants

Adjuvants typically drive positive amplification and dampen suppressive signals of the immune system (Chiarella, 2007). Potential mucosal adjuvants were assessed for their ability to upregulate the intestinal immune response in chickens, using the intraperitoneal immunisation model.

The regulatory role of cytokines in directing and fine-tuning the immune system makes them ideal candidates for immunomodulation (Asif et al., 2004). As locally produced interleukin-6 (IL-6) influences IgA expression at the intestinal site (Ramsay et al., 1994) we assessed the ability for locally administered exogenous IL-6 to increase intestinal IgA antibody production in chickens. Repeated oral delivery of exogenous IL-6, around the

time of the oral delivery of the booster antigen, in birds previously primed via intraperitoneal antigen injection, generated a significant increase in the intestinal antigen-specific IgA antibody titres. This significant increase has been observed with two different antigens, i.e. a protein and a bacterial antigen.

Given the presence of IgA precursory cells in the aggregated immune tissues located along the intestinal lumen, it follows that some dietary substances may manipulate the activation, maturation and/or function of local immune cells. Our investigation of this proposal has included dietary ingredients such as vitamin E (Muir et al., 2002) and vitamin C (Muir and Gough, 2004) and omega-3 fatty acids (Muir et al., 2005). The results from these studies have been variable.

Conclusion

While the research presented here outlines some of the advances in our understanding of the intestinal immune system of the chicken, further work is required. Other novel immunisation and immunomodulatory technologies, that are showing promise in other animals, and in particular those that enable oral delivery of antigen to intestinal lymphoid aggregates, may also improve the intestinal immune response in chickens. It is only through well designed experimentation that their potential in the chicken will be realized.

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Dietary Phytate and Microbial Phytase in Broiler Nutrition

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Poultry production in Australia has an annual feed requirement in the order of 3 million tonnes. This corresponds to the consumption of approximately 30,000 tonnes of phytate or 8,500 tonnes of phytate-bound phosphorus (phytate-P), which is only partially available to poultry. A phytase feed enzyme was locally introduced in 1996 with the capacity to increase P digestibility and reduce P excretion in pigs and poultry and others have followed. The Poultry Research Foundation has made quite substantial contributions towards a better understanding of the phytate-phytase axis in poultry nutrition, which, in no small way, should be attributed to the efforts of 'Ravi' Ravindran during his tenure at Camden (1994-1998). However, despite the fact that phytase feed enzymes first became available in 1991, and have been the subject of large numbers of investigations, numerous critical questions remain unanswered and there appears to be very considerable scope for future advances.

There is an escalating world wide demand for food production. However, global grain outputs have consistently failed to meet demand as supplies have fallen from 115 days on hand in 1999-2000 to a projected 53 days in 2007-08 (Qualman, 2007). This represents an average, annual depletion of global grain reserves of 9.2% since the turn of this century. Consequently, higher priced feeds ingredients are an increasing challenge to viable chicken-meat production. Fortunately, the modern broiler is a highly efficient converter of cereal grains and protein meals into chicken-meat. Presently,

broilers can achieve feed conversion ratios of 1.45 at 2.0 kg live-weight (Ravindran, 2006), which is approaching a 2-to-1 conversion of feed into chicken-meat. That broilers require relatively lower feed inputs is a distinct advantage for chicken-meat over beef and pork production.

Particularly given the 'low ME' wheat problem, the inclusion of NSP-degrading enzymes in wheat-based broiler diets has contributed to more efficient chicken-meat production over the last fifteen years. Alternatively, phytase feed enzymes permit reductions in P specifications of broiler diets, improve P digestibility and reduce P excretion, which is environmentally beneficial. The simultaneous inclusion of phytate- and NSP-degrading enzymes in wheat-based broiler diets is an option and synergistic responses have been reported in some instances (Ravindran *et al.*, 1999; Selle *et al.*, 2003). In addition, there are indications that phytase increases protein and energy utilisation in broilers via its so-called 'extra-phosphoric' effects. However, this issue remains controversial due to the inconsistent magnitude of these responses. Ideally, the situation should be clarified so that the full potential of phytase can be harnessed in the present context and outlook of highly priced feed ingredients.

The substrate: Phytate

Phytate or 'phytin' was first described in 1855. Phytate, the mixed salt of phytic acid (*myo*-inositol hexaphosphate; IP₆), is found in all feed ingredients of plant origin, predominantly as IP₆ in mineral-

phytate complexes involving magnesium and potassium. Consequently, phytate is invariably present in practical poultry diets at concentrations in the order of 10.0 g/kg phytate or 2.82 g/kg phytate-P. In broiler chickens, phytate is a partially digestible nutrient with anti-nutritive properties. Therefore, the P component is poorly available and the consequent P loss in excreta is an environmental threat to aquatic ecosystems. Phytate is a polyanionic molecule with a tremendous capacity to bind positively charged nutrients, which is fundamental to its anti-nutritive properties. As a prime example, phytate has the capacity to form protein-phytate complexes at acidic pH in the gut and, importantly, complexed protein is refractory to pepsin digestion.

The enzyme: Phytase

Phytase activity was first detected in 1907 and occurs widely throughout nature. Attempts to develop a phytase feed enzyme commenced in 1962 in North America, but it was not until 1991 that an exogenous phytase of fungal origin became commercially available in The Netherlands. Initially, the acceptance of this phytase feed enzyme, outside of its country of origin, was negligible. More recently, however, the global acceptance of phytase feed enzymes has rapidly expanded and their usage now exceeds that of NSP-degrading feed enzymes. A number of factors have contributed to this increased acceptance including more attractive inclusion costs relative to inorganic P supplements, the removal of meat-and-bone meal from monogastric diets in certain countries and the increasing adoption of legislation designed to curb the P load on the environment. Also, there is some recognition that exogenous phytase enhances protein and energy

utilisation in broilers and, effectively, reduce feed costs.

Phytate degradation by phytase in broilers

In broilers, degradation of phytate occurs primarily in the crop; however, very few credible studies have determined the extent to which phytase feed enzymes degrade phytate. On the basis of limited data, it appears that fungal phytases (eg *Aspergillus niger*) degrade less than 35% of dietary phytate at the level of the ileum at standard inclusion rates. More recently, bacterial phytases (eg *Escherichia coli*) have been introduced and there are indications that they are more effective; however, to the author's knowledge, their capacity to degrade phytate at the ileal level in broilers has yet to be established. Numerous factors influence the susceptibility of phytate to enzymatic hydrolysis and a pH of 5.5 is critical to the solubility of Mg-phytate complexes, which rapidly declines under more alkaline conditions. In addition, it has been suggested that high dietary levels of inorganic P and/or calcium (Ca) negatively influence phytase efficacy. Also, there is some evidence to suggest that heat-treatment of broiler diets may reduce the solubility and enzymatic hydrolysis of phytate. Clearly, there is enormous scope to develop superior exogenous phytases (or enzyme 'cocktails') with the capacity to degrade the majority of phytate present in broiler diets. It remains to be seen if this development will take place but presumably, such an enzyme would be highly active over a wide pH spectrum and be resistant to the activity of endogenous enzymes with the capacity to hydrolyse phytate in both the fore-stomach and along the small intestine.

P equivalence of phytase

It is accepted that the dietary inclusion of phytases is equivalent to 1.15 g/kg inorganic P (or approximately 6.4 g/kg dicalcium phosphate or 23 g/kg meat-and-bone meal). However, these equivalence values are usually established by comparing the effects of graded additions of inorganic P and microbial phytase to P-deficient basal diets on weight gain and bone mineralisation (percentage toe ash). These values are likely to be inflated because phytase may promote weight gains independently of enhanced P digestion. Arguably, a more indicative P equivalence value would be a function of determined dietary phytate-P concentrations coupled with accurately established phytate degradation rates induced by phytase. For example, in diets containing 2.82 g/kg phytate-P, a 35% degradation rate would correspond to a release of 0.987 g/kg P. However, it should be stressed that analytical methods to determine phytate concentrations are not straightforward. Indeed, the majority of phytate analyses performed are still based on the 'ferric chloride-precipitation', which was established in 1914, and these methods have real limitations. The development of a rapid and accurate analytical method to determine phytate concentrations across all sample categories would benefit both scientific research and the practical application of phytase feed enzymes considerably.

Aquaculture

Interest in phytase is not confined to pig and poultry nutrition. In Aquaculture, the farming of carnivorous fish species is confronted with the 'fishmeal trap' because, in 1999, the expanding industry required 2.1 million tonnes of fishmeal or 32% of global production. Clearly, there is an urgent need to increase plant protein

levels in diets for farmed fish, including salmon in particular, to reduce the dependence on the 'wild-catch' for fishmeal production. Because phytase may enhance protein utilisation in plant-sourced protein meals considerable research into the inclusion of phytase in farmed-fish diets has been completed, including the on-line pre-treatment of relevant feedstuffs or 'dephytinisation'.

The 'protein effect' of phytate and phytase

Some sixteen years ago, Ted Batterham reported that phytase substantially enhanced ileal digestibility of amino acids from Linola meal in growing pigs and this finding has been confirmed by Poultry Research Foundation in several assays in broiler chickens. Nevertheless, the capacity of phytase to increase amino acid digestibility remains an unresolved, controversial issue. That this remains the case stems from an incomplete understanding of the mechanisms whereby phytate depresses amino acid digestibility coupled with ambiguous outcomes from phytase amino acid digestibility assays in broilers.

Protein-phytate complexes were first recognised some eighty years ago. Under acidic conditions in the gut, phytate has the capacity to bind protein, via basic amino acid residues, resulting in the de novo formation of binary protein-phytate complexes. Based on in vitro data, phytate has the potential to complex up to half the protein present in the diet but the actual extent of protein-phytate complex formation has not been established and would be governed by several factors. Importantly, bound protein is refractory to pepsin digestion, which interferes with the initiation of the protein digestive

process. Also, it seems likely that a proportion of dietary protein is less readily digested in the small intestine following its aggregation with phytate in the fore-stomach. While speculative, it follows that the refractory nature of phytate-bound protein would stimulate gastric secretions of pepsin and hydrochloric acid as a compensatory mechanism. Recently, phytate has been shown to increase mucin secretion in broilers, which could be attributed to additional gastric pepsin and hydrochloric acid outputs.

While previously suspected, it was recently established that phytate exacerbates flows of endogenous amino acids (Cowieson and Ravindran, 2007). Increasing dietary phytate levels (8.5 versus 14.5 g/kg) increased endogenous flows of seventeen amino acids by 27.2%; conversely, 500 FTU/kg phytase reduced these flows by 20.0%. Pepsin has a unique amino acid profile due to a paucity of arginine, histidine and lysine residues. Interestingly, it may be deduced from this study that variations in endogenous amino acid flows generated by both phytate and phytase are significantly correlated to the amino acid profile of pepsin and this also applies to mucin. This supports the concept that phytate triggers pepsin secretion and, in turn, mucin secretion. This, of itself, would contribute to increased endogenous amino acid flows.

It has been demonstrated that phytate drags sodium (Na) into the small intestinal gut lumen and that this phenomenon is counteracted by phytase. This raises the possibility that phytate compromises intestinal uptakes of amino acids via Na-dependent transport systems and the activity of the so-called 'sodium pump' (Na^+, K^+ -ATPase). Moreover, in a recent study

(Ravindran *et al.*, 2008), phytase increased AID coefficients of thirteen amino acids (arginine, cystine, glycine and methionine were not considered) by an average of 5.04% in diets containing 1.5 and 1.8 g/kg Na but numerically depressed (−0.70%) digestibility of amino acids in the 5.2 g/kg Na dietary treatment. The difference could indicate that the sparing effect of phytase at low Na levels facilitated intestinal uptakes of amino acids, which was muted by high dietary Na levels. Thus, phytate and phytase may influence uptakes of amino acids and, presumably, other nutrients via their effects on Na movements in the small intestine. It is conceivable that phytate drags Na into the gut as NaHCO_3 to maintain pH, possibly to buffer increased outputs of hydrochloric acid.

A comparison of three phytase amino acid digestibility assays is instructive. In one study, the inclusion of an *Escherichia coli*-derived phytase at 1000 FTU/kg in corn-soy broiler diets increased amino acid digestibility coefficients by an average of 5.92% (Ravindran *et al.*, 2006). Phytase responses ranged from 2.7% for methionine to 10.2% for threonine amongst the essential amino acids, which is a classical pattern. In contrast, in two similar studies (Dilger *et al.*, 2004; Onyango *et al.*, 2005), the same phytase inclusion did not influence amino acid digestibility. Importantly, however, different dietary markers were selected; titanium oxide was used in the first assay and chromic oxide was used in the two other studies. Moreover, in thirteen phytase amino acid digestibility assays in broilers (Selle *et al.*, 2006) phytase responses were consistently more pronounced when titanium oxide or acid insoluble ash was used as the marker in comparison to chromic oxide. Of

relevance, is that two research groups have concluded that titanium oxide is a superior marker to chromic oxide. Thus, it would appear that chromic oxide is an important contributor to the ambiguous outcomes of phytase amino acid digestibility assays reported in the literature.

Amino acid matrix values

Given that phytase has the capacity to enhance amino acid digestibilities, one approach to take advantage of this is to assign matrix values for amino acids to the feed enzyme. This approach was

successfully evaluated by Shelton *et al.* (2004). However, as shown in Table 1, the quantities of ileal digestible amino acids generated by phytase in the assay completed by Ravindran *et al.* (2006) were substantially greater, by a four-fold factor, than the amino acid matrix values assigned to phytase. This discrepancy clearly illustrates the need to establish accurately the extent to which phytase enhances amino acid digestibilities so full advantage can be taken in practice.

Table 1 Digestible amino acid matrix values assigned to phytase for essential amino acids (Shelton *et al.*, 2004) compared to ileal digestible amino acids generated by phytase (Ravindran *et al.*, 2006)

Amino acid	Matrix value (mg/kg)	Quantity generated (mg/kg)	Index
Arginine	80	363	4.5
Histidine	60	296	4.9
Isoleucine	110	386	3.5
Leucine	170	748	4.4
Lysine	150	372	2.5
Methionine	30	137	4.6
Phenylalanine	110	439	4.0
Threonine	120	635	5.3
Tryptophan	30	119	4.0
Valine	130	439	3.4
Mean	99	393	4.1

Similarly, phytase has been quite consistently shown to increase energy utilisation by broilers (Selle and Ravindran, 2007). Again, the underlying mechanisms need to be identified and the extent to which phytase increases the energy density of broiler diets needs to be defined.

Calcium and phosphorus

In a recent phytase amino acid digestibility assay (Centeno *et al.*, 2007), as a main effect, phytase, increased AID coefficients of 17 amino

acids by an average of 5.03% where acid insoluble ash was used as the marker in corn-soy diets. However, responses to phytase were pronounced in diets containing 1.4 g/kg available P diets (12.2%), but this was not the case in diets containing 2.7 g/kg available P (-2.1%). This discrepancy was reflected in significant treatment interactions for all amino acids assessed, except alanine. Dietary levels of Ca were kept constant, so this study suggests that dietary levels of inorganic P and/or Ca:P ratios had a

substantial impact on phytase efficacy in respect of amino acid digestibilities. Moreover, a more subtle, but similar, pattern of amino acid responses to phytase was previously reported (Ravindran *et al.*, 2000). Clearly, the direct and indirect impacts of dietary levels of nonphytate P, phytate-P and Ca on phytase efficacy demand elucidation. This probably applies to Ca (as limestone) in particular. Limestone has a high acid binding capacity with the potential to increase gut pH which could directly influence microbial phytase activity, reduce phytate solubility and influence the extent of *de novo* binary protein-phytate complex formation. Alternatively, the extent to which phytase increases Ca availability, which mainly stems from reduced Ca-phytate complex formation in the gut, requires clarification.

Future developments

Given that contemporary phytase feed enzymes only partially degrade dietary phytate, the anti-nutritive properties of phytate are not being fully declared. Thus one remaining challenge is the accurate definition of the full extent of the anti-nutritive properties of phytate in respect of P, Ca, protein/amino acids and energy density of broiler diets. The hydrothermal pre-treatment of feed ingredients with exogenous phytase to eliminate phytate (dephytinisation) may remain one means of achieving this objective. However, in practice, it may not be possible to remove phytate without fundamentally altering other nutritional properties of the pre-treated feedstuff.

Arguably, the standard phytase inclusion rate in broiler diets (500-600 FTU/kg) is conservative and higher inclusion levels could be advantageous given the erosion of feed enzyme prices. However, this approach will

probably require more radical adjustments to dietary P and Ca levels if the benefits are to be realised. Arguably, dietary levels of both P and Ca levels should be at an acceptable minimum in association with phytase supplementation. Nevertheless, it is imperative that skeletal integrity is maintained, so this represents a real conundrum to nutritionists. The development of even more advanced exogenous phytases remains a real possibility in the future and their efficacy may be enhanced by several nutritional and management strategies. In association with this, the development of entirely appropriate matrix values for such phytase feed enzymes would be necessary to maximise their impact in least-cost ration formulations. The likelihood is that the near-complete elimination of phytate from broiler diets would result in substantial enhancements of P, protein and energy utilisation. This would be both an economically and ecologically beneficial outcome for sustainable chicken-meat production facing the challenge of a deteriorating price and supply situation for feed ingredients that constitute broiler diets.

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Poultry Production Research Horizons

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Introduction

Over the last 50 years there has been a very rapid increase in the consumption of poultry meat by the Australian population. There is now more poultry meat consumed per capita than beef, lamb or pork. This reflects consumer demand which is driven by the “healthiness” of chicken meat, convenience and price. The relative low cost of chicken meat reflects significant improvements in efficiency of poultry production that have occurred during this period. Research by the Poultry Research Foundation has made a significant contribution to increased production efficiency. Another major factor has been the integration of poultry production. It is interesting in this forum to consider some of the research avenues that will contribute to further increased productivity.

Science and poultry production

Avian science has facilitated the major increases that have occurred in poultry growth rate and feed conversion efficiency. The underpinning sciences of genetics, nutrition, reproduction and disease management have been instrumental in allowing these improvements to occur.

The Poultry Research Foundation has largely concentrated its research effort in the area of nutrition. It is apparent that further improvements will be made in the sciences that contribute to improved poultry production efficiency including environmental management and immunological status. Importantly, all of these factors come together to improve bird welfare.

Applications of new technologies to poultry production

Over the next few decades there will be advancement in nutrition, reproduction, genetics and the husbandry of the bird. The technologies that will drive these advances will be genomics and electronics.

(a) Genomics

There has been much progress in the application of genomics to disease prevention and control, especially the development of vaccines. In the foreseeable future the application of similar genomic technologies to nutrition, or nutrigenomics, will facilitate similar advancements.

In the post-genomic era much attention has been given to functional genomics or the relationship between genes and higher levels of organisation in the cell. However, this approach is only going to tell part of the story as the operational functional units in a complex biological system are the metabolic pathways of the whole organism. In other words, it will be the measurement of the outputs of these pathways i.e. metabolic or molecular fluxes, that will allow the breakthroughs and advancements to be made in areas such as nutrition. Classical approaches using a combination of arterio-venous differences and isotopes will facilitate increased understanding.

(b) Electronics and information technology

There will undoubtedly be increased applications of information technology

in the management and husbandry of livestock and poultry as we move into the 21st century. Sensors to monitor individual bird responses and low cost video cameras to monitor activity, exist and these will be further refined and linked with sensors and computer networks to monitor and control husbandry and bird management through sophisticated decision support systems.

Both technologies will be used in conjunction with traditional approaches in genetics, reproduction and nutrition to improve bird performance. This will be conducted within an environment in which there is an increased emphasis on sustainability and also the welfare of the bird. For these approaches to maximise the benefits that maybe derived will require interdisciplinary research teams and close collaboration and cooperation between Government, research providers and industry in an environment with appropriate ethical safeguards.

Universities

The role of the University, through its core activities of teaching and research, is to educate and train scientists, technicians, producers, managers and other end users involved in the industry so competitive advantages can be maintained and advanced. However, this is going to be difficult with the credibility that agriculture faces, the difficulty of recruiting students, changing student demographics and expectations and the cost to students of University education.

Moreover, the real financial cuts that Universities have suffered over a number of decades has resulted in less money being available for innovative research infrastructure and significant decreases in the staff : student ratio. Funding from Government now

contributes approximately half of total University operating revenue so that it is a difficult time for Universities to meet some of the challenges and accept some of the opportunities that exist without major financial contributions from other sources.

Conclusion

There are many challenges and opportunities on the research horizon. The goal of future research will be to supply safe, affordable and nutritious poultry products, produced under conditions that consumers find acceptable and presented in a way that optimises unique quality characteristics.

Challenges facing the Australian egg industry – can research meet the need?

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The Australian egg industry operates in an environment that presents many challenges impinging on the profitability and sustainability of the industry. The majority of these challenges cannot be influenced by individual producers but many of the critical issues can be managed effectively over time with a collective industry approach underpinned by agreed strategies and processes. As a component of such an approach, a well directed research and development program plays a crucial role in addressing many of these challenges.

Key Research Areas:

As the sole national provider of integrated marketing, promotions, communications and R&D services for the Australian egg industry, the Australian Egg Corporation Ltd (AECL) invests in R&D funding to enhance the competitiveness and sustainability of egg businesses by targeting key issues relating to on-farm production, supply chain enhancement, and market education. Based primarily on consultation with industry stakeholders, the egg industry's R&D investments are prioritised within a number of key areas.

(a) Flock health and disease management

In the face of new and more virulent emerging diseases, the industry needs to provide an ongoing commitment to understanding disease characteristics - including aetiology and epidemiology - and enhancing control measures to improve flock management. The egg industry is constantly under the threat

of animal disease incursions and, as a result, minimising disease outbreaks remains essential to the industry's ongoing sustainability.

(b) Animal welfare

Layer hen welfare is a major issue facing the egg industry today and is an area strongly influenced by government policy and public perception. Some sectors of the wider community view the egg industry as not "welfare friendly", however, this attitude is often formed by misinformation communicated by animal protection groups and promoted by the media. Continued research to obtain objective assessment of the impact of management on flock welfare will provide outcomes that can be used to guide policy development based on factual rather than emotional evaluation, and more effectively shape community attitudes towards the egg industry.

(c) Feed availability and nutrition

The ongoing availability of feed grains at economically viable prices is under threat from climate change and increased demand from other traditional grain users and the emerging biofuels sector. As issues of feed availability and nutrition continue to impact on flock performance and production costs, ongoing research focussed on more effective feed formulations and the identification of new feed sources will maximise returns on feed expenditure and ensure an adequate supply of quality feed ingredients.

(d) Food safety

Food safety is a major concern for consumers and a number of foodborne disease outbreaks caused by *Salmonella* in recent years have implicated eggs as the source of contamination. Continued research in this area will remain a priority for the egg industry in order to promote best practice in production, storage, handling and usage along the entire supply chain and minimise the risk of egg-related food poisoning incidents.

(e) Environmentally sustainable management

The area of environmental management is becoming increasingly important as government and public pressure develops for all industries to demonstrate their “clean and green” credentials. Research aimed at minimising the egg industry’s carbon footprint and more effectively managing the environmental impact of by-products of egg production (dust, odour, waste) will ensure that the egg industry meets growing community expectations and regulatory requirements in this area and will contribute to a sustainable future for Australia’s egg production.

(f) Product Quality

Egg quality has emerged as a key research priority in the past two years and activities in this area are directed to address industry issues specific to improving and maintaining consistent egg quality based on preferred consumer characteristics that can be objectively measured. Focussed research in this area is in response to two factors: 1) recent consumer market research indicating that more than 30% of consumers indicated experiencing quality problems with eggs; and 2) observations by scientists, industry members and the consuming public of declining egg quality, particularly manifested by albumen runniness (watery whites). Research activity in

this area scopes areas of on-farm production and supply chain management.

(g) Human Health

In recent years egg consumption has been adversely effected by a negative association with cholesterol and heart disease and, accordingly, the benefits of egg consumption as a part of a balanced, healthy eating plan have been largely overlooked. This perception amongst consumers and healthcare professionals is slowly changing and continued research in this area is crucial to addressing the long-held cholesterol myth and promoting the human health benefits of regular egg consumption.

(h) Training, Information and Technology Transfer

Ongoing education and support for training within the industry is essential to facilitate information and technology transfer and ensure the required skills base across all sectors of the industry. In particular, the provision and effective communication of information in areas of on-farm production, business management and marketing is critical to assist egg producers to run competitive enterprises in an ever-changing and increasingly demanding operating environment.

Current and future challenges to the Australian broiler industry

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Record high feed costs are a major challenge to all intensive livestock industries including broiler. Global commodity prices seem likely to remain high for the foreseeable future. The industry's reliance on wheat is a drawback particularly with recent deviations from milling wheat price premiums over feed grains. Wheat alternative are needed that can be produced in areas not suited to milling wheat. Candidates produced locally or imported include pearl millet, triticale, feed wheat, pulses and cassava (tapioca). Imports may become more common, if not regular, and traits of imported feedstuffs may be different (eg mycotoxins). Becoming familiar with imported raw materials will be a research and commercial challenge. DDGS and palm kernel meal seem unlikely to be cost competitive for broilers.

Genetic potential of broilers is not reached commercially and great gains are still possible through improved growth rate, feed efficiency and mortality. Returns from improved feed efficiency increase as feed costs rise.

Feed ingredient such as amino acids, enzymes and organic minerals become more competitive as their cost relativity to major materials decreases. Maintaining performance with lower protein levels, utilising higher levels of a wider range of synthetic amino acids is a challenge to research.

Utilisation of existing feed raw materials can be increased. Feed enzymes have improved utilisation of grains over the last 15 years. Scope for further gains may be limited. However, protein meal utilisation can be improved. Digestibility studies have shown wide variation within and between meal types. Research emphasis needs to be on improving digestibility and reducing variation, not on showing variability. Processing conditions have the greatest effect on digestibility. Researchers need to collaborate with processors and meal users. Soybean meal, long regarded as the benchmark protein source can be improved. Canadian work with canola is leading the way. Improving animal by-product meal quality is a greater challenge because of the number of rendering operations (over 100 in Australia), variation in raw material inputs and differences in processing systems.

Adequate rapid testing of feed raw material quality still eludes industry. Advances in NIR technology are encouraging but more work is needed on methods to generate sufficient data for NIR calibrations. 'Reactive lysine' shows promise for protein digestibility.

The effects of feed processing need to be better understood. Typical commercial steam-pelleting conditions, for example, may be detrimental to feed quality.

Maintaining and improving bird health is a continuing challenge. Biosecurity, immune competence and efficacious vaccines are key components. Understanding and improving gastrointestinal tract health and function should produce performance dividends.

Customer and regulatory forces create many challenges including: use of antibiotic growth promotants, genetically modified products and animal proteins; animal welfare; food safety (microorganisms and residues). Also there are the environmental issues including odour, water, noise, energy use, litter supply and disposal.

Feed Additives, Food Safety and Consumer Perceptions

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Summary

A diverse range of feed additives is included in poultry feeds and these have important roles to play in the health and performance of chickens and in the economics of production. Uppermost in the mind of the feed formulator in selecting these additives is their efficacy. In many cases the need for inclusion is clear: certain vitamins and trace elements must be added as they are essential nutrients, critical for health and performance. Certain medicinal additives are considered necessary to control known diseases.

Other additives may not be regarded as essential but can have an important bearing on performance, perhaps through enhanced growth rate or efficiency of feed use. In the case of such non-essential additives it is the value proposition or return on investment which is the main deciding factor for the formulator.

In addition to the above performance and economic determinants, another important consideration in the selection of all feed ingredients is their suitability in terms of quality, safety and traceability, employee health and environmental implications.

Although arguably embellished and inflamed by the media, food safety is a major issue for consumers and therefore for the food industry worldwide and this clearly includes the poultry industry. It is not difficult to understand these concerns given the large number of reports on food safety issues from around the globe: Sudan dye in chili pepper (UK) and eggs

(China); melamine and cyanuric acid to augment crude protein levels in feed (USA, Canada); industrial coolant in toothpaste (Panama); contaminated vitamin A (Belgium) to name but a few recent cases.

Many stakeholders in the food chain would agree that food safety is the most important food quality attribute. A 2006 report from the European Health Focus organization highlighted that the main worries of consumers, about which they were “extremely or very concerned”, were antibiotics and hormones in meat and poultry (57% of consumers) pesticide residues in food (54%) use of GMO ingredients (48%) and food adulteration (47%). This raises the point that notwithstanding the truth of the matter, consumer perceptions will prevail. The classical example of this is the question of hormones in chicken, which exist only in the minds of (some) consumers!

The purpose of this presentation is to focus on the value of quality, safety and traceability in the food chain, specifically related to the use of feed additives in poultry production. It will also touch on ways in which the additive industry and future research may contribute in mitigating consumer concerns.

How can or will the Poultry Research Foundation meet the future challenges to conducting Poultry Research?

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There are ongoing challenges facing the poultry industry. In order for poultry research to maintain pace with these changes, the industry and research community must work more closely together to capitalise on expertise and availability of facilities. The Poultry Research Foundation has a long history in this area and herein are some suggestions on ways this could be improved. There are a number of constraints to doing research and these are by no means equal around the world. In some cases this may drive some research to more “friendly” operating areas. To overcome this and to promote a better research platform, as well as generate criticisable and meaningful data, it would be advantageous to generate a universal “reporting form”. The Poultry Research Foundation needs to develop a strong collaborative framework of laboratories that recognise its central roll as an experimental animal unit capable of generating accurate and repeatable data using commercial poultry species. There is also an opportunity to build into this research profile new concepts on measuring and monitoring poultry species and developing new tools for research and industry application.

Introduction

The poultry industry is dynamic and the on-going changes in genetics, available ingredients and supplements, market demands and governmental policy are creating new challenges associated with production, animal health and wellbeing, profitability,

impact of environmental footprint, and product quality and safety. As a consequence there will be ongoing demands for research to allow the industry to adapt and expand. To enable research and facilitate its capacity, we collectively, as members of industry, academia and the public, need to become informed and active. The USDA estimated that poultry research (1975 to 1995) resulted in the poultry industry’s ability to reduce costs of production by more than 50%. Research not only contributes to the industry’s competitiveness, it also increased the consumer’s choice of both poultry meat and eggs. This discussion will highlight some of the restrictions and opportunities for poultry research and specifically to the future of poultry research by the University of Sydney Poultry Research Foundation.

Restrictions to conducting research

Of serious, but not presently insurmountable, concern are restrictions to doing research (some are also similar to those faced by the industry in doing business). These restrictions are not equal in all countries, and are becoming the most restrictive in the EU. As a consequence, research (as well as production of meat, eggs and bioproducts) may move to less restrictive environments concerning: ethical use of animals; impact on environmental sustainability (i.e. carbon footprint, endangered species, etc); employee and employer safety and liabilities, respectively; and

societal or ideological grounds (the politicising of science) restricting, for example, use of genetically modified materials and embryonic stem-cells.

It is up to the researchers, their supporting organisations (institutions and funding agencies), industry partners and the public to become proactive in addressing research constraints. A rigorous and coordinated pre-screening of research is important, some tough questions have to be asked and answered satisfactorily to make research transparent and sustainable. To achieve this it would be extremely worthwhile to have a “universal” method of screening and reporting: research objectives; standards relative to environmental monitoring and nutrition reporting; analytical and statistical rigour and method, etc. Universal, meaning that all organisations (at least nationally, preferably globally) use one method of reporting research protocols and experimental criteria. Not only would this minimise the exhaustive reporting (ethics committees, funding agencies, and journals all have different formats), it would generate important information that would justify research by making it transparent and comprehensive as well as making “mining” (meta-analysis) of information in the literature more feasible. A colleague (van Kempen, personal communication, 2007) strongly feels that if this information had been present in previous studies, significant advancements would have been achieved through mining of existing research. Developing a digital system that can generate reports and publishable data that is complete and criticisable should be a priority and an opportunity for an organisation such as the Poultry Research Foundation with in the University of Sydney.

Good Clinical and Laboratory Practices will naturally evolve in all laboratories that adopt a universal reporting system and would become a critical component of these practices. These standards are becoming essential elements to research designed to meet registration requirements for new products or claims of efficacy. This is a key element to transparency of research that should have been not only adopted, but led by Universities through both teaching and research.

For the researcher, accept that you must be accountable and find the best possible means of making your accountability productive and easy! In the case were factors associated with the experiment are of concern, it simply means that “a tough question” needs to be answered/ justified – it should not restrict the choice if it is defensible. For the ethics committees, this should again direct concerns to non-defendable questions (and defining solutions), automate report deliveries, and allow more time to develop stronger working relationships with researchers. For funding agencies, such a system will provide necessary details for assessment, and give you more time for creating funding opportunities for the valuable research that needs to be done. Policy makers, your job would be redundant and give you time to help funding agencies generate more research dollars and confidently assure consumers that research is being accountable.

(a) Ethical issues

Serious concern needs to be given to addressing ethical issues, hence why I have highlighted this as a sub-heading under restrictions to research. The “policies” concerning ethics on animal well-being are strongly based on emotion rather than experience and scientific evaluation. Similarly, this

filters out as legislation; for example, codes of practice for production. Legislation of this nature, according to Garland (2004), is generated from concerns of a small minority of vocal public, again driven by emotion rather than science.

With respect to animals used in food production, it is clearly obvious that the final outcome of their existence is the production of food. Arguments have raged over measures of well-being of food animal production (and research). Observation that an animal capable of attaining its genetic potential must have minimal stress is countered by assessment of animal frustration and anxiety due to an inability to express innate behaviour (irrespective as to whether it attains its genetic potential or not). With respect to animal welfare, Bekoff (2007) comments “the question is not: can they love? Nor can they laugh? But can they suffer? As fascinating as the wealth of animal emotions is, it is really only this last question that matters when we (re)consider our treatment of animals”.

Pain and suffering. Our response is a need to address scientifically the degrees of pain experienced by an animal, so that it can be acknowledged and although the term is harsh, justified as required. This is in part to address societal pressures, but it is also a means to creating sound scientifically based practices to ultimately reduce pain (associated with misdirected behaviour, management and disease) encountered by large numbers of animals used for food production. One of the most powerful assessments of well-being is achieved by careful monitoring and understanding normal response / behaviour / health. We must become much better at “listening to the animals”. Developing consistent

observation skills is difficult, and to some extent I feel it may be “known” only to individuals who effectively have been “raised” by the animals. Recognising that these animals are the basis of one’s livelihood needs to be installed and that their well-being is critical to one’s own survival. Not discounting the need for those working with animals being provided with an education on monitoring animals, we also need to develop proficient (practical, easy to apply) tools to “interpret” what the animals are telling us. Dawkins (2006) presents some grounded recommendations on improving animal welfare in practice.

(b) Intellectual property

One of the most potentially costly and restrictive limitations to research, in my personal opinion, is related to securing and implementing legal aspects associated with intellectual property (IP). Based on experience (academic and industry) extensive amounts of time (money) and effort (money) are driven by securing IP (money). This is reducing funds available for research and increasing repetition of efforts (and mistakes). Defending legal claims on intellectual property need to be rigorously discussed and all associated costs made transparent to the public. We are in the business of producing food and reducing disease – there must be a saner way of generating faster response and still securing profits for industry. If there is a solution to this, I’m positive it won’t come from the business liaison offices of this or any other university (or funding body). This is certainly an area that industry also needs to rationalise; currently industry defines (i.e. funds) research proposals on their capacity to generate products / opportunities that can be adequately protected. This again, does not define the cost of replication of efforts; in

both cases, the public pays ultimately in higher costs associated with food. Furthermore, protected (hidden) IP has significant impact on the scientific / research community's progress.

Opportunities for research

The cooperative research approach is designed to provide the most “bang for your buck” and offer up “win win” opportunities (I try and avoid these sayings) by maximising the use of existing resources (people, laboratories, equipment) and developing team effort. However, unless the team works together willingly this becomes one of the most arduous aspects of managing a research program.

In the future, more and more research projects are going to be defined by team approaches that will facilitate the maximum harvesting of information using new techniques (expertise and equipment); employment of biotechnology being the current example. For too long we have been defining our research outcomes by gross changes to or quantity of an end product or level of efficiency – “feed'em and weigh'em”. In many cases, research gains have been missed because these responses have been masked by: nutrient imbalance / limitation and/or an inability to maintain optimum or challenge “environments” (in the broadest sense the term “environments” include ambient conditions, diet, disease, etc).

Future studies should readily have an arsenal of measures that can be easily drawn on (directly or via a team approach) that can more accurately assess a biological hypothesis. If we are going to make headway we must be able to limit the extent that progress is masked by the conditions of the experiment and our inability to

measure small incremental changes successfully. If feed efficiency of broilers was positively influenced by 1% (FCR 1.700 vs 1.683), on a worldwide basis (60 billion broilers/yr) this is equivalent to over 1 million tonnes of feed savings. This does not account for the future benefits associated with an ability to demonstrate a reduced carbon footprint? How many experiments, how many field trials, are capable of statistically demonstrating changes of less than 2 points (1%) in FCR?

As an example, one of the most puzzling observations in broiler chick studies is that early growth advantages are often lost before the end of the study (i.e. market age). As a consequence, the early treatment advantages are often discounted. This attitude puzzles me as the industry relies on predicting flock performance based on 7 day body weight. My explanation for this is related to a failure of the early advantaged bird to sustain growth, rather than compensatory gain of the disadvantaged bird. The question(s) that needs to be addressed include: does early rapid growth often equate to chronic (and sometimes severe) metabolic disease (skeletal, cardio-pulmonary, immune) that limits subsequent performance or does early growth increase maintenance requirements faster than the bird's ability to consume, digest and partition nutrients to support linear growth and maintain the early advantage?

Metabolic disease is effectively an expression of a flock's inability to balance the high demands for growth and production with supply organ (skeletal, cardio-pulmonary, digestive, immune, reproductive) capacity. This will become increasingly important as demands (increasing growth and egg

production) increase metabolic heat (not only for anabolism and catabolism of tissue, but also related to reliance on higher heat increment diets) that effectively command lower ambient heat loads to facilitate more effective heat transfer and maintenance of body temperature. Some serious thought needs to be given to “redesigning” commercial poultry in conjunction with ongoing efforts to develop optimum environments.

Recently, it became clear that current trials are not effective in screening new products and/or concepts (solutions) for efficacy. Effectively, why does a given computer simulation or *in vitro* (chemical, cell culture, *in ovo*) proven hypothesis not work *in vivo*? The questions we need to address are the limitations of transferring *in vitro* successes to *in vivo* outcomes realistic? Yes, I think they are a lot more realistic today given our increasing capacity to monitor *in vivo* responses (histological, physiological, lumen microbial ecology, gene transformations, enzyme and hormonal activation or signalling, etc.) and available technology to “by-pass” the severe environment of digestion so that test materials are delivered intact to the gut interface (and possibly assist in their uptake and activity). Once these barriers are overcome, we can address why we still didn’t get a 1% reduction in FCR when the treatment positively affected more than 100 genes important in metabolic function.

The potential for bioassay evaluations using large numbers of treatments tested under carefully controlled and common environments requires further elaboration so that more in-depth assessments become routine. Likewise, it is important that “measurable differences” reflect a meaningful physiological response and have real

impact on health, efficiency and/or production (Klasing, 2007). Only with this more comprehensive understanding will small positive incremental changes be possible (or likely discovered) and measurable.

The Poultry Research Foundation’s role is to complete part of the research puzzle by securing a poultry research facility that can minimise variation within and between trials and replicate consistent environmental challenges (again, in the broadest sense this would include ambient conditions, diet, health status (or susceptibility in disease challenges), etc). This facility needs to be appropriately staffed and directed so that operation and monitoring are optimised. Finally, bridges need to be built between this facility and the multitude of other laboratories with different research expertise of equal reputation as the PRF’s poultry laboratory. There should be no expectation or desire of a researcher to become a “Jack of all trades and a master of none”; rather develop an appreciation that maximum research effectiveness will be achieved by specialisation and collaboration.

There seems to be another cycle (I am getting old enough to count multiple cycles in this case) of discussion on the merits of research laboratories devoting time to measures of nutrient level, availability and net utilisation or efficiency. Nutritionists are using information that is not current with respect to: bird requirement changes due to continued selection (Leeson, 2007; Gous, 2007); ingredients modified for nutrient composition or level of anti nutritional factors; new additives that impact the availability of nutrients and require quantification of this in terms of diet formulation. My personal feeling is that none of this is of any consequence until we

understand limitations to intake (Scott, 2005, 2007). Variation in voluntary intake both limits the capacity of the bird to utilise nutrients fully and directly impacts the accuracy of measurements of nutrient utilisation. Poultry scientists need to closely align themselves with cereal breeders and chemists to give insight and input on selection for feed value. Keep in mind, our ingredients are rarely selected for feed value, but are either surplus (or rejected based on quality) or by-product of other end-use.

Another aspect is the potential for the poultry industry to integrate (pun intended) themselves more closely with the various capabilities of the Veterinary Faculty. In particular, Australia could make significant inroads in epidemiological monitoring and demonstrate a strong lead in this exciting research area. Develop what needs to be measured and monitored in the field and mine this data. Information from this would be extremely valuable in managing and utilising records kept (and monitoring how well they are kept!) as well as developing research direction.

Funding research is at a crisis point! More accurately, research support (funds, direction, managing, and protection) is in crisis. Tyson Food Inc recently spent 70 million USD to launch (i.e., advertise) their new line of AGP-free chicken (Feedinfo, 2007)¹. How can the research community compete for these expenditures? Particularly when the industry still faces significant issues pertaining to production of poultry without AGP's (e.g., EU 2012 ban on ionophores). If consumers are willing to pay for advertisement; why aren't companies willing (or able) to pass similar investments in research, to generate a better food product, on to the

consumer?? Ultimately it is the consumer who must pay for research (taxes, food costs); so can we not find a more justifiable means of securing this support and being transparent about its source and how it is utilised?

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¹“Tyson will promote 100% All Natural™, Raised Without Antibiotics chicken as part of the company's new marketing campaign. The \$70 million advertising and promotion plan is titled “Thank You” and will convey how Tyson products help make Mom a hero at mealtime. The marketing plan includes TV and radio advertising, plus strong consumer promotions to drive new and repeat purchases.”

Future Direction of Research for the Chicken Meat Industry – an RIRDC Perspective

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Over the coming decade, the chicken meat industry is expected to be increasingly driven by several (sometimes competing) imperatives – these being to produce safe and quality food, at a competitive price, and in a manner that is both bird and environmentally friendly. None of these imperatives/drivers are new to the industry, but their impacts on how chicken meat will be produced in Australia in the future will become increasingly significant. Research programs which support the industry will need to adapt to give industry the tools it requires to understand and address challenges created in these areas.

Environmental burdens

All industries are coming under increasing pressure to decrease their environmental burdens, particularly their use of resources, such as energy and water, and their emissions to the environment, particularly those which contribute to global warming and eutrophication.

Poultry production has a significant competitive advantage over the other land-based animal production systems in this respect. In fact, chicken meat production is the most energy efficient of all animal proteins. Basing their estimates on US agricultural production systems, Pimental and Pimental (2003) estimated that each 1 kcal of chicken meat protein produced requires an input

of 4 kcal of fossil energy. Turkey production was estimated to be the next most energy efficient (10 kcal of energy input: 1 kcal protein produced), followed by pig meat and milk (14:1), beef (40:1) and lamb (57:1). Similarly, chicken meat is the most water efficient land-based animal protein production system. Pimental and Pimental (2003) also estimated that 1 kg of chicken meat can be produced with about 2.3 kg of grain, which requires approximately 3500 litres of water, whereas 1 kg of beef requires about 105400 litres of water for the production of hay and grain alone, and in rangeland (grass fed) production systems, this estimate could be as high as 200000 litres of water.

Williams *et al.* (2006) also calculated the environmental burdens of production of ten agricultural and horticultural commodities in England and Wales and found poultry meat to produce lower burdens per functional unit produced than the other livestock production systems. For example, poultry meat's contribution to global warming (its global warming potential modeled over 100 years, and based on emissions of greenhouse gases in CO₂ equivalents) was modeled to be 3.6 per 1 tonne carcass weight, compared to 4.9 for pig meat, 15 for beef and 17 for lamb, and to 3.8 per 20000 eggs or 11 per 10000 litres of milk.

Williams *et al.* (2006) attributed the lower burdens produced by products

from monogastric species vs ruminant-based products to several major factors, these being the much higher daily gains, better FCRs and higher fecundity of breeding stock, so that breeding overheads are lower.

In fact, analyses undertaken by companies in Australia suggest that in excess of 90% of the major resources used and environmental emissions associated with production of chicken meat here are due to indirect sources, in particular the resources used in and emissions from producing feed. It therefore follows that improvements in feed conversion efficiency will make a very significant impact on the environmental sustainability of the industry.

Improved feed conversion efficiency has long been a major goal of the industry, and significant progress has been achieved in this area by the Australian chicken meat industry over the past four decades (see Figure 1). However, while the importance of this performance criterion has always been recognised by industry, primarily for its impact on the economics of production, in the future, its significance in terms of its environmental consequences will gain greater importance in the eyes of the community more broadly. For this reason, research which is directed at reducing the amount of feed (and particular grain) required to produce each tonne of chicken meat will be a major focus of the RIRDC Chicken Meat Program's R&D program into the future. Further analyses undertaken by Williams *et al.* (2006) also demonstrated the very significant impact that crop yield can have on the resources required to produce feed ingredients. Breeding a

new variety of wheat that increases yield by 20% could reduce energy use in wheat production by 9%. Given the large contribution of feed to resource use by and the environmental emissions of chicken production, a large proportion of this reduction can be converted to reductions in the environmental burden of chicken production. Therefore, an interest and possible involvement of the R&D funding agencies supporting the industry in the development and commercialization of improved or alternative feed ingredients which produce poultry nutrients in a more resource efficient way can be expected in the future. While the primary driver for involvement in R&D in this particular area will be the need to secure ongoing access to the industry's most significant input (feed) at a price which keeps the product competitive, the environmental imperative provides a further dimension to and incentive for this research.

Similarly, an interest in improving the return of resources from current waste streams into production inputs is likely. This could include a greater interest in the generation of energy or feed from current waste streams, and the development of strategies to allow greater reuse of water in the industry.

Bird welfare

In fulfilling its obligations under the Australian Animal Welfare Strategy, the chicken industry will increasingly need to develop the science to underpin key animal welfare standards, whether to support existing practices or to evaluate and support the implementation of new practices.

Welfare standards will not just be driven by science and economics, but by

community expectations, and the industry will require R&D which assists it to document the impacts which changes in practice driven by community expectations will have on the safety, quality, affordability and environmental sustainability of chicken production. In this respect, the finding reported by Williams *et al.* (2006) that the environmental burdens of free range (non-organic) poultry meat production are quantifiably higher than for all housed production is of interest.

Food safety and public health

Other than for price, food safety probably has the greatest potential for impact on sales. If consumers do not believe that the product is safe to use and eat, then they will not buy it.

While the ultimate control point for ensuring the safety of chicken meat for consumers is in the kitchens and homes in which it is cooked and served, the reality is that consumers and regulators are increasingly requiring the industry to take greater responsibility for ensuring the safety of poultry products. This trend will not diminish. Novel strategies to

minimise contamination of live birds entering the processing plant with potential human pathogens, rigorous adherence to microbiological controls within the plant, and the adoption of new or improved in-plant intervention strategies to reduce microbiological contamination rates will all be needed to address existing and emerging food safety risks. R&D will be required in all these areas to assist industry to deliver a safe product to consumers and to assist in generating consumer confidence in the product.

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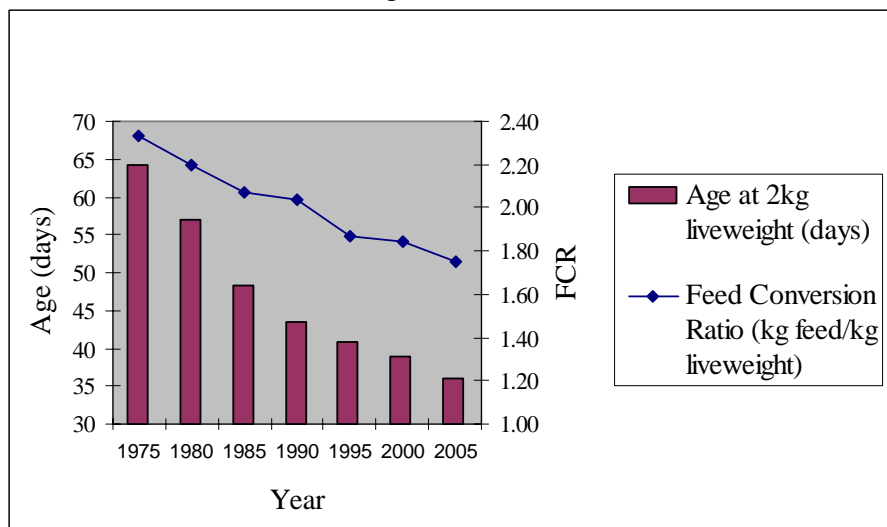


Figure 1. Trends in flock performance 1975 to 2005.

The University of Sydney Poultry Research Foundation: Recent Activities.

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While the Poultry Research Foundation has an emphasis on providing high quality research there continues the need to support the demands for teaching and learning. There has been an increased emphasis on research based teaching as a core University strategy in the past couple of years. The Poultry Research Unit provides the resource base for teaching and learning in the degrees of Veterinary Science and Animal Veterinary Bioscience (AVBS). The latter is a recent addition to the Faculty of Veterinary Science structure with the first full intake of graduates entering their final year in 2008. The number of final year students in 2008 is 35 but this will increase to around 70 by 2010. This is expected to place some strains on the Faculty resources especially with our ability to provide adequate research projects for students. The Faculty has appointed 8 new lecturer positions since June 2006 as part of the efforts to resource this new degree. The Poultry Research Unit continues to provide final year students with research projects for completion of their honours commitments. It is normal for the unit to make available 2-4 research projects for these students. In 2007, 3 students completed projects with two of these having been awarded Poultry CRC scholarships. Two of these students are to undertake post-graduate studies and the other has taken up employment in the poultry industry. Presently there are two post-

graduate students undertaking PhD studies at the Poultry Research Unit.

The structure of the new AVBS degree does provide some concerns for the interests of the intensive animal industries. Previously all final year students completed units of study that were compulsory. These compulsory units included studies in Poultry Science. However, since 2007 all final year units of study are electives. There is no longer any compulsion for students to select 'Intensive Animal Industries' or 'Poultry Science and Technology' both electives involving course material relevant to training students in poultry related areas. In 2008 'Poultry Science and Technology' will not be offered as an elective in the final year of the AVBS degree as there was no interest shown for this unit by the relevant third year students. If the industry sees the AVBS degree as a relevant source of future employees, there is an obvious need to identify employment opportunities to students before they enter their final year. In 2007 members of the Faculty organised a careers night for the third year students with representatives of industry operating information stalls and providing face-to-face meetings with individual students. During these conversations employment opportunities were discussed. It is probably important that the Foundation consider having participants involved in such activities. There remains limited understanding by students of

the range of career opportunity available in the poultry industry. If students are to study in areas related to poultry they need to be made aware of the opportunities this will provide after graduating.

The RIRDC and AECL continue to be major sources of funding for research-based activities at the Poultry Research Unit. Over a five-year period, AECL supported research into the development of procedures for measuring corticosterone in egg albumen as a non-invasive means of determining stress in laying hens. With albumen being accumulated over a period of some hours during egg formation, the concentration of corticosterone in albumen was found to be representative of the circulating blood concentrations during the period of its deposition. After hens are exposed to events that are stress provoking the concentration of corticosterone in the albumen increases. After confirmation of its usefulness as an indicator of stress in hens, a three year research project evaluated the effects of commercial husbandry practices on stress in laying hens. Probably, of greatest interest to many was a collaborative study undertaken with researchers at the University of Queensland, evaluating different housing systems. In this study, three replicates of the common housing systems used in Australia, barn, free range and conventional cages, were established on the Gatton campus of the University of Queensland. Various measures of welfare were carried out on hens maintained in these facilities for a full production cycle. Corticosterone concentration in egg albumen was determined in eggs collected at 33 and 70 weeks of age. The egg albumen corticosterone concentration was found to be no higher in hens housed in conventional cages than the floor based systems. This result was confirmed in a second production cycle using a

different strain of laying hen. This observation created major interest worldwide following a story published in the Queensland popular press. The recent interest is probably sufficient to warrant more detailed evaluation of the housing systems in larger study on commercial farms. To this end a full research proposal has been submitted to AECL.

Present projects being undertaken at the Poultry Research unit are funded by RIRDC 'Chicken Meat' and 'Buffalo, new animal products and rare natural animal fibres' programs. Under the Chicken Meat program, a three year project 'Physiological and nutritional approaches to alleviate heat stress in broiler chickens' has been in progress since mid 2007. The project aims to develop practical management strategies that can be easily applied in commercial sheds to improve broiler performance and thermo-tolerance under summer conditions, particularly prior to marketing, as the susceptibility to heat stress increases with age.

Under the RIRDC, 'Buffalo, new animal products and rare natural animal fibres' program, a three year project, 'Efficient, environment and bird friendly commercial duck production' is into the second year. There are two major duck producers in Australia. One of these Pepe's Pty Ltd, is working with the University as the industry partner in the research. Presently, Pepe's maintains two strains of Pekin duck, the Cherry Valley and Grimaud Freres, with parent genetic stock imported from overseas. While the demand for duck increases annually, by more than 10%, the requirements of the market are very specific, requiring a 2.85 kg liveweight duck at slaughter. While this can be achieved by 42 days using the Grimaud Freres, the yield of edible meat is relative low. The Perkin strains developed overseas and using

nutritional research from the same origins is not ideal for Australian conditions or market requirements. Therefore, the industry is in urgent need of research to provide concise and standard growth patterns of ducks under local conditions. This includes having the ability to predict the precise age at which optimum lean muscle deposition occurs, with a favourable fat content. In the first year of the project, the effects of sex, pen sex, strain and season on the growth rate of the commercial duck strains used by Pepe's have been evaluated. The project is currently into its second year and the research emphasis is on aspects of nutrition.

The Poultry Research Foundation – its role in future research.

P. J. Groves

The University of Sydney, Camden, NSW 2570

All of the speakers today have beautifully outlined the Foundation's history, objectives and successes over fifty years of committed research. The Foundation has produced valuable scientific outcomes and, more importantly, fostered the development of many people now enthusiastically involved in working within the poultry industry and making contributions that are too immense to really measure. The industry as a whole has benefited greatly from the Foundation and will continue to do so as long as useful research projects continue to flow.

The Foundation's facilities are first class and the expertise of the research and support staff is of the highest calibre. As such, the Foundation represents an important continuing asset for the poultry industry, as similar facilities run by some state government departments that have been of value to the industry continue to be closed down. The future of the Foundation's contribution will be best served by maintaining a close liaison with the industry, targeting the industry's current and foreseeable needs. The unique industry membership structure of the Foundation facilitates this strongly.

During my time as Acting Director I visited many of the poultry industry's leading nutritionists and discussed research areas where the Foundation's facilities and expertise could be of value. A brief summary of the issues that were commonly mentioned and appeared to be most relevant and important follows. I'll split these into broiler and layer industry categories:

Broiler research priorities

- Early growth and skeletal integrity
- Grain utilisation (maldigestion) and bird variation in AME values
- Feed processing – effects of different temperatures and treatments on feed quality
- Alternatives to antibiotics
- Protein digestibility, especially from processed meals
- Re-use of litter
- Maintenance of breeder fertility
- Breeder electrolyte balance and wet litter
- Reproductive tract health
- Public health issues
-

Layer research priorities

- Albumen quality
- Shell quality
- Welfare
- Public health issues (Salmonella)

The way forward will be to build a clear strategy for the Foundation to proceed, developing an integrated research approach. I feel there is an imperative need for an experienced, respected nutritionist to be at the helm of the Foundation's research path into the future. Someone with appropriate vision and a strong foundation in digestive physiology with the ability to listen to the industry and to identify productive research projects so as to generate enthusiasm from the industry to support progress. Attracting a person of this calibre is important, not only to the University but also for the industry and, as such, will require a strong investment from the industry.

SPEAKER PROFILES

Frank Annison

Born (1926), raised and educated in London. Graduated in Chemistry, (1st Class Hons) in 1946, and completed Ph.D. studies at Lister Institute of Preventative Medicine, Chelsea, in 1950 before joining the newly established Institute of Animal Physiology, Cambridge in 1951. Seconded to the Rowett Research Institute, Aberdeen (1951-52) before leaving Cambridge in 1958 to join the Faculty of Rural Science, University of New England in Armidale, NSW. Returned to the U.K. in 1965 to take up a position at Unilever Research Division at Colworth House, Bedford. In 1974 was appointed to the Chair of Animal Husbandry (later termed Animal Science) at the University of Sydney, and based at Camden. The Headship of the Department, and the position of Director of the Poultry and Dairy Foundations were rotated on a three yearly basis which I did until 1991. Retired in 1994.

Research interests have largely focused on the physiology and metabolism of ruminants, pigs and chickens.

Balkar Bains

Graduated from the Veterinary School, University of Queensland in 1964 and immediately pursued a career in the poultry industry. For the first 12 years, employed as a Senior Technical manager by Provincial Traders P/L. During this period apart from establishing diagnostic laboratory, the notable achievements include successful production of Infectious Bronchitis vaccine for commercial use, Salmonella epidemiology, Selenium in poultry feed and the first time recognition of the presence of Reo and Adeno viruses and their significance in the poultry industry in Australia. From 1973 – 76, as an external lecturer taught poultry diseases to the fifth year Veterinary Science students. During 1977, was employed as a Senior Lecturer in the Department of Pathology and Public health at Massey University, New Zealand. From there

onwards employed by Roche Products P/L as a Director of VFC division for the first 10 years and Director of Technical Services (Far East Asia) till 1994. The subsequent years, was retained as a consultant to Roche Products VFC division with a focus on the poultry industry. During this period, written 3 books, Manual of Poultry Diseases, Application of Vitamins in Commercial Poultry, Physiological and metabolic functions of Ascorbic Acid in Chicken. In edited journals published 34 articles and 57 articles in non edited magazines and proceedings.

Leo den Hartog

Born in The Netherlands 1955, completed studies of Animal Production at the Agricultural University in Wageningen specialising in Animal Husbandry, Animal Nutrition, Crop Production and Farm Economics in 1978. Professor den Hartog completed his PhD on “The effects of energy intake on development and reproduction of gilts and sows in 1984. He was chairman of five pig and poultry trade missions of the Dutch Ministry of Agriculture, Nature Management and Fisheries in co-operation with various Dutch companies to Taiwan, Korea, Philippines, China, Brazil, Argentina, Chile, Latin America and South Africa along with being a member of several scientific and industrial committees. Professor Leo den Hartog is currently the Director of R & D and Quality Affairs with Nutreco and a part time Professor in Animal Production at the Wageningen University.

Mingan Choct

Professor Mingan Choct's main academic interest is in the area of carbohydrate chemistry, feed enzymes and monogastric nutrition; he has supervised more than 30 postgraduate students and published over 270 papers in journals and conference proceedings. Mingan has a PhD in polysaccharide chemistry, worked as human nutritionist, and is the CEO of the

Australian Poultry Cooperative Research Centre based at University of New England in Armidale. He is on the editorial board of several international journals (assistant editor of British Poultry Science, Poultry Science) and has been an invited keynote speaker at many national and international conferences and has extensive links with institutes and industries throughout the world. Mingan is also a scientific advisor to the International Foundation for Science and the winner of The World's Poultry Science Association Syd Wilkin's Prize (1990), The Australian Animal Production Young Scientist Award (1991), The Australian Poultry Award (2004), the Alltech Biotechnology Global Medal of Excellence (2005) and the British Poultry Science Association Gordon Memorial Prize (2008 confirmed).

Russell Lyons

National Sales and Marketing Manager, Russell has nearly 30 years' experience in the Australian stockfeed industry. Joining Ridley AgriProducts in 1996, Russell is responsible for the development and implementation of sales and marketing strategies across the company's major markets.

Derick Balnave

Dr Balnave graduated from The Queen's University, Belfast with 1st Class Honours B.Sc, majoring in Chemistry in 1964 and subsequently completed a PhD degree in 1966 in the Department of Agricultural Chemistry at the same university. He was awarded the degree of Doctor of Science by The Queen's University in 1983 in recognition of his published scientific work.

His initial appointment in 1966 was to the Animal Nutrition Research Division of the then Ministry of Agriculture for Northern Ireland and in 1967 he was also appointed an Assistant Lecturer in the Department of Agricultural Chemistry at The Queen's University, Belfast. He held a Readership at the University and the position of Principal Scientific Officer in the Ministry by the time he took up a position with the New South Wales Department of

Agriculture at Seven Hills, Sydney in 1977. He accepted an appointment at The University of Sydney in February 1978 and was Research Director of the Foundation until his retirement in 2001. He was also Adjunct Professor at North Carolina State University, USA from 1995 to 2005.

Dr Balnave has published over 300 scientific articles, approximately 150 of these in peer-refereed journals. He supervised 30 postgraduate students and was the recipient of the 1998 World's Poultry Science Association's Australian Poultry Award.

Greg Hargreave

Greg Hargreave is the nutritionist for Baiada Poultry, the third largest broiler company in the Australian market. He is also the nutritionist for Pace Farms, the largest egg producer in Australia. He has worked in the stockfeed/livestock industries since 1976.

His qualifications include a Bachelor of Science in Agriculture from The University of Sydney and a Master of Business in Finance and Economics from Curtin University in Perth, Western Australia.

His prime responsibilities are for the feed supply and nutritional feed programmes for Baiada Poultry and Pace Farms. This includes all the formulation work, deciding on appropriate livestock husbandry programmes (in conjunction with company livestock managers and veterinarians) and overseeing the raw material procurement and feed supply decisions. Feed output involves working with up to 12 mills, each producing from 2,000 to 20,000 tonnes per month.

The overriding focus of these responsibilities is to optimise broiler and egg production costs for all the company's livestock operations.

Ron MacAlpine

In 1972, Ron MacAlpine graduated from UNE (Bachelor of Rural Science, 1st Class Honours) and then completed his PhD at

University of Sydney in 1980. Ron's thesis was entitled: "*Energy-protein interrelationships in broiler chicken nutrition*". Ron MacAlpine's name is synonymous with Inghams Enterprises where he has worked since 1972 and is now the National Nutrition Manager. In this position, Ron is responsible for overall management of feed ingredient supply and nutrition for Ingham's operations in Australia and New Zealand. Inghams Nutrition Centre, located in Sydney, incorporates a feed analysis laboratory and advanced broiler feed testing facilities. The nutrition team is primarily focussed on feed programs and performance of the company's poultry operations. Ron MacAlpine shares an active interest in industry research programs through membership of the Chicken Meat Committee of RIRDC and the Research and Development Committee of the Australian Poultry CRC. Most appropriately, Dr MacAlpine was a recipient of the Australian Poultry Award in 2003.

Wendy Muir

Wendy is currently a lecturer at the University of Sydney, where her research focus is on the avian immune system. Her research interests principally concern mucosal immunity in the chicken, with a focus on the local intestinal immune system, its structure and function and opportunities for immunomodulation through vaccination, cytokine delivery, and more recently, nutritional manipulation.

Wendy achieved a BScAgr (Hons 1), in 1988 and a PhD in avian intestinal immunity in 1996. Both degrees are from the University of Sydney. She continued to pursue her research interests, working as a Postdoctoral Research Fellow from 1996 – 2001. In 2001 Wendy completed a GradDipEd from UNE and in 2002 she was appointed as a Lecturer in Animal Science at University of Sydney, Camden campus. From January 2002- July 2003 Wendy was also overseeing the day-to day operations of the Poultry Research Unit. Her teaching responsibilities include immunology /animal health, poultry

husbandry, animal science and junior microbiology.

Peter Selle

Peter Selle graduated in Veterinary Science from Sydney University in 1967 and became a Member of the Royal College of Veterinary Surgeons in 1978. From 1970 to 1988, Peter worked for Bayer Animal Health in Australia followed by a secondment to Bayer Germany. In mid-1991, Peter returned to Australia and joined BASF Animal Nutrition where he became involved with the registration and local development of Natuphos® phytase.

Peter Selle completed his PhD at Camden [*Phytate and phytase: Consequences for protein and energy utilisation by pigs and poultry*] under the supervision of Wayne Bryden in 2001. Since 2002, Peter has been involved with the Poultry Research Foundation as an Honorary Associate to the Veterinary Science Faculty.

Wayne Bryden

Wayne Bryden completed a Bachelor and Master of Rural Science at the University of New England and then undertook a PhD at the University of Sydney within the Poultry Research Unit at Camden under the guidance of Frank Annison, Derek Balnave and the late Charles Payne.

He subsequently joined the staff of the University of Sydney and rose to the rank of Associate Professor and was Director of the Poultry Research Foundation in 2001. He became an Honorary Governor of the Foundation in 2002. He is currently Professor of Animal Science at the University of Queensland, an Adjunct Professor at North Carolina State University, President of the Nutrition Society of Australia and a member of the WHO Expert Panel on Food Safety.

Professor Bryden has over 500 publications of which 200 appear in international journals or as book chapters and he has supervised some 50 postgraduate students. His current research interests include various aspects of monogastric nutrition, especially amino

acid metabolism, and the relationship between diet and immunity. The interactions of feed toxicants, especially mycotoxins, in the feed chain is an ongoing research theme.

David Witcombe

David completed a BAppSc in biotechnology at the University of Technology, Sydney (UTS) in 1991, while working part-time as a Scientific Officer with Genetic Technologies Corporation performing DNA profiling for forensic and paternity cases. He moved to Biotech Australia in 1994 as a Quality Assurance Officer for 12 months, before transferring to the Molecular Biology Research Division for the next three years. The focus of his work during this period was the development of vaccines against economically significant ectoparasites and nematode parasites of livestock and pets.

With the support of a RIRDC scholarship, David returned to UTS in 1998 to undertake his PhD, characterising an important vaccine candidate from the apicomplexan parasite *Eimeria maxima*, a causative agent of coccidiosis in chickens. He continued with the UTS *Eimeria* research group as a Postdoctoral Research Fellow to lead the vaccine development team from 2002 to 2004, before accepting a research fellowship identifying and characterising novel drug and vaccine targets in the ruminant barber pole worm, *Haemonchus contortus*.

David has published numerous scientific papers in peer-reviewed journals and conference proceedings, is author of an international patent for a recombinant coccidiosis vaccine, and has presented his work regularly at national and international scientific meetings. In 2005, he moved to his current position as Research and Development Program Manager at the Australian Egg Corporation Limited (AECL), a role that serves to establish, support and manage R&D projects for the direct benefit of the Australian egg industry.

Jack (Jacob Barnard) Houweling

Jack Houweling was born in Holland and migrated to Sydney as a child in 1956 with his family where his parents became involved in both broiler and layer farms. Jack matriculated and joined Inghams at their Austral complex and then moved to the Tegel laboratory at Leppington as a technician where he remained until 1975. In 1975, Jack moved to the Badgerys Creek breeder complex operated by Consolidated Poultry Industries. In 1979, Jack travelled north to Queensland to become livestock production manager for Woodlands Enterprises at Beerwah. In 1982, Jack joined Darwalla Milling Company as the Operations Manager, currently he is the General Manager of the group.

Jack Houweling has been highly active with both PIX (appointed Vice President in 1997) and the Queensland Branch of the Worlds Poultry Science Association (appointed Treasurer in 1994). In 2002, Jack was presented with the Noel Milne Queensland Poultry Industry Award in recognition of his services to and his involvement in the poultry industry

Tim Walker

Tim Walker has enjoyed more than 30 years in the feed and integrated broiler industries in Australia and New Zealand. After completing bachelor and Ph.D degrees at the University of New England, Tim spent 4 years in commercial nutrition in New Zealand. Since 1978, Tim has been based in Sydney and has held several technical and commercial management positions with feed manufacturing and integrated broiler companies. Tim's present position is with Bartter Enterprises where his focus is poultry nutrition and feed raw material supply.

Ian Partridge

After completing a BSc degree at Newcastle, UK and MSc at Guelph, Canada, Ian worked for 14 years at the ARC Research Institute at Shinfield, Reading UK. He was awarded his PhD degree by Reading University in 1976. His research covered many aspects of pig nutrition including digestion, absorption

and metabolism of nutrients; applied trials of feed additives and alternative protein sources; studies on nutrient requirements and diet composition for early weaned pigs and the evaluation of feedstuffs.

During these 14 years of swine nutrition research, Ian presented more than 60 scientific papers in refereed journals, at scientific meetings and in popular publications.

He joined Roche in the UK in 1986 and has had assignments with that company in Switzerland and Australia. During 1994-5 he was Manager of the Vitamins Division of Roche in Vietnam. He then returned to Sydney, where for 10 years he managed the DSM Nutritional Products business (formerly Roche Vitamins) for Australia and New Zealand. From 2000 to 2005 he served as President of the Poultry Research Foundation at the University of Sydney.

In 2005 he was appointed DSM's Director of New Business Development for Asia Pacific and in this role he is currently based in Singapore.

Tom Scott

Tom is a Canadian (rural Saskatchewan) and is currently Director of Research – Poultry for Provimi and is located in Brussels at Provimi's Research and Innovation Centre. Provimi maintains research in poultry at eight locations world-wide with a focus on complete feeds and feed supplements. Prior to starting with Provimi (January, 2007) he was the Chair in Poultry Science (and Director of the Poultry Research Foundation) of the University of Sydney maintaining a teaching and research programme based in Camden. Tom likes Australia! Having received his PhD from the University of Sydney and then returning to hold a research fellowship with USyd with support from the NSW Egg Corporation. He has also been a research scientist (14 yrs) with the Research Branch of Agriculture and Agri-Food Canada working in research centres located in Nova Scotia and British Columbia. Research interests are related

to poultry nutrition and physiology, with a focus on the use of bioassays to facilitate this research. Poultry, poultry science and its industry have been his sole working focus. He maintains and repeats to those who will listen – “chooks have been good to me!”

Vivien Kite

Deputy Director, ACMF, and Research Manager, Chicken Meat Program of the Rural Industries Research and Development Corporation (RIRDC)

After completing her PhD on the behaviour of meat breeder hens, under the supervision of Associate Professors Rob Cumming and Monica Wodzicka-Tomaszewska at the University of New England, Dr Kite took up a post-doctoral research position at the then Poultry Research Centre (now the Roslin Institute) in the UK, working with Dr Ian Duncan on a Commission of the European Community funded animal welfare research program grant studying transportation stress in meat chickens, and developing methods for measuring motivation in chickens.

Upon returning to Australia in 1987, Vivien took something of a career change, making her first move into the world of agri-politics in taking up a position with the NSW Farmers' Association, where she was responsible for looking after the interests of the egg industry, and for managing the Association's interests in the areas of animal welfare and research.

Two years later, she took up the position of Assistant Executive Director and R&D Manager with the Australian Poultry Industries Association. She has remained with the industry organisation for the ensuing 18 years.

She is currently Deputy Director of The Australian Chicken Meat Federation (Inc) and Australian Poultry Industries Association, as well as holding the positions of Research Manager of the Chicken Meat Program of RIRDC, and Deputy Director of the Australian Poultry CRC.

David Fraser

Born in New Zealand. Graduated in Veterinary Science from the University of Sydney in 1962. Graduated PhD in 1967 from the University of Cambridge in nutritional biochemistry. From 1967 until 1986 was employed on the scientific staff of the British Medical Research Council in Cambridge, specialising in micronutrient nutrition and on vitamin D metabolism and function, in particular. In 1986 appointed to the second chair of Animal Husbandry (later Animal Science) at the University of Sydney. Research activities in Sydney have roamed widely on calcium homeostasis, bone development and vitamin D status in domestic animals and humans. Served as Director of the Poultry Research Foundation 1992-2000.

Jeff Downing

Dr Jeff Downing is employed as a Lecturer providing instruction to both Veterinary Science and Animal Veterinary Bioscience students. Having completed a Diploma of Agriculture from Wagga Agriculture College he joined CSIRO as a Technician. After some years at CSIRO, Jeff studied as an external student and was awarded a B.Sc. degree from Macquarie University, and then a PhD.

Initial employment at the University of Sydney was as a Research Fellow working on regulation of ovarian follicle development in broiler breeders. This was a continuation of work commenced at CSIRO. At this time other areas of interest were fat metabolism in broilers and evaluation of ways to increase the omega-3 fatty acid content of broiler meat. More recently, major research efforts have focused on stress physiology in laying hens. A important accomplishment has been the development of procedures to measure corticosterone in egg albumen as a non-invasive measure of stress in laying hens. Presently, Jeff is involved in evaluating physiological and feeding strategies to alleviate heat stress in broilers and development of growth models for Pekin ducks under Australian conditions.

Since 2003 Jeff has been employed as a lecturer in Animal science providing

instruction in areas of poultry and pig husbandry, artificial breeding, reproductive endocrinology and welfare.

Peter Groves

Peter graduated in Veterinary Science in 1977 from the University of Sydney. After a couple of years in mixed practice Peter took up a research role with Pfizer Agricare at Bringelly. In 1981 Peter joined Elanco Products Company as a research veterinarian and here became involved in poultry work, mainly involved with coccidiosis. The interest and hold of the poultry industry became quite strong and Peter joined Ingham's Enterprises in 1985 as a field veterinarian in NSW. In 1987 Peter moved to the growing Baiada Poultry operation as their Technical Services manager, maintaining that role until 2003. During this time Peter completed a PhD through the University of Sydney on the epidemiology of the broiler ascites syndrome (supervised by Dr Garry Cross). A major focus during this time has been on Marek's Disease which included strong collaborative research projects between Baiada and the University of New England with Dr Steve Walkden-Brown.

Since 2003 Peter has worked as a private veterinary consultant to the industry, primarily consulting to Baiada Poultry and also to some pharmaceutical companies and vaccine manufacturers. He operates a small poultry research unit in western Sydney.

Since 2005 Peter has provided teaching for veterinary science students in poultry health and poultry husbandry at the University of Sydney (Senior Lecturer) and Charles Sturt University (Adjunct Senior Lecturer). In 2007, Peter took on a role as acting director of the Poultry Research Foundation in a part time capacity.

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