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WPSA ACTIVITIES IN NEW ZEALAND – AN HISTORICAL VIEW

MIKE CUNDY

This conference celebrates the 50th Anniversary of the founding of the New Zealand branch of the World's Poultry Science Association and as a past president and long time member it's my pleasure to review the history of our organisation.

Anyone from today suddenly finding themselves magically transported back to 1960, the founding year of this branch, would find themselves in a dramatically different world, both generally and from a poultry point of view.

The New Zealand of 1960 would still be recognisable, but barely so: there were no supermarkets, no motorways worth the name and television had arrived but was limited to two hours a week on Wednesdays; Kiwis still bought groceries by the pound not the kilo, in British pounds shillings and pence and their passports, if they had them, were still British; The Ford Anglia and Triumph Herald were the toast of new car showrooms; a young man called Rob Muldoon entered Parliament for the first time. It was a highly regulated society with prices and wages largely government controlled, but life was pretty good for most and there was virtually full employment.

The poultry industry was also vastly different from today, with a large number of small flocks and no real broiler industry as such. The industry had been very active from the turn of the century and by 1960 there were close to 4 million layers in the national flock, but half of them were still in backyard flocks of less than 25 birds! There were 1800 flocks boasting over 100 birds but only 15 with over 4000. Only a third of all eggs went through egg floors.

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The Government seemed to have a hand in everything via the New Zealand Poultry Board, controlling bird numbers and margins obtainable by the producer, the distributor and the grocery store. On the other hand there was a free veterinary diagnostic service, MAF employed 12 poultry advisors based throughout the regions and producers were paid a small government subsidy. Eggs cost the housewife about 4 shillings a dozen, equivalent to over $10 a dozen in today's money!!

There is ample evidence from various sources dating back as far as the early 1900s that many keen individuals throughout the poultry industry were applying scientific principles (in terms of genetics, health, management and nutrition) from very early on. Records tell us that leading producers and industry personnel were individual members of the WPSA and attended the World Congress from the early 50s and the keenest among them in due course saw the need for a New Zealand Branch. They were Fred Bobby (MAF Chief Poultry Officer), Alf Bridle (Chairman of the NZ Poultry Board), Ted Chambers (a leading South Island egg producer), John Kissling (manager of the poultry unit at the Massey Agricultural College) and Norm Smith (nutritionist with the Tauranga Egg Marketing Co-op). They held the first official meeting on 11th February 1960 in Palmerston North during the annual Massey Poultryfarmers' Refresher Course. The meeting was attended by 27 WPSA members and some 50 interested observers attending the course. Also present was Mr Otto Moll, secretary/treasurer of the Australian Branch of WPSA, more of whom we shall hear later.

The five named above comprised the inaugural committee with Mr Bobby in the chair as the first President, which was fitting as he was the prime mover. If we take the minutes book literally, they spent much of the next year or so sorting out branch rules, bank accounts and other minutiae. However, from brief mention, more was obviously happening behind the scenes with delegations being coordinated to attend meetings in Australia and elsewhere and Professor Leo Norris from the USA being hosted – the first of many prestigious overseas scientists to be brought to New Zealand by NZWPSA over the years.

HIGHLIGHTS BY DECADE

The 1960s

President: Fred Bobby (1960-62, when he died); Alf Bridle (1962-65); Professor Alan Rae, Massey University (from 1966)
Secretary/Treasurer: Norm Smith (1960-63); Harold Watson (1964-66); Milton Watts (from 1967).

Membership rose rapidly to 174 by 1964. There were active North and South Island sub-branches and numerous meetings were held, though no major conferences. Group travel to conferences in Australia and elsewhere was allowing the building of contacts that would prove important in future years.

The 1970s

President: Prof Rae (1966-71); Dr Mike Sissins [NRM] (1971); Ted Chambers (1972-78, when he died); Peter Thompson [MAF] (1978); Noel Robertson [NRM] (from 1979).
Secretary/Treasurer: Milton Watts (from 1967).

These were the years when branch activity began to ramp up, with recognition that regular seminars at Massey and Lincoln were very useful, but these did not reach all areas, so a Travelling Speaker scheme was instituted to disseminate more widely the latest ideas for improving productivity. The Branch organised the first major poultry conference to be held in New Zealand, the Australasian Poultry Science Convention, which was held in 1972 in Auckland and was very successful. The New Zealand Poultry Award (for meritorious service to the industry, to be awarded on an 'as justified' basis, not every year) was also instituted and the first award was duly made in 1979 to John Kissling from Massey. Rex Patchell, who eventually succeeded Kissling as head of the Massey Poultry Research Centre, joined the executive committee in 1974 and was to go on to win the award in later years. The Branch also hosted a series of big names from the

world of poultry science including Dr Milton Scott from Cornell, Dr Peter Biggs from the UK, Bill Jasper and Stan Coates from the US and Dr Simon Bornstein from Israel. These people were leaders in their field and opened our eyes to many new concepts and gave us ideas for new ways of tackling our everyday jobs.

The lack of formal training opportunities for young people entering the industry, which was to become a recurring theme, was first discussed at a meeting in 1979.

The 1980s

President: Noel Robertson (1979-87); Mike Cundy [PCL Feeds](from 1988)
Secretary/Treasurer: Milton Watts (1967-85); Laurie Prior [Elanco] (from 1985)

The 80s were an active decade and kicked off with the highly successful 1980 South Pacific Poultry Science Convention. The scientific programme featured leading speakers from all over the world and over 400 delegates attended from far and wide. As usual it involved a huge amount of voluntary work from a long list of people, mainly WPSA but from the wider industry too. Industry sponsorship was a key factor in making this event a success and this valuable support from commercial companies has continued over the years and has been greatly appreciated by WPSA.

Noel Robertson and Milton Watts were instrumental in setting up the Far East and South Pacific Federation of WPSA Branches in the early 80s, comprising New Zealand, Australia, Japan, Korea, Malaysia, Philippines and Fiji. The industry was undergoing major change at this time. Farmer numbers were dropping and membership decreased with it to around 120, but the executive committee was very active. The NZ Poultry Award went to Milton Watts in 1980, Les Batkin of Bromley Park in 1982 and to Marion Stewart and Malcolm Mitchell jointly in 1984. Welfare concerns got their first real mention in the minutes from 1984 and in 1985 the threat of exotic disease was discussed. With PIANZ in its infancy and there being no official egg farmers' organisation the WPSA had to take the lead on a number of issues. With the demise of the Poultry Board and deregulation of the egg industry there was concern that the Poultry Research Centre at Massey would have to close and the WPSA was vocal and very active in working with others to see that it kept going. In 1987 the executive were very busy again, organising

the very successful Third Conference of the Far East and South Pacific Federation that ran concurrently with the Asian Association of Animal Production held in Hamilton. The branch introduced regular local newsletters during this time.

The 1990s

President: Mike Cundy (1988-92); John Foulds (1993-96); Alan Gibbins (from 1997)
Secretary/Treasurer: Laurie Prior (1985-93); Ashley Gibbs (from 1994)

Regional seminars were introduced as a means of serving (and boosting) the membership. Featured topics included poultry welfare (the anti-cage brigade were getting active) and food-borne microorganisms. These met a ready need and total attendance figures exceeded 450. A new-style newsletter was introduced as a result of Otto Moll, long-time WPSA stalwart from Australia, retiring to New Zealand and volunteering to be the editor. Self-supporting financially as a result of advertising 'donations', in due course this newsletter was distributed to all egg producers and broiler growers three times a year. Branch membership climbed to 202 by the end of 1991. In 1992 the Poultry Award was presented posthumously to John Howell's family on John's behalf. In 1993 it went to Mike Cundy and in 1994 to Laurie Prior who had served as both Secretary and Treasurer for over eight years.

The WPSA planned and actioned an exotic disease awareness exercise in Taranaki with buy-in from PIANZ (the Poultry Industry Association of NZ). Further activity by WPSA was required at this time, with Messrs Foulds, Cundy and Dennis O'Meara from Bromley Park taking the lead, to co-ordinate industry funding to ensure the viability of the poultry scientists' position at Massey. This post was filled initially by Leon Pijls and later on by Ravi Ravindran, of course.

Otto Moll handed over editorship of the newsletter to Neil Christensen in 1995. Sadly Otto died later that year, just before being awarded his place in the International Poultry Hall of Fame by the WPSA world body, a great honour indeed.

Kent Dietemeyer, Alan Gibbins and others including Les With had been actively pushing for the industry to take up the offer from AgITO to get a poultry training scheme going and their efforts came to fruition in 1996 with the first intake of students and its success grew from there. WPSA provided regular student sponsorship of $1000 a year to encourage participation by those unable to afford the course costs.

2000 to the present day

President: Alan Gibbins (1997-2004); Kent Dietmeyer (2005-

Secretary/Treasurer: Ashley Gibbs (1994-2002); Blake Camden (2003-4); Don Thomas and colleagues (from 2005)

The biennial NZ Poultry Industry Conference, organized by WPSA, which became a regular feature during the 90s, has continued ever since. It has moved around the regions over the years and together with the annual Massey Technical Update Seminars, has proved to be a great opportunity for people in the industry to get together and listen to presentations on recent developments. An obvious trend over the years, associated with our changing industry, has been a decrease in the number of farmer attendees at these meetings. Efforts were made during the 90s and again early in this century to boost the attendance of broiler growers but without great success. Focus turned more specifically to meeting the needs of technical service people in the industry with the expectation that they in turn would have an influence at farm level.

Worthy recipients of the NZ Poultry Award in recent years have included John Foulds, Bob Diprose, John Winter and, Sue and Trevor Clark. All readily met the yardstick ‘for meritorious service over and above the call of duty’.

Alan Gibbins handed over the Chair to current President Kent Dietemeyer in 2005 and subsequently Alan was elected as President of the Asia Pacific Federation of WPSA, reflecting his regular encouragement of sponsorship by the NZ Branch of visiting Pacific Island students to our meetings in New Zealand. Between 2005 and 2008 a series of very successful workshop were held on a variety of topics including coccidiosis, ethics and welfare, and the environmental impact of the poultry industry on its neighbours.

Enthusiasm for the AgITO industry training scheme continued, with significant additional support flowing through from EPF and especially key members of PIANZ.

CONCLUSIONS

Looking back over the last 50 years, there is no doubt that the membership of the NZ Branch of the Worlds Poultry Science Association has made a tangible contribution to the general development of the industry in New Zealand over this time. The WPSA has always focused on Education, Organisation and Research and it's clear even from the brief summary above that real contributions have been made in all these areas.

Further to that, these five decades have seen incredible improvements in bird performance and efficiency of production and this is no better exemplified than in looking at efficiency of feed conversion, because feed is clearly our biggest cost item. Through a combination of genetic selection, development of vaccines and understanding of biosecurity, and improved nutrition, housing and management, (in other words, application of poultry science), we can now produce here in New Zealand 1kg of eggs on around 2kg of feed, whereas in 1960 the comparable figure would have been close to 4 kg. As a consequence, eggs today are much lower in relative cost than they were in 1960, making them a very price-competitive source of great nutrition. The broiler industry, of course, can boast of comparable or even more impressive trends in efficiency and competitiveness. Poultry people from all around the world have contributed to these advances that our industry here has made but it would be good to think that the WPSA in New Zealand has also played its part. I for one think that it has.

NEW ZEALAND WPSA- CHALLENGES FOR THE FUTURE

JOHN FOULDS

The New Zealand Branch of WPSA was formed 50 years ago with a combined initiative from both poultry producers and the services industries. While strong support came from service industries, it was notable that in these early years there was a very strong representation from producers which was maintained until about 20 years ago. The organization in those early years had a strong egg production bias as the chicken meat industry was still relatively small while the egg industry had been through a strong growth phase associated with supplying egg products to Europe after World War 2 and was relatively mature, well structured for the economic climate and financially protected delivering good profitability at producer level.

In these years WPSA was quite active in meeting its charter and met the requirements of both producers and service industries according to its charter covering EDUCATION, ORGANIZATION and RESEARCH. These were the years of rapid improvements in all aspects of poultry production at producer level. Active research programmes covering Nutrition, Management and Disease control were being pursued in most countries and information was being widely distributed with WPSA taking a lead in initiating and supporting relevant conferences. It is interesting to also note that most of the research providers in these days were also very active members of the WPSA and provided a strong link between the producer and the research requirement. In New Zealand there was a strong Poultry Research Group at Massey University under Dr Rex Patchell who was also a WPSA member.

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The reorientation of the New Zealand economy in the 1980's coupled with both the growth of the chicken meat industry and a change in emphasis from production to a market orientation presented WPSA with new challenges and continues to do so. In addition farms have consolidated in size and the number of producers has declined enormously in the egg sector while only good growth has kept the number of producers in the chicken meat industry slowly increasing over a long term trend line. The number of service companies has also declined as has the number of marketing/distributing companies. These trends are reflected in WPSA membership which has seen the following % shifts in its different categories over the last 10 years.

Affiliates (companies)	-31.0%
Individual	-41.5%
Life	-58.3%

The Affiliate membership has fallen 20% in the numbers of poultry/feed producers while a fall of 37.5% has been seen in servicing industries company memberships. While it is difficult to separate the exact number of producers out of the Individual membership it is known to be small compared to company supported Individuals. In addition, the large number of chicken meat producers is very poorly represented in the membership. This presentation takes the above situation and offers a view of future roles which the NZWPSA can constructively play in our local industry.

MOVING THE NZ WPSA BRANCH FORWARD: REDRESSING THE BALANCE OF SCIENCE WITH HUSBANDRY

KENT DEITEMEYER

This conference is an important benchmark in our history as we celebrate our branch's 50th anniversary. For our membership, it is important for us to celebrate the legacy left by those who came before us, measure what we have done in more recent years, and prepare for the future. The latter is a rather more sobering exercise with what we will need to do to ensure the legacy we have today is honoured by building on the branch's continued service to the New Zealand poultry industry to support its sustainable future.

Thirty-two years ago, I held an evening workshop on poultry vaccination at the Brydon Hotel in Oamaru. There were thirty local poultry producers in attendance. It was a most memorable workshop as this was as keen of a group of poultrymen I had ever met. It was a time when there was considerable progress in the poultry vaccine field. These North Otago poultry producers listened intently and asked insightful questions well into the night.

Now, in 2010, not a single one of those farms exists in the Oamaru district and that base of skilled poultry husbandmen has since disappeared. This is an example of the major change we have experienced and reflective of the consolidation of the commercial egg industry around the country in the past three decades. Combined with the development of the broiler integrator sector and contract grower arrangements, we are left with the challenge of adapting our branch's activities to maintaining our relevance and contribution to the industry.

President, NZ Branch of the World's Poultry Science Association

New Zealand followed the global trend of agricultural universities overseas where poultry science departments lost their identity or even worse, disappeared completely. Even our extension services were terminated and never replaced. Fortunately, we came back with the AgricultureITO and established the successful national poultry training programme.

I believe we still have a major challenge ahead of us to re-invent the wheel and gear our WPSA branch for changing times and look towards fulfilling our role in terms of the WPSA mission of 'Education, Organization and Research'. It is time to look at our organization's activities in light of our resources of skills and experience and address how we will remain relevant and supportive for the poultry industry.

I believe we have one key area of concern: poultry husbandry is a skill that we risk losing if we are not more careful. When we changed the emphasis from poultry husbandry to poultry science, I feel we made a mistake that took us down a path where we inadvertently downgraded husbandry for the sake of all the promises science was going to deliver.

As an immunologist and a strong devotee of ethical applied science, I was fortunate to learn applied husbandry skills long ago working for years on a Colorado cattle ranch in the foothills of the Rocky Mountains where traditional husbandry skills still remain highly valued today…and probably much more valued by these old ranchers than my degree in animal science!

I take my hat off to these old high plains cattleman. They were my teachers who never strayed from the Ancient Contract where the principles of husbandry and animal welfare implore us to take care of our animals and in return, our animals will take care of us.

Those lessons in the art and philosophy of animal husbandry have stuck with me ever since.

I agree with my good friend Professor Bernie Rollin: the wise old cattle grazier of the high plains serves as a model of husbandry skills where the individual animal is still valued beyond its economic output.

My message today is about re-balancing science with husbandry. In my view, a sustainable poultry industry needs to keep a dual focus on the art of husbandry and adapt science to the requirements of tested principles of husbandry (and not other way around).

So, where do we go forward as a branch? Let's look at some of the factors and issues the industry faces today. The direction our branch should take is not always obvious with branch membership shrinking. Indeed our numbers in the industry have dropped off quite markedly in the past twenty years as poultry operations have consolidated or disappeared, folks laid off or many have retired or simply moved on. Some large companies who supply our poultry industry remain conspicuous by their absence in supporting a higher calling to the industry. Then there is another factor that many of us, including yours truly, are nearing our own sunset years thus begging the question: "Are we planning for the future or just going to waffle on and hope for the best?"

We remain active of course and highly conscious of the role that our WPSA branch plays in support of the New Zealand poultry industry. Many years ago, we were fortunate to have a forward-looking branch leadership who recognized we had a shrinking membership with changing interests and established a strategic direction to preserve the financial wellbeing of the branch to enable a sustainable and active organization for the future.

First of all, I am forever grateful to my predecessors for their vision and am pleased to say we have maintained our financial strength but we need to find a new momentum and continue to develop and direct our resources to programmes that will sustain the poultry industry.

We have already achieved a number of important missions that we set out to do to ensure we are going forward.

Taking on the challenge of establishing the national poultry training programme under the auspices of the Agriculture ITO and the Monogastric Research Unit at Massey, several of our branch members volunteered and were pivotal in getting the programme off the ground.

Those were tough days for some of us to attempt to persuade the industry to be more forward thinking. However, we persevered and I am happy to say that this all changed with Michael Brooks' chairmanship of the poultry training committee that enabled us to put the poultry training programme into high gear. We now have a very successful training programme with a large number of employees and growers coming through the AgITO system. As a branch, we contribute financially and our members remain very much involved.

Our branch took another important initiative to establish a workshop in the alternate years between our bi-annual conferences. Over the years we have organized and funded various workshops on such important topics and issues including coccidiosis, resource consents, poultry welfare and campylobacter.

Workshops are a WPSA branch function that I would personally like to see us reinforce in the future by increasing the frequency and relevancy of the workshop programme to reach out further to the poultry industry in manner similar to the poultry extension services of yore.

And finally, this bi-annual conference is where we place our greatest emphasis. It takes a considerable amount of effort on behalf of the organizing committee, speakers and the financial contribution of our sponsors to make the conference possible and function as a main event in the branch's work agenda.

But we feel we could do more. So, where do we go from here?

With a shrinking membership base, we need to focus on how we re-develop the branch's activities so that we ensure both the sustainability of our resources and have a pro-active programme following the WPSA's tenets of Education, Organization and Research.

I also believe there is still room to improve how we work together with the poultry producer associations so that we are maximizing the use of WPSA resources, our knowledge and skill base for the entire benefit of the NZ poultry industry.

I believe there are a number issues facing the industry where the WPSA could lend its resources to the industry.

Food Safety, Quality and the Consumer

This is all about consumer confidence in our poultry products. The recent re-call of salmonella-contaminated eggs in the United States is a stark reminder of how things can go wrong when the regulatory system is broken and operators ignore their responsibilities to the consumer and ignore good husbandry practices. Making the headlines in the New York Times with "Egg Farms Violated Safety Rules" is something none of us want to see. I want to ensure "that it can't happen here"…not because of serendipity, but because we are pro-active.

We had a campylobacter issue in NZ and paid a severe public relations price. But with an aggressive response from the NZ poultry industry, 'campy' has been significantly reduced and proved that these issues can be resolved with taking positive action.

The health and wealth of the NZ poultry industry will depend on having the consumer on our side by taking a very positive line on food safety and making sure our production systems are pro-active in taking steps to control food-borne pathogens will be important.

This is an area where I think the WPSA has a specific role to play in assisting the poultry industry in organizing extension service workshops to raise the level of importance food safety is to the consumer and help give our producers the understanding and the tools to not only comply with regulations, but promote the industry as exceeding its obligations to the consumer. Using contacts with food science departments, Massey's EpiCentre, ESR, etc there is a way for us to create a pro-active poultry extension institute as an outreach programme with the poultry industry associations.

Poultry Health

In terms of poultry health, New Zealand is certainly a 'Lucky Country' and we want to keep it that way. Our freedom from many poultry diseases gives us an economic, health and welfare advantage that is highly enviable and not to be taken for granted. Our poultry health status is something to cherish and maintain. But we cannot be complacent. There are a number of issues to be aware of in the poultry health field that is impacting us.

First, it's the consolidation of the animal health industry into a handful of very large players. Five companies are merging into two. This will have consequences yet to be determined as the dust is still settling on the extensive merger activity currently taking place. Will there be a new burst of activity in the poultry health field or will it just become a mere sideline for these large companies dominated by their human health divisions? Watch this space.

Secondly, in world terms, our poultry industry is rather modest and we are at the end of the spectrum in terms of market size to make it attractive for companies to enter the market or support us. For one thing, regulatory compliance has become far too expensive and onerous to justify veterinary product registrations where the volumes are just too small to justify the effort. For instance, we cannot take many of the common vaccine presentations so are restricted to special ordering some vaccines that are either very expensive to produce or there is no interest for manufacturing companies as the volume is just too small.

Thirdly, the veterinary vaccine industry has embraced biotechnology. Many technological barriers have been broken and we are seeing vaccines based on recombinant organisms. There are very good reasons for this trend: improved efficacy and safety. This "biotechnology train" already left the station and is roaring down the tracks and beginning to replace conventional vaccines in the poultry industry. It is something we all need to be aware of and we will have to "grasp this nettle" – from consumers, activists, government and to the industry.

Next is the threat of poultry imports where the New Zealand poultry market becomes a trading card in international trade negotiations. We have already seen what imports have done to the NZ pork industry from both an economic and disease status. Being thrown under the bus for the sake of another livestock industry's trade access raises serious ethical questions but jeopradises the risk of disease that we have jealously guarded ourselves against or eradicated after a great deal of effort and expense.

Finally, while we have very little poultry health research in New Zealand, we do need to be thinking of building up our applied poultry health resources. There are very few of us in this field and we need to be looking at the longer-term future of where our poultry health expertise will come from. Some of us that are active in this sector are not getting any younger and I see that this will become our Achilles' heel in maintaining a sustainable poultry industry.

I believe there is scope for the WPSA to look with the NZ poultry industry at ways we can encourage filling this gap. I see two possible ways: by contributing to a scholarship for a young veterinarian keen on poultry health or, as the NZ Pork Industry Board has done, create a position for an extension education technician that has a strong husbandry, health and nutrition background. I believe there is considerable need for such position and WPSA and its membership can help the poultry industry in bringing this into fruition.

Poultry Welfare

I do not think our poultry industry has any illusions about what our consumer society wants in terms of welfare and I am convinced the industry is moving as rapidly as economics will allow to meet welfare standards.

Poultry husbandry skills make the difference. I was reminded of this during last year's layer workshop in Auckland when our speaker pointed out there were more differences WITHIN each type of egg production system than there were between systems. It is NOT a question about traditional cages, enhanced cages, barns or free-range systems being automatically better than another production system…the difference was in the quality of our husbandry and how we practiced stewardship in taking good care of the animals in our care.

For me, there is an elephant in the room when we talk about welfare in the poultry industry.

What is missing in the poultry welfare equation in New Zealand is the full commitment of the entire supply chain's involvement in seeing that the poultry industry is enabled with the financial resources and educational base to meet society's expectations for optimal animal welfare.

Positive change will only happen once elements of the supply chain do not consider that marketing eggs is a 'zero sum' game where the producer runs at breakeven or is generating losses while on-farm margins are unilaterally shaved by the dictates of downstream distribution where eggs are sold as a loss leader or 'white labeled' eggs shove branded eggs off the shelf.

Such a situation does not optimize sustainable animal welfare. While we create layer and broiler codes, we are missing the economic elephant in the room that is holding the egg industry back from enhancing welfare by being able to keep up with investment requirements and fund an educational base to ensure we keep the science and husbandry skills in the industry.

I do not see where the WPSA can enable the resolution of this issue with the economics of the industry without the supermarkets climbing on board with us.

But we can support the poultry industry in any way that contributes to it achieving its welfare goals with continuing husbandry training, support of the AgITO training programme, organizing workshops or having a poultry institute.

I also believe we need to be talking to consumers and bringing them on our side with what we are doing in the poultry industry to ensure they have a high level of confidence in the quality, safety and welfare that we provide.

SUMMARY

From my perspective, I see our NZ Branch of the WPSA asking for a greater role in contributing to the poultry industry through an increased cooperation with the existing associations and institutions towards supporting our producers at the coalface with a range of new extension services.

I hope this talk can be converted into an on-going discussion with the poultry industry associations to see how we can better co-operate in the form of a tangible partnership to see that the branch's considerable expertise and motivation can be harnessed better for the benefit of the New Zealand poultry industry.

I believe this is a natural step that will have a major impact on retaining the sustainability of our poultry producers.

As always, I am ready to help.

WPSA ACTIVITIES IN AUSTRALIA

JULIET R ROBERTS

THE INTERNATIONAL ORGANISATION

The World's Poultry Science Association commenced with the foundation of the International Association of Poultry Instructors on July 18, 1912, making it one of "the oldest international societies in the world (Jasper, 1978 – WPSA President 1974-1978). Australia was represented at this very first meeting. The first World's Poultry Congress was held in The Hague, The Netherlands, in 1921 and the name "World's Poultry Science Association" (WPSA) was used from 1928. The first national branch of WPSA was established in 1946 and, at that time, the countries with the largest number of members were the U.S.A and U.K. In 1946, Australia had 2 affiliate members and 9 individual members. The Objectives of WPSA International are:

1. To promote the advancement of knowledge of all aspects of Poultry Science and the Poultry Industry.
2. To disseminate knowledge pertaining to all branches of the Poultry Industry and facilitate the exchange of such knowledge among people throughout the world having an interest in the industry.
3. To encourage the promotion of World Poultry Congresses and Regional Poultry Conferences.
4. To co-operate with other international organizations in achieving these aims.

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THE WPSA AUSTRALIAN BRANCH

The Australian Branch of WPSA was established in 1956, 10 years after the formation of national branches. In 1956, Australia had 11 affiliate members and 60 individual members with another 56 individual members joining in 1957. By the time WPC was held in Sydney in 1962, the Australian Branch had 28 affiliate members and 458 individual members. Sub-branches were established in all states of Australia, with three sub-branches in NSW. The objects of the Branch which were approved in 1956-7 were:

1. To facilitate and to promote the exchange of knowledge in all fields of the Poultry Industry in accordance with Article II of the WPSA.
2. To expand membership of the WPSA.
3. To promote the holding of meetings of members of the Branch for discussions on scientific and practical problems of interest to the Poultry Industry.
4. To assist in Australia's participation at World's Poultry Congresses.

WPSA AUSTRALIAN BRANCH AWARDS

The Australian Branch of WPSA has given two main awards. Many of the recipients of these awards will be known to people in the poultry industry.

Australian Poultry Award

The Australian Poultry Award is presented annually to an Australian resident who has made a long-term outstanding contribution to poultry science and/or the Australian poultry industry. The Award takes the form of a suitably inscribed plaque which includes the winner's name, together with a framed citation. Nominations are called for early each year from the membership of WPSA, and completed nominations require to be forwarded to the Secretary of the Australian Branch no later than 31st July. The selection committee consists of the Australian Branch Management Committee of WPSA (10 members) as well as Award recipients from the previous 10 years who are still active in the Australian poultry Industry. Voting is by secret postal ballot, and if more than two candidates are nominated, a preferential voting system is used. The Award is made to the

winner at suitable forums where poultry industry people are gathered, such as the annual Australian Poultry Science Symposium, the biennial Poultry Information Exchange (PIX), and the triennial Australian Poultry Convention.

Recipients of the award are:

1964	Mr. A.O. Moll	1987	Mr. E. Rigney
1965	Dr. M.W. McDonald	1988	Mr. W. Shaw
1966	Professor R.B. Cumming	1989	Dr. H. Bray
1967	Mr. F. Skaller	1990	Dr. M. McKenzie
1968	Professor G.L. McClymont	1991	Professor D.J. Farrell
1969	Dr. S. Hunt	1992	Dr. B.L. Sheldon
1970	Dr. L. Hart	1993	Mr. R. Macindoe
1971	Mr. N. Milne	1994	Mr. B. Bartlett
1972	Mr. R. Morris	1995	Dr. R.A.E. Pym
1973	Mr. J. and Mr. R. Ingham	1996	Dr. E.E. Best
1974	Ms. S.J. Wilkins	1997	Mr. M. Peacock
1975	Professor C.G. Payne	1998	Professor D. Balnave
1976	Mr. W. Stanhope	1999	Dr. H. Westbury
1977	Professor B. Sinkovic	2000	Mr. L. Brajkovich
1978	Mr. J. Douglas	2001	Dr. R.J. Hughes
1979	Mr. D. Blackett	2002	Dr. T.M. Grimes
1980	Dr. A.F. Webster	2003	Dr. R. MacAlpine
1981	Mr. R. Fuge	2004	Professor M. Choct
1982	Dr. J.G. Fairbrother	2005	Professor P. Spradbrow
1983	Dr. R.K. Ryan	2006	Professor J. Roberts
1984	Mr. C. Donnelly	2007	Dr. V. Kite
1985	Dr. P. Gilchrist	2008	Mr. R. Horn
1986	Dr. C.A.W. Jackson	2009	Professor W. Bryden

Syd Wilkins Memorial Prize

The Syd Wilkins Memorial Fund was set up in 1983-84 by the Australian Branch of the World's Poultry Science Association (WPSA), with the active collaboration of the Poultry Husbandry Research Foundation (PHRF) as it was known at the time, with the help of a major opening donation from Allied Feeds. The purpose of the fund was to honour the many contributions of Syd Wilkins to the Australian poultry industry. The practical use of the Fund was to provide an award, called the WPSA Syd Wilkins Memorial Award, for outstanding work by young poultry scientists working in Australia. The first annual award was made in 1984 but the definition of young has been extended twice from the initial 30 years to 35 years.

Syd Wilkins received his tertiary education at Hawkesbury Agricultural College and developed a career as a Poultry Officer in the NSW Department of Agriculture, becoming its Senior Poultry Officer by the late 1950's. In the mid to late 1960's he transferred to Allied Feeds, where he remained as a Senior Executive of the Allied Mills Group until his untimely death in 1982. During all this time he was very active in the affairs of the WPSA Australian Branch, including a period as President.

Recipients of the award are:

1984	Jennifer York	1995	Sandra Sapats
1985	Ian Wallis	1996	Carmel Ruffolo/Chris Siastskas
1986	Tom Scott	1997	No Award
1987	No Award	1998	Wendy Muir
1988	Darren Shafren	1999	No Award
1989	No Award	2000	No Award
1990	Mingan Choct	2001	Andreas Kocher
1991	Kevin Sanderson	2002	No Award
1992	No Award	2003	No Award
1993	Zee Upton	2004	Kristy Weir
1994	No Award	2005	Megan Jolly

He was also elected as one of the Vice Presidents of WPSA world body in the 1970's, a position he still held on this death. He was actively involved in the conduct of the 1974 and 1978 World's Poultry Congresses in New Orleans and Rio de Janeiro. Syd Wilkins was also involved with the PHRF virtually from its beginning, and served many years as its Vice-President. He was the recipient of the Australian Poultry Award in 1974. Syd's career was contemporary with the application of the 20th century poultry technology revolution in Australia. In his own low-key and unassuming way he contributed very significantly to its progress.

The Syd Wilkins Memorial Prize has been discontinued.

THE WORLD'S POULTRY CONGRESS 2008

A highlight for the WPSA Australian Branch was the hosting of WPC2008 at the Brisbane Convention and Exhibition centre from 30 June to 4 July 2008. This was the second WPC held in Australian, following the 1962 WPC in Sydney. The following is taken from Dr. Bob Pym's report to the WPSA Australian Branch AGM in 2009. There were approximately 2300 participants from 82 countries at the Congress, which also included the following meetings: 6th Asian Pacific Poultry Health Conference (AP6), 4th International Ratite Science Symposium (4IRSS), 2008 Australian Poultry Information Exchange (PIX), Australian Poultry Pure Breeds Workshop and the Australian Turkey Federation Workshop. There were 600 oral presentations, which included 120 keynote and concurrent session invited speaker presentations, and 400 poster presentations. The Congress included a Youth Program with 60 participants from 30 countries; the Congress provided registration and accommodation as well as a four-day post-Congress tour of southern Queensland and northern New South Wales. In addition, 15 young scientists from developing countries participated in the Young Scientist program, which provided travel costs as well as registration and accommodation over the period of the Congress.

Many of the delegates were from developing countries which necessitated an active and effective fund raising program to support the attendance of a significant number of these. An important stream, culminating in a workshop on the final day, was associated with support for the development of a sustainable poultry industry in developing countries, and in impacting meaningfully on the burgeoning world food crisis through efficient small-scale family poultry production. There was good representation from groups involved globally in support for small-scale poultry production in developing countries, including FAO, INFPD, IRPC, WPSA, GTZ, DANIDA etc

The poultry trade exhibition which was held in the 5000m^2 exhibition hall adjacent to and under the same roof as the Convention Centre, included 220 exhibitor booths, with exhibitors from 20 countries. Interaction between Congress delegates and the trade exhibition was facilitated by the location of morning and afternoon teas as well as lunch box distribution in the exhibition area.

AUSTRALIAN POULTRY SCIENCE SYMPOSIUM

The WPSA Australian Branch co-sponsors the Australian Poultry Science Symposium which is held, usually annually, at the University of Sydney. This symposium is the premier poultry scientific meeting in Australia and always features invited international speakers. Immediately following the Symposium in February 2010, a Workshop "Improving poultry production in developing countries in SE Asia and the Pacific Region" was held in Sydney on February 3-5. This workshop was sponsored, in part, by the WPSA Australia Branch and was attended by 20 participants from Papua New Guinea, The Solomon Islands, Tonga and East Timor.

EDUCATIONAL ACTIVITIES

The WPSA Australian Branch regularly hosts visiting speakers for its sub-branches. For example, in 2010, Dr. Koen de Reu (Belgium, food safety) visited the South Australian sub-branch, Dr. Jan Dirk van der Klis (Netherlands, nutrition and gastrointestinal

physiology) visited the Queensland and New England sub-branches. WPSA Australian Branch, in combination with Mr. Martin Simmons of Outback Environmental Control (OEC), sponsored Mr Stanley Kaye (U.K., Poultry Consultant) to visit sub-branches in South Australia and New England to speak about ventilation and heating in broiler and layer sheds. WPSA Australian Branch would welcome the opportunity to combine with WPSA New Zealand Branch to invite international speakers to address WPSA members.

SCHOOLS PROJECT

The Queensland sub-branch of WPSA Australian Branch established a highly successful Schools Project in which schools participate. The project culminates with a Field Day at which students present the posters arising from their projects and prizes are awarded to the winners. The South Australian sub-branch has now established a similar project and there are plans to establish the project in the New England region of NSW. The Poultry CRC as well as government departments and industry organizations provide valuable input, both financial and in-kind, to the schools project. It is hoped that the project can be extended to all states.

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ADVANCES AND FUTURE DIRECTIONS IN POULTRY NUTRITION

V.RAVINDRAN

INTRODUCTION

Poultry industry has advanced remarkably over the past 50 years. In particular, poultry meat production has undoubtedly been the most successful of any animal industry. Production standards of broilers and layers have continually improved over this period, with male broilers currently reaching a live weight of 2.5 kg at 33-35 d of age and white egg layers capable of producing 330 eggs in 52 weeks of lay. Genetic selection brought about by commercial breeding companies is responsible for bulk (85 – 90%) of the improvements in broiler growth and advances in nutritional management have provided 10-15% of the changes (Havenstein et al., 2003).

The need to achieve and sustain the improvements in genetic potential was the driving force behind the recent advances in poultry nutrition and, there had been continuous refinement in the nutrition and feeding of commercial poultry. Compiling an overview of the advances in nutrition over the past 50 years is a daunting task and beyond the scope of this presentation. In this paper, only the key advances in poultry nutrition are discussed under three main categories: (i) Understanding of nutrient metabolism and nutrient requirements, (ii) Quantification of the supply and availability of nutrients in raw materials, and (iii) Formulation of least-cost diets that bring nutrient requirements and nutrient supply together in an effective manner. The overall target is feeding to lower costs and maximise economic efficiency. In the past, there was a tendency to over-formulate diets when doubts exist on the availability of critical nutrients or if the nutrient requirements were uncertain. This practice of over-formulation is no longer acceptable because this is not only wasteful, but also excess nutrients are excreted in the manure and ultimately a source of pollution.

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MAJOR ADVANCES IN POULTRY NUTRITION

Defining nutrient requirements

A major challenge in defining the nutrient needs is the fact that they are influenced by a number of factors and are subject to constant changes. Nutrient requirements are influenced by two main factors, namely bird-related factors (genetics, sex and, type and stage of production) and external factors (thermal environment, stress, husbandry conditions). Precision in defining requirements involves accuracy at both these levels. Requirements of major nutrients for various classes of poultry are now available and these developments are made possible largely because of increasing uniformity of genotypes, housing and husbandry practices in the poultry industry.

Historically, the industry has utilised the nutrient requirements recommended in the publication by National research Council (NRC). The most recent publication on poultry was in 1994 and now 16 years old, which is a long period given the genetic advances that have made in both broilers and layers over this period. Currently the recommendations suggested by commercial breeding companies provide guidelines that closely match the requirements of modern bird strains than those recommended by NRC (1994).

Of all the dietary components, the most expensive and critical are essential amino acids and energy. Defining the requirements for the ten essential amino acids poses considerable degree of difficulty, but has been made easier by the acceptance of ideal protein concept. Like other nutrients, the requirements for amino acids are influenced by various factors, including genetics, sex, physiological status, environment and health status. However, most changes in amino acid requirements do not lead to changes in the relative proportion of the different amino acids. Thus the actual changes in amino acid requirements can be expressed in relation to a balanced protein or 'ideal protein'. The ideal protein concept uses lysine as the reference amino acid and the requirements for other essential amino acids are then set as a percentage (or ratio) of the lysine requirement. The ideal protein balance for meat chickens at different growth phases is shown in Table 1.

Table 1 Ideal amino acid ratios of meat chickens at three growth periods

Amino acid	1 to 21 days	22 to 42 days	43 to 56 days
Lysine[1]	100	100	100
Arginine	105	108	108
Histidine	35	35	35
Isoleucine	67	69	69
Leucine	109	109	109
Methionine + cysteine	72	72	72
Phenylalanine + tyrosine	105	105	105
Threonine	67	68.5	68.5
Tryptophan	16	17	17
Valine	77	80	80

[1] Recommended digestible lysine requirements for meat chickens during 1to 21 days, 22 to 42 days and 43 to 56 days are 1.070, 0.865 and 0.745%, respectively (Baker, 1996).

The advantage of this system is once the lysine requirements under a variety of conditions are determined, the needs of all other essential amino acids can be calculated. This approach has now become an accepted practice in the industry to set the amino acid specifications in feed formulations

Defining nutrient composition and ingredient quality:

The principal role of feed ingredients is to provide the nutrients that can be digested and utilised for productive functions by the bird. Over the years, enormous volume of data has been generated and compiled on the nutrient composition of raw materials. The variability that is inherent to each raw material is also recognised and such variability places pressure on precise feed formulations. Data on variation (or matrixes) are available for the main feed ingredients and applied in feed formulation packages to achieve better precision. A related development is the availability of rapid

tests, such as the near infrared reflectance (NIR) analysis, to predict gross nutrient composition and to access the variability in ingredient supplies on an on-going basis.

However, not all of the nutrients in ingredients are available for production purposes and a portion of nutrients are excreted undigested or not utilised. With advances in feed evaluation techniques, data have been accumulating on the availability of nutrients, especially of amino acids and phosphorus, for poultry. In the case of amino acids, a recent development had been the wider use of digestible amino acid concentrations, rather than total amino acid concentrations, in feed formulations (Ravindran et al., 1998; 2005; Bryden et al., 2009). The use of digestible amino acids is particularly relevant to situations where diet formulations consist of a range of poorly digestible ingredients. Formulating diets based on digestible amino acids makes it possible to increase the range and inclusion levels of alternative ingredients in poultry diets. In effect, this approach improves the precision of formulation, may lower feed cost and ensures more predictable bird performance.

The use of appropriate energy system is a critical issue because of the importance of energy to bird performance and diet cost. Despite its limitations, metabolisable energy (ME) has been the system of choice of describing available energy (NE) system, which is a refinement of the ME concept, has received attention from time to time. However, no real progress has been made in determining the NE of raw materials for poultry. In theory, NE will more closely describe the energy available in an ingredient for bird's metabolic functions and is more predictive of animal performance. It is, however, difficult to assay, costly and time consuming, and has limited use in the routine screening of ingredients. A research project is currently being funded by Australian Poultry CRC on NE determination, but to be acceptable to the commercial industry, formulations based on NE values should demonstrate an economic advantage over the current system.

Better feed formulation

Once the nutritional needs are defined, the next step is to match these needs using combinations of ingredients and supplements. The object of formulation is to derive a balanced diet that will provide appropriate quantities of available nutrients at least cost. Given the range of possible ingredients and nutrients involved, a large number of arithmetical calculations are needed to produce a least-cost diet.

Over the years, feed formulation has evolved from a simple balancing of few feedstuffs for limited number of nutrients to computer-aided linear programming systems. Currently newer systems of stochastic non-linear programme are becoming popular with the commercial availability of this formulation software. Because variability in ingredient composition is non-linear, stochastic programmes address this issue in the most cost-effective manner possible.

A related development is the use of growth models to simulate feed intake and production parameters under a given husbandry condition. Such models are effective tools to (i) compare actual versus potential performance, which can indicate the extent of management or health problems in the flock, and (ii) provide economic analysis of alternative feeding regimens. It must be noted, however, the models are only as good as the datasets used to develop them.

Feed additives

Feed additives are products used in animal nutrition for purposes of improving the quality of feed and the quality of food from animal origin, or to improve the animals' performance and health, e.g. providing enhanced digestibility of the feed materials.

In-feed antibiotics have been thus far the most effective and successful additive used by the poultry industry. One could say that in-feed antibiotics are partly responsible for the performance efficiency currently enjoyed by the industry. However, the recent mandatory or voluntary removal of in-feed antibiotics from poultry diets, spurred by reports of potential antibiotic resistance in humans, is creating a major challenge. As discussed later, a number of alternatives are being tested and researched, but yet to be broadly accepted by the commercial industry.

The growth in acceptance of other feed additives in pig and poultry production over the last two decades has been an extraordinary development. Perhaps the most important additive to enter the animal feed market is exogenous feed enzymes, which have evolved from an undefined entity to a well-accepted tool to improve nutrient utilisation. The availability of glycanases (xylanases/ glucanases) in the 1990's has effectively overcome the anti-nutritive effects of non-starch polysaccharides (NSP) and enabled the increased use of viscous grains in poultry diets. Today, the use of these enzymes in wheat and barley-based poultry diets is routine. During the past decade, the use of another enzyme, microbial phytase, in poultry diets is on the increase, in response to concerns over phosphorus pollution from effluents from

intensive animal operations. Most recently, carbohydrase enzymes such as xylanases, amylases, and glucanases, as well as other exogenous enzymes such as proteases, are also gaining commercial relevance. Combinations of these enzymes have been shown to be effective even in maize-based diets (Cowieson, 2010), which contain low levels of NSP.

The availability of crystalline amino acids is another major development and this additive has enabled the nutritionists to more precisely meet the ideal amino acid profile and, to improve the performance and yield of high-producing modern birds. Currently three crystalline amino acids, namely methionine, lysine and threonine, are available to the industry at competitive process. Valine and isoleucine are expected to become available in the near future and may allow further improvements in feed formulation.

Among the other additives, mycotoxin binders need special mention. The negative effects of mycotoxins have been known for many years. But until the 1990's, the only avenue of control was the use of clays such as bentonite. During the past two decades, the availability of more effective/ specific mycotoxin binders/ deactivators has substantially lowered the risk of compromised bird productivity.

With high-energy prices, there is recent interest in the use of digestion aids (emulsifiers) to improve the utilisation of fats by breaking up the fat into small, finely divided globules and increase the access for lipase action. In recent years, some effective emulsifiers, compared to the older versions (crude lecithin and phospholipids), have come into the market.

Feed processing

The progress in the technology of feed manufacture during the past 50 years represents a major and necessary development in improving bird performance. The technology has progressed from simple mixing of mash feed to pelleting, which involves various physical, chemical and thermal processing operations.

Currently, majority of the feed used in the production of broilers is fed in pelleted or crumbled form. Offering feed to poultry in pellet or crumbled form has improved the economics of production by improving feed efficiency and growth performance. These improvements are attributed to decreased feed wastage, higher nutrient density, reduced selective feeding, decreased time and energy spent for

eating, destruction of pathogenic organisms and, thermal modification of starch and protein.

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Phase feeding

Phase-feeding, a form precise-feeding, is another development during the past two decades. This is a feeding system in which dietary amino acid levels are reduced steadily over time in an attempt to reduce costs associated with excess dietary protein or amino acids. Commercial phase feeding programmes may include several phases to step down amino acids and other nutrients for broilers and layers. The number of phases to be implemented in production cycle is dictated by both economics and the practicability.

The wider implementation of phase/precise feeding, however, is limited by several issues:

- Data on ingredient variation and the reliability of matrix values need to be updated on continuous basis
- More data on digestible amino acids, at least in the major raw materials, are needed.
- Information is needed on the comparative digestibility of amino acids for different classes of chickens - layers and broilers of different age groups. In particular, it is known that digestibility of various nutrients and metabolisable energy during week 1 is lower compared to older birds (Thomas et al., 2008; Tancharoenrat et al., 2010).
- Information on metabolisable energy and digestible amino acid requirements for different classes of poultry is seriously lacking.
- Finally, it is unfortunate that we do not have objective rapid tests, which the industry can use to estimate metabolisable energy/ digestible amino acids as the raw materials are received at the feed mill.

FUTURE DIRECTIONS IN POULTRY NUTRITION

Future directions in poultry nutrition will be driven by on-going changes in world animal agriculture and by societal issues. Sometime in the future, we may have to modify feed formulations to accommodate not only science-based needs but also the needs of the society. The impact of social issues (in-feed antibiotics, environment, welfare, traceability, use of meat and bone meal, GM ingredients etc) will influence the decision-making from farm level to retail distribution of poultry products (Leeson, 2007).

Ban on in-feed antibiotics

The ban in the European Union and different degrees of voluntary withdrawal in other parts of the world on the use of in-feed antibiotics will put extra pressure on the gut health and general health of animals. Currently, there is increasing focus on alternatives to sustain good gut flora and gut health, and these include enzymes, probiotics, prebiotics, essential oils, botanicals and organic acids. In the last 10 years, these products have been widely tested and the evaluation will continue in the future. While most of these products are reported to mimic the effects of in-feed antibiotics on gut microflora, it is obvious none on their own will be able to replace antibiotics in terms of sustaining animal performance. It is possible that these alternatives may be more effective in combination rather than individually. However, to be accepted by the commercial industry, effects of these products must be demonstrated by improvements in animal performance, similar to that achieved with in-feed antibiotics.

In addition to these antibiotic replacers, a combination of nutritional and management strategies may be needed to promote gut health and good gut flora and these may include,

- Use of highly digestible pre-starter diets
- Use of lower dietary protein levels and better balance of amino acids
- Use of coarse particle size/ whole grain feeding to enhance gizzard development
- Maintenance of good litter quality
- Stocking density, improved climate control etc.

Gut integrity is equally important as good microflora balance. Intestinal integrity for commercial poultry can be defined as the maintenance of intestinal health to enable the expression of the full genetic potential for growth and yield, and to fully utilize the dietary nutrients. Normal flora plays an important role in maintaining gut structure, strengthening the gut mucosal barrier and protein metabolism of the gut. In situations where the profiles are shifted by pathogenic flora (e.g. clostridium, coliforms), there is significant damage to the mucosal layer and the barrier function. Coccidiosis is another major cause of poor gut integrity and an effective anti-coccidial programme must be in place. Raw material quality is another contributing factor for poor gut integrity. Substances (e.g. mycotoxins) or raw materials (e.g. fibrous feeds) that can irritate the gut must be closely monitored.

Sustainability

With increasing public interest over environment, the reduction of nutrient excretion in effluents from intensive animal operations has now become a major issue. Not long ago, when feeds were formulated, the main objective was how to supply the nutrients (nutrient input). Today there is much public concern about what comes out of the bird (nutrient output). Animal agriculture, including commercial poultry sector, clearly has a problem of releasing excess nutrients into the environment and it must assume ownership of its impact on environment, especially water quality.

From the nutrition point of view, the most obvious strategy is to feed the bird to match the requirement and to improve the efficiency of nutrient utilisation by the bird, which in turn will reduce nutrient load in the manure. Among the other possibilities to improve the nutrient utilisation efficiency, the use of feed enzymes is most promising.

Alternative raw materials

It is projected that the global demand for pig and poultry continue to increase over the next decade and such a growth will have a profound effect on demand for feed and raw materials. It is also becoming clear that the requirements for traditional raw materials, both energy and protein sources, cannot be met even with optimistic forecasts. The first strategy available to the industry is to evaluate potential new raw

materials**.** Once these are characterised, the next step is to examine ways to maximise their value by judicious use of additives such as feed enzymes, supplemental crystalline amino acids etc. Given that high fibre (and NSP) levels may be limiting nutrient availability in most of these ingredients, development of appropriate enzyme combinations targeting the fibre fraction (mannanases, cellulases) will be crucial.

New feed enzymes

In the future, there will be more pressure to extract every kcal of energy and every unit of nutrients. A combination of strategies has to be employed and exogenous feed enzymes will have a key role to play in maximising the release of nutrients. One can expect development of new enzyme products that are effective in range of diet formulations. There is evidence suggesting that preparations with multiple enzyme activities may provide a competitive strategy to improve nutrient utilization in poultry diets (Cowieson et al., 2006; Selle and Ravindran, 2007). Such enzyme cocktails, rather pure single enzymes, represent the next generation of feed enzymes. This is because feed ingredients are structurally exceedingly complex. In the 'native' stage, nutrients in raw materials are not isolated entities but exist as complexes with various linkages to protein, fat, fibre and other complex carbohydrates.

Advances in enzyme technology will continue and one can expect that better forms of enzymes will be developed in the future. The 'next-generation' enzymes will be close to being 'perfect', with high specific catalytic activity (per unit of protein), good thermostability, high activity under wide ranges of gut pH, resistance to proteolysis and good stability under ambient temperatures.

Basic research into barriers to digestion

Though broilers and layers are highly efficient in converting feed to food products among farm animals, still they excrete significant amounts of unutilised nutrients. For example, broilers lose almost 25-30% of ingested dry matter, 20-25% of gross energy, 30-50% of nitrogen and 45-55% of phosphorus intake in the manure. Thus there is considerable room to improve the efficiency of conversion of feed to animal products. Much of the inefficiency results from the presence of undesirable components and indigestibility of nutrients in the feed. For this reason, future nutritional research in poultry should focus on issues relating to identifying barriers to effective digestion and utilisation of nutrients, and approaches to improve feed utilisation. In this

endeavour, poultry nutritionists must combine their expertise with those of specialising in other biological sciences, including immunology, microbiology, histology and molecular biology.

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POULTRY HEALTH: PAST, PRESENT AND FUTURE.

DAVID MARKS

INTRODUCTION

In researching this topic I quickly discovered how difficult it would be.

Firstly would I look at poultry health diagnostics and the progression from more or less 'textbook' disease presentation and diagnosis approach through to an understanding and appreciation of more complex disease conditions, patterns and indeed clinical syndromes. This progression will necessitate a review of Koch's postulates and simple cause and effect through to a developing understanding of the interaction of the various disease agents and the environment and how that interaction is manipulated through flock management, the nutritional requirements (and interactions) for maintenance performance and health, the changes in genetic make up of the birds themselves and of course immunology.

The initial drivers of poultry health were a more 'pure approach' consisting of understanding the agent involved in a disease and then controlling it. The aim being to stop mortality.

Or could I look at emerging disease to give some insight of the future. However the problem with emerging diseases is that there has always been emerging diseases. Every major conference I have gone to since my graduating many many years ago has had a session on emerging disease. So emerging diseases reflect past present and future. No we even talk about re-emerging disease again a reflection on past present and future.

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The poultry health drivers we face currently face are more determined by welfare and zoonosis (food safety and public perception included) and biological performance. Of course we can't take our eyes off straight disease control.

My prediction for the future is that the drivers for poultry health will steadily move towards achieving a complex balance between animal welfare, economic imperatives, social and cultural interactions and sustainability.

Pasteur, Koch's Postulates and the 'birth' of Poultry Health.

Back in the 1850's Pasteur was asked to look at the reason why some wine turned sour. He of course discovered that there were things in the air called germs that caused the wine to go off. This progressed to Pasteur's publishing his 'germ theory' in the 1860's on the link between germs and disease. This theory largely discredited the beliefs at the time about spontaneous generation.

Robert Koch further developed this to show the link between specific germs and specific diseases. He developed a methodology that came to be known as Koch's postulates to show the causal link between a particular germ and a particular disease. This was tremendously important as it paved the way for control of specific diseases by using vaccines using those specific organisms and targeted chemical therapies.

We were able then to control the major poultry diseases that threatened the emerging poultry industry. We also learnt that with biosecurity and isolation we could actually separate our flocks from those organisms and also prevent disease. This is a lesson that needs to be re-learnt in the present and also I predict into the future.

Many would regard this as the 'Golden Age' of poultry science.

But of course life is never that simple.

Things never remain that 'simple' for long. Like many animal industries we found that when we started to push the boundaries with intensification, when we started to manipulate the bird's environment we started to see some strange things occurring. Things we couldn't explain by the simple elegance of Koch's postulates. We started to understand that biology is a wonderfully complex entity. This complexity we can exploit but it can also cause us grief.

There are diseases of complex aetiology that are largely due to our manipulation of the total environment (nutrition management genetics and in the case of infectious agent, exposure.). There are also disease complexes or syndromes that require a complex interaction of infectious agents.

We have learnt to manipulate poultry health by manipulating those components.

Leg health in broilers is an example. Leg health is a significant welfare and an obvious performance and economic issue. Birds with leg deformities and significant gait issues are in distress, probably pain and cannot compete in the shed. They will not grow and therefore are an economic burden. We don't want them.

Genetics play an obvious role in the development of leg health. To get a significant clinical picture you do need a fast growing bird. We as field technicians cannot alter that. But we can alter the expression of that genetic predisposition and therefore the type of clinical picture we see can be significantly influenced by our manipulation of nutrition and management and health.

Some diseases are complex by their interactions, as an example I will use swollen head syndrome and spiking mortality syndrome.

Food Safety

If there is one thing that characterises the present, it is probably food safety. Whilst strictly not a poultry health issue, the control of food safety organisms at the livestock level is about immunology and biosecurity. Again concepts intricate to the control of poultry disease.

Poultry Health and the Future

The future is a complex being and if predictions were easy then obviously I would be doing something else.

My predictions for the drivers of poultry health into the future would have to be towards achieving a complex balance between animal welfare, economic imperatives, social and cultural interactions and sustainability.

Sustainability is implicit in all of these parameters but is a fairly nebulous term that is poorly understood and widely interpreted and misinterpreted. In this context sustainability is as defined by the New Zealand Ministry for The Environment as "sustainability is about meeting the needs of today, without adversely impacting on the needs of tomorrow" and as such covers drivers such as environmental economic as well as social.

The current and continuing concern over genetic selection, the subsequent fast growth rates and the potential that has for predisposing poultry to adverse health effects on poultry health will continue to be an issue. The geneticists are giving us in the broiler field a day's growth and 1-3 points of feed conversion efficiency each year. This places considerable continuing physiological stress on the bird. The geneticists however are also selecting in a sustainable way taking into account the environments in which the birds will be housed, the pressures they are under and welfare parameters.

Environmental sustainability the effect of livestock industries on carbon footprints is an increasing concern. Over 30 % of direct green house emissions are from agriculture. .Studies have shown that the poultry meat industry and egg industry are well ahead of other livestock based industries when it comes to environmental measures of sustainability. A complex Life Cycle Analysis on livestock industries was commissioned by DEFRA and the work done through Cranefield University. Poultry meat and egg production fared very well on measurements of improvements made since 1998, GWP100 (a measure of global warming potential) eutrophication and acidification as well as direct emissions. So what does this have to do with poultry health, well a lot really.

The criteria use to look at the sustainability question were mortality FCR daily weight gain and reproductive rate (egg production in layers). So the more efficient the animal the greater its impact on sustainability. Poultry health and biological performance are intimately related. I see into the future sustainability being a driver for biological performance and thus poultry health as a driver of sustainability.

Social and cultural influences will become more important influences on poultry health. These influences include increasing awareness and demands on animal welfare as well as the appreciation of cultural and social differences in disease control and the development of disease as well. Ai is the classical example here in Asia and some other countries.

Past and Present Influences on the Future

Some disease agents use the past and the present to shape their own future. Marek's Disease epidemiology and evolution is the classical example here. Virulence with MD has evolved over the years due to the selection pressure we have put on the agent due to vaccination programmes. A more holistic approach is warranted.

50 YEARS OF SELECTION IN THE BROILER BREEDER INDUSTRY AND BEYOND

DOMINIC ELFICK

INTRODUCTION

Globally the broiler industry consumes approximately 410-million parent stock (PS) per year, the equivalent of an estimated 58 billion broilers. The US industry alone now generates over US$44 billion per year in retail sales (USDA). Although commercial broiler production started in the Delmarva Peninsula of the USA in the 1920's, improvement of these stocks by independent commercial companies did not take off until the 1940's and independent sales of these birds were unusual before the 1960's. Over the years selection for improved efficiency has been extremely successful. The cost of producing a pound of live chicken dropped from US$2.32 in 1934 to US$1.08 in 1960 down to US$0.45 in 2004 in today's money (USDA poultry yearbook, 2006).

Whilst within a flock, improvements in veterinary medicine, environmental control, nutrition, etc, have undoubtedly had dramatic impacts on bottom line performance, Havenstein (2003, Poultry Science, 82, 1500-1508) stated that his results "indicate that genetic selection brought about by commercial breeding companies has brought about 85 to 90% of the change that has occurred in broiler growth rate over the past 45 yr. Nutrition has provided 10 to 15% of the change."

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CHANGES IN SELECTION CRITERIA

In 1945 A&P organized the first of its "Chicken of Tomorrow" contests. Qualifying trials were conducted in 1946 and 1947 and the national finals held in 1948. For the finals, breeders submitted a case of 30 dozen hatching eggs to an Eastern Shore hatchery, where the eggs were hatched and the offspring fed until they were market weight and then slaughtered. Broilers were judged on several factors, including growth rate, feed conversion efficiency, and the amount of meat on breasts and drumsticks. Despite the fact that these contests were held only three times they enabled breeders such as Peterson, Vantress, Cobb, Hubbard, Pilch and Arbor Acres to make their names.

The initial breeders relied only on "mass selection", selection of the individual based on purely its own characteristics. The most important of these characteristics was weight and the original purpose of the majority of these birds was to grow faster to slaughter. Weight is a simple trait to select for; simply identify the heaviest males and females. It is also moderately heritable, with heritability estimates in the range 0.20 - 0.40 (20 - 40% of the trait is determined solely by the genes). This allowed very good progress to be made.

Over time selection criteria for broiler breeders has undergone an evolution, driven mainly be the market forces in play during the time period. As the industry became more integrated and consolidated it was no longer acceptable to look only at the growth of birds, the cost of growing a bird became more vital. Feed accounts for between 65 and 70% of the input cost for a broiler, therefore selection for feed efficiency became a must.

Negative correlations between growth and reproductive traits started to impact the ability of the breeders to produce chicks cost effectively and therefore selection procedures that took into account egg production and hatchability became important. With these negative correlations at play in most breeding company's selection objectives, mass selection was no longer an effective selection tool and the use of Selection Index theory, where information on family members was taken into account, became the norm.

As the major markets for chicken meat (US and Europe) matured in the Eighties and early Nineties, there was a shift from sales of eviscerated carcasses to tray pack, and so components of yield became more important than purely whole bird yield. This trend continued as the markets become more mature. Now there is even a shift from tray-pack fresh meat to more further-processed products, with an even greater emphasis on breast meat yield, in the most highly developed markets.

The major Westernized markets for chicken became increasingly focussed on the welfare of the birds and the safety of food during this period. With the increase in selection objectives required of the breeders, BLUP (Best Linear Unbiased Prediction) selection tools, which look that the individuals own and family performance along with an understanding of how traits relate to one another, were incorporated into selection programs. The variation in success of these implementations and the drive for more cost effective production drove the consolidation of the Primary industry, until by the late 2000's only three sizable breeding groups remained, Cobb-Vantress (with the Cobb, Avian, Sasso and Hybro brands), Aviagen (with the Ross, Arbor Acres, Lohmann Indian River and Peterson brands) and Groupe Grimaud (with the Hubbard and Grimaud Frere brands).

Today the history of the industry continues to influence selection criteria, with growth still important throughout the world. Associated with that, feed efficiency remains the highest priority. The ability to produce products with an economically credible number of eggs and chicks remains important, and becomes increasingly so as companies become more integrated. Meat yield of cuts and their fitness for purpose is also crucial to the continued success of the industry.

SUSTAINABILITY

Sustainability has become the watch word of the early twenty-first century and these welfare and environmental traits are becoming increasingly focussed upon. The way that this is often looked at is, "Is the individual bird fit for purpose and will the breeding program continue to be so, with increasingly scarce and costly resources?"

Accumulations of leg health issues, poor immune responses, high feed intake or high outputs of waste product are today not considered suitable for a long term sustainable breeding program, nor for the individuals that it produces.

When individuals are looked at in this way four very important issues are addressed:

1) Does this safe guard human health?

2) Does this ensure that the animal is bred with due regard to its health and welfare?

3) Does this further the financial success of the customer?

4) Does this improve the long term sustainability of the industry?

The publication of a report in the UK (AC0208, DEFRA, 2008) indicated that of all the meat producing livestock species; commercially raised broilers have the lowest green house gas (GHG) emissions per kg of meat produced. Genetic selection of broilers over the last 20 years has shown a reduction of GHG emission of around 25%, with this reduction predicted by the authors to continue for the next 20 years or so. Commercial geneticists feel that this is a very conservative estimate given the enhanced technologies available today and in the near future. Selection targets for efficiency, especially in feed conversion ratio and meat yield have driven this reduction, at the same time as reducing the wholesale price of high quality, healthy animal protein to the customer.

Many campaign groups and welfare orientated scientists have made claims as to the negative physiological health status of broiler chickens caused by commercial selection practices, discussing issues of leg defects, especially Tibial Dyschondroplasia, and ascites, amongst other syndromes. Some groups have gone as far as to recommend or campaign for the end of intensive broiler farming due to these issues. Whilst these claims may have been valid in the Nineteen Eighties, twenty years of continued focus on these areas, using advances in medical as well as genetic technologies, has reduced these issues to very low incidences on effectively run commercial production facilities. Whilst effective measurement of the reduction of these concerns is difficult large datasets, like those available from the Canadian Meat Inspection Service, indicate dramatic improvements in both the underlying genetic susceptibility of modern broilers to these issues, and an increased awareness as to the management requirements of these improved individuals.

Further research and development into new issues associated with welfare and sustainability are being implemented globally. Breeders respond to emerging trends as swiftly as they can. However due to the multiplication structure of the industry, there is a genetic lag of approximately five years from when the issue is first selected upon until the first effects of these selections can be seen. These improvements are often small at first, but act like compound interest to create dramatic change over time. For example, foot pad condition is currently perceived as one of the primary metrics of welfare in the newly released European Broiler Directive. Selection to both improve foot pad quality and reduce the incidence of the conditions that can lead to this condition, have been underway for some years, however due to genetic lag, there remains a requirement to manage birds effectively to improve paw condition whilst the genetic improvements make their way down the generational pyramid.

GLOBAL AWARENESS AND FUTURE TRENDS

In New Zealand and Australia, much like Europe and other developed markets, there is a drive to improve absolute bird performance, by maximising the use of current knowledge of environmental control, veterinary medicine, nutrition and so forth. By selecting pedigree individuals under close to ideal conditions, performance in these environments is maximised. Indeed the New Zealand poultry industry leads the world in many areas of broiler production with the highest growth rates and best feed efficiency, in part due to the lack of endemic poultry diseases in the country, but also due to attention to detail in all areas of poultry management.

The possibility of hitting biological barriers to improved performance has long been discussed, and yet due to the high levels of variation in the chicken genome these have yet to materialise. It has been theorised that Feed Conversion Ratios of less than 1:1 are possible and New Zealand will undoubtedly be the first to see if this is true on a commercial scale. There remain many parts of the chicken that have yet to benefit from direct selection, so further tailoring of selection lines to suit novel markets for the future remains a real possibility.

Whilst per capita consumption of chicken is generally highest in the developed, Western world. The absolute volumes of chicken production are shifting to more emerging markets, with Asia being the prime growth area. Whilst energy and feed costs remain high and with the increasing price of land and other resources, it is likely that many commercially produced chickens will remain growing under less than ideal environmental and disease conditions for the foreseeable future. Indeed there are indications that even in developed markets the increased costs over recent years have squeezed margins to such an extent that ideal nutritional and management practices are sometimes reduced, in order to keep companies in business. Therefore it is crucial, that through the use of emerging genetic technologies and testing of existing populations under sub-optimal conditions, birds are selected to perform effectively under the varied production strategies that they will be exposed to globally.

FUTURE POTENTIAL

With the publication of the full chicken genome (Nature, Dec 2004) the inclusion of genomic technologies into commercial poultry breeding programs has come a step closer to reality, with all the current primary breeding groups investing heavily into these areas. It is unlikely that the use of transgenic technologies (artificially moving genes from one individual or species to another, or removing genes) will be acceptable to the majority of consumers world-wide at present, so the focus is very much on the understanding of the function and effect of genes already present in the breeding populations. This knowledge will be used to select more efficiently and effectively for traits of economic importance. The traits that will benefit the most from these technologies are likely to be the ones for sustainability, as these are traits often difficult or destructive to measure in a traditional breeding structure.

CONCLUSIONS

In developed nations the percentage of house hold income spent on food can be as low as 7.4% (USA) however in less developed countries this can be over 50% (India and Philippines). The improvement of chicken production efficiency over the last 50 years, coupled with many other agricultural advances, has helped bring high quality, low fat animal protein within reach of all but the very poorest of individuals worldwide. Continued advances in genetics as well as the other associated improvements in optimisation of broiler production will bring chicken within the budget of all.

Whilst reducing the absolute cost of a kilogram of chicken, further improvements in sustainability will be seen within the industry, both on the individual bird basis of improved health and well being, but also on a global scale, by the most effective use of precious resources and reduced waste products. Whilst there remains the possibility of a biological barrier to further genetic improvement some time in the future, this seems unlikely to happen in the majority of the world in the next 20 years.

PAST PROGRESS IN LAYER GENETICS, PREDICTED ADVANCES AND CHALLENGES

JOEL PENDUFF

It is an honour for ISA to be present at the New Zealand WPSA Conference on the occasion of its 50th Anniversary, and we thank you all for your participation. I will try my best to explain my presentation in English, being a French citizen.

This presentation is about past progress in Layer Genetics, and predicted advances and challenges. First of all, last year, 2009, was the 200th anniversary of the birth of Charles Darwin. Darwin inspires our way of working today: 'Fittest animal genetics company = highest genetic progress'.

Our Company: ISA

Our company is ISA, Institut de Selection Animale, a Hendrix Genetics company which was created in 2006 by merging the activities of ISA France and Hendrix Poultry Breeders, Holland. In 2008, Hendrix Genetics, a family-owned company, purchased from NUTRECO the genetics activity of EURIBRID (Hybro Broilers, Hybrid Turkeys, Hypor Pigs). The Hybro Broiler was then sold to Cobb-Vantress and, since 2008, we have a formal cooperation with Cobb-Vantress with regard to genetics research and development.

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Today the Hendrix Genetics Company is present in 23 countries and has 1000 employees.

- Our head office is in Boxmeer, Holland
- Our different products, described by the six original brand names are: ISA, Shaver, Babcock, Hisex, Bovans and Dekalb. Within each brand we have one white layer, one brown layer, and two black layers (brown eggs).

A short history, of the six brand names

Our genetic family tree shows for each brand name and product when Genetic Selection started and the integration of all the brand names into the ISA Company. Each of the brands had special individuals behind them pioneering our industry, including for example Donald Shaver, the founder of the hugely successful Shaver brand.

We have many different facilities located throughout the world, most importantly our three R&D centers, in Canada, France and Holland. Genetics for the brown bird is developed in France, genetics for the white in Holland and we have replicates for both brown and white in Canada. We are also organized to deliver to all our markets and customers from those three countries for all our products.

Local Relationships and Bird Performance

Summarising our relationships in this part of the world:

Bromley Park Group in New Zealand with Shaver Brown, since 1972.

Baiada in Australia with ISA Brown, since 1992.

Ingham in Australia with Hisex Brown, since 1991.

We regard the current performance figures for Shaver Brown commercial layers in New Zealand as very impressive. They are the highest and consistently best results in the world, exceeding our Shaver Brown standard performance figures by at least 10 %.

Our Breeding Program

Explaining the hybridization program from Pure Line to commercial layers:

- One pure line bird produces 80 Grandparents, which produce 6,400 Parent breeders. In turn these will produce 550,000 commercial layers and these birds will then produce more than 180,000,000 eggs over their lifetime!!! Selection of our pure line birds is very important, to say the least!
- It is important to appreciate that the commercial layer of today comes from pure line stock of 2007. Today at pure line level we are preparing the commercial bird that our customers will be farming in 2013.

Egg Industry Trends

Some major trends are influencing the layer business throughout the world and as a breeding company we have to understand them and respond accordingly:

1. In many countries producers are having to or choosing to change to alternative systems (aviary, barn, free range).
2. There is more legal pressure or bans on bird treatments such as decombing, debeaking and detoeing.
3. The industry has to use reduced quantities of antibiotics or none at all.
4. Animal welfare considerations, such as force moulting, are an issue in many markets.
5. Consumer and public opinion has to be considered, with concerns regarding animal welfare and egg quality.

Other trends influencing genetics include segmentation in several markets between table eggs and egg processing (reaching 30 % in some countries), greater use of by-products as feed ingredients and an environmental message asking us to use less feed, less water and less energy. We also have to recognize that increasingly we will see longer cycles for both parent stock and commercial layers.

As a breeding company, we have to respond to all these trends. The breeding program has to develop the best birds to cater for current and new trends and meet the needs of different markets through:

- Selection
- New combinations
- Research projects with international Research Institutes and Universities.

In anticipation of predicted layer industry trends, we now keep our Pedigree and Pure lines in cycles of 100 weeks. This allows us to make the necessary further measurements and prepare the layer of the next generation to have high persistency in lay with good egg quality, even when kept longer than today. The main traits under selection with a specific focus are egg quality, livability, persistency in lay and egg weight curve.

The selection environment is important. We target 'optimum' conditions in the pure lines and 'field' conditions in recurrent tests in which we apply the different management conditions observed in various countries.

Genetic Gain

The genetic gain for egg numbers is an additional 2.3 eggs per year. Our typical commercial layer has gained 70 eggs between 1990 and 2008. By 2020, the commercial layer will produce around 500 eggs by 100 weeks of age.

Comparing past and predicted future performance, in 1970 they laid around 239 eggs with an FCR of 3.16 and an adult body weight of 2.49 kg. In 2020 we are targeting 500 eggs, an FCR of 2.02 or better (kg of feed per kg of eggs produced) and an adult body weight of 1.9 kg.

New Technologies

Hendrix Genetics and ISA are also working hard on new technologies. One of them, genomics selection, prepares the company and the product of the future. A 'bio-bank' has been created in France for the preparation and storage of all DNA samples of all breeding animals in the turkey, swine and layer programs. The bio bank is fully automated with robotic equipment to exclude human error. In the layer breeding program, genetic markers are developed and used to identify certain genes/traits. In the genomics research program conducted by Hendriks Genetics and ISA a 60,000 SNP ("snip") chip is being developed and analyzed. Correlations between the 60,000 SNP and performances traits in the field are calculated.

By using these genomics tools, more genetic progress can be made. The selection decisions can be made faster, inbreeding can be managed better and there will be more focus on difficult traits like disease resistance and bird behaviour.

CONCLUSIONS

ISA Company is "listening" to the present and future needs of the layer industry in the different markets of the world and is well prepared and organized to give "replies" and product solutions to the expected challenges in the layer industry.

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SUCCESS, SUSTAINABILITY, ETHICS, AND ANIMAL WELFARE

BERNARD E. ROLLIN

Changes in the poultry industry during the first half of the 20th century betokened the most monumental changes in the history of agriculture since the domestication of animals over 11,000 years ago—the rise of animal science or, as the textbooks put it, "the application of industrial methods to the production of animals." This major revolution, ushering in modern agriculture, was the result of a variety of converging factors rendering the change in production methods historically inevitable.

Industrialization of animal agriculture in the U.S. occurred for a variety of understandable and even laudable reasons that are worth recounting. When industrial agriculture began, roughly in the 1930s and 1940s,(although poultry was earlier—as early as 1915 in America and New Zealand), the U.S. was confronted with a variety of new challenges related to food. In the first place, the great economic Depression and Dust Bowl (severe drought) had soured many people on farming, and even more dramatically, had raised the specter of starvation for the American public for the first time in U.S. history. Vivid images of bread-lines and soup kitchens drove the desire to assure a plentitude of cheap food. By the late 1960's and 1970's, the U.S. had large-scale industrialized animal agriculture with much bigger units compared to Europe. Better jobs were to be found in cities, and rural people flocked to them in hopes of a better life, creating a potential shortage in agricultural labor.

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Correlative with the growth of cities and suburbs came encroachment on agricultural land for various forms of development, raising land prices and moving acreage once available for agriculture out of that pool. Many people who would otherwise have been happy with a slow, rural way of life were exposed to greater sophistication by virtue of military service in World War I and II, and thus were dissatisfied with an agrarian existence. Recall the song popular after World War I, “How ya gonna keep ‘em down on the farm after they’ve seen Paree?". Demographers predicted a precipitous and dramatic increase in population, which turned out to be accurate.

With the success of industrialization in new areas, notably Henry Ford’s application of the concept to the automobile, it was probably inevitable that the concepts of industrialization would be applied to agriculture. (Ford himself had already characterized slaughterhouses as “disassembly lines”). Thus was born an industrial approach to agriculture, with machines taking the place of labor. In this transition, human labor was replaced by machinery, in turn requiring large amounts of capital, farm units grew larger, eventuating in the mantra of the 1970’s “ get big or get out”. Agricultural research stressed producing cheap and plentiful food, and moved in unprecedented directions. With animals confined for efficiency and away from forage, much research was directed towards finding cheap sources of nutrition.

There is no question that industrial agriculture was wildly successful in realizing its goals, the production of large amounts of cheap and wholesome and plentiful food. In the case of chicken, industrial agriculture turned chicken into the most affordable source of meat protein from what had historically been a luxury food item reserved for special occasions or Sunday dinner. Herbert Hoover's famous promise of "a chicken in every pot," actually stolen from Henry the IV th and never said by Hoover, though it appeared in his campaign literature, was an eloquent attestation to chicken as a luxury.

Yet the price of chicken became and remained eminently affordable thanks to industrialization. In 1951, whole chickens cost 60¢ a pound. Now, they cost $1.03 – if you want a whole chicken instead of a boneless chicken breast. But whole chickens would have cost $4.74 today if they followed inflation of other prices. In my own lifetime, I have seen the price of candy bars go from 5 cents to $1—an increase of 2000%! The price of whole chickens, on the other hand, has not even doubled. The incredible productivity of the poultry industry has led to the production of 10 to 11 billion broilers per annum in the U.S. alone.

There is thus no question of the great success of the poultry industry if success is judged by the criteria that were regnant during the period in which modern poultry production began. Chicken is plentiful, cheap, and accessible to all. Producers generate millions of birds under highly efficient conditions. Whereas it takes 8 pounds of feed to produce one pound of beef, generating a feed conversion ratio of 8:1, chicken is 2:1—one pound of meat produced for every two pounds of feed. Yet despite this astounding success, industrial agriculture, including poultry, is ever-increasingly subject to blistering criticisms, the most currently influential being the Pew Commission Report on Industrial Farm Animal Production, which raises major criticism of modern agriculture in the areas of human and animal health, loss of small agriculture and rural communities, animal welfare, and environmental despoliation.

Agricultural people see such recent criticisms as paradigmatic intrusion by urban ignoramuses into things they know nothing about, i.e. animal production. One often hears from farmers that the citizenry is spoiled, ungrateful, and needs to go hungry for a while to appreciate agriculture. In the United States this attitude results in a complete breakdown of communication between agricultural producers and the public that, rightly or wrongly, makes the rules by which they comport their business.

The most important misunderstanding on the part of agricultural producers is their failure to realize that the general public is operating from a platform of very different ethical values than is the producer community. Producers believe that if they continue to provide cheap and plentiful food for the general public, their moral obligations are fulfilled. Ever increasingly, however, the general public is importing

numerous other ethical considerations into their evaluations of modern agriculture. It is convenient within the context of this symposium to lump societal
ethical considerations under the rubric of "sustainability."

The most fundamental sense of "sustainability" is probably clear to all parties to the debate about modern agriculture. As children, many of us learned about balanced aquariums. If we wished to keep a fish tank where the fish lived and we didn't want to keep tinkering with it, we needed to assure that the system in question was as close to a "perpetual motion" machine as possible, a system that required little maintenance because all parts worked together. That meant including plants that produced oxygen and consumed carbon dioxide, enough light to nourish the plants, or rather plants that thrived in the available light source, water that was properly constituted chemically, scavengers to remove wastes, and soon. When such a system worked, it required minimal maintenance. If something were out of balance, plants and animals would die, and require constant replacement. The fish tank aims at being a balanced ecosystem, and thus represents a model of traditional approaches to cultivation of land and animals, wherein one sought to grow plants and animals that could be grown indefinitely with available resources, which conserved and maximized these resources, which would not die out or require constant enrichment. Hence the beauty of pastoral agriculture, where pasture nourished herbivores, and herbivores provided us with milk, meat, and leather, and their manure enriched the pasture land in a renewable cycle.

But this is in fact a very limited notion of sustainability. As I have pointed out elsewhere, sustainability not only means balancing outputs and resources, it also means *morally acceptable to the society in question.* To take a simple and trivial example, from the point of view of resources alone, slavery prior to the American Civil War provided for a very sustainable agricultural system for example in the production of cotton. Slaves provided the requisite manual labor, reproduced successfully so as to ensure a predictable supply of such labor, and earned via their labor far more than what it cost to preserve them. The only problem was, that slavery was not morally sustainable, being repugnant to a vast number of members of society. Similarly, confinement raising of veal calves has long revealed itself to be societally unacceptable on animal welfare grounds, leading the industry to institute massive change.

One, perhaps the most, striking example of lack of ethical sustainability in modern industrial animal production is exemplified in the issue of animal welfare. There is one monumental conceptual error that is omnipresent in the agricultural industry's discussions of animal welfare – an error of such magnitude that it trivializes the industry's responses to ever-increasing societal concerns about the treatment of agricultural animals. When one discusses farm animal welfare with industry groups or with the American Veterinary Medical Association, one finds the same response – animal welfare is solely a matter of "sound science".

Those of us serving on the Pew Commission, better known as the National Commission on Industrial Farm Animal Production, encountered this response regularly during our dealings with industry representatives. For example, one representative of the Pork Producers, testifying before the Commission, answered that while people in her industry were quite "nervous" about the Commission, their anxiety would be allayed were we to base all of our conclusions and recommendations on "sound science". Hoping to rectify the error in that comment, as well as educate the numerous industry representatives present, I responded to her as follows: "Madame, if we on the Commission were asking the question of <u>how</u> to raise swine in confinement, science could certainly answer that question for us. But that is <u>not</u> the question the Commission, or society, is asking. What we are asking is, <u>ought</u> we raise swine in confinement? And to this question, science is not relevant". Judging by her "huh", I assume I did not make my point.

Questions of animal welfare are at least partly "ought" questions, questions of ethical obligation. The concept of animal welfare is an ethical concept to which, once understood, science brings relevant data. When we ask about an animal's welfare, or about a person's welfare, we are asking about <u>what</u> we owe the animal, and to <u>what extent</u>. A document called the CAST report, first published by U.S. Agricultural scientists in the early 1980's, discussed animal welfare, and affirmed that the necessary and sufficient conditions for attributing positive welfare to an animal were represented by the animals' productivity. A productive animal enjoyed positive welfare; a non-productive animal enjoyed poor welfare (CAST, 1981).

This notion was fraught with many difficulties. First of all, productivity is an economic notion predicated of a whole operation; welfare is predicated of individual animals. An operation, such as caged laying hens may be quite profitable if the cages are severely over crowded yet the individual hens do not enjoy good welfare. Second, as we shall see, equating productivity and welfare is, to some significant extent, legitimate under traditional animal husbandry conditions, where the producer does well if and only if the animals do well, and square pegs, as it were, are fitted into square holes with as little friction as possible . Under industrial conditions, however, animals do not naturally fit in the niche or environment in which they are kept, and are subjected to "technological sanders" that allow for producers to force square pegs into round holes – antibiotics, feed additives, hormones, air handling systems – so the animals do not die and produce more and more kilograms of meat or milk. Without these technologies, the animals could not be productive.

The key point to recall here is that even if the CAST Report definition of animal welfare did not suffer from the difficulties we outlined, it is still an ethical concept. It essentially says "what we owe animals and to what extent is simply what it takes to get them to create profit". This in turn would imply that the animals are well-off if they have only food, water, and shelter, something the industry has sometimes asserted. Even in the early 80's, however, there were animal advocates and others who would take a very different ethical stance on what we owe farm animals. Indeed, the famous five freedoms articulated in Britain by the Farm Animal Welfare Council during the 1970's (even before the CAST Report) represents quite a different ethical view of what we owe animals, when it affirms that:

The welfare of an animal includes its physical and mental state and we consider that good animal welfare implies both fitness and a sense of well-being. Any animal kept by man, must at least, be protected from unnecessary suffering.

We believe that an animal's welfare, whether on farm, in transit, at market or at a place of slaughter should be considered in terms of **'five freedoms'** (see www.fawc.org.uk).

1. **Freedom from Hunger and Thirst** – by ready access to fresh water and a diet to maintain full health and vigor.
2. **Freedom from Discomfort –** by providing an appropriate environment including shelter and a comfortable resting area.
3. **Freedom from Pain, Injury or Disease** – by prevention or rapid diagnosis and treatment.
4. **Freedom to Express Normal Behavior** – by providing sufficient space, proper facilities and company of the animal's own kind.
5. **Freedom from Fear and Distress** – by ensuring conditions and treatment which avoid mental suffering.

Clearly, the two definitions contain very different notions of our moral obligation to animals (and there is an indefinite number of other definitions). Which is correct, of course, cannot be decided by gathering facts or doing experiments – indeed which ethical framework one adopts will in fact determine the shape of science studying animal welfare.

To clarify: suppose you hold the view that an animal is well-off when it is productive, as per the CAST Report. The role of your welfare science in this case will be to study what feed, bedding, temperature, etc. are most efficient at producing the most meat, milk, or eggs for the least money – much what animal and veterinary science does today. On the other hand, if you take the FAWC view of welfare, your efficiency will be constrained by the need to acknowledge the animal's natural behavior and mental state, and to assure that there is minimal pain, fear, distress and discomfort – not factors in the CAST view of welfare unless they have a negative impact on economic productivity. Thus, in a real sense, sound science does not determine your concept of welfare; rather, your concept of welfare determines what counts as sound science!

The failure to recognize the inescapable ethical component in the concept of animal welfare leads inexorably to those holding different ethical views talking past each other. Thus, producers ignore questions of animal pain, fear, distress, confinement, truncated mobility, bad air quality, social isolation, and impoverished environment unless any of these factors impact negatively on the "bottom line". Animal advocates, on the other hand, give such factors primacy, and are totally unimpressed with how efficient or productive the system may be. A major question obviously arises here. If the notion of animal welfare is inseparable from ethical components, and people's ethical stance on obligations to farm animals differ markedly across a highly diverse spectrum, whose ethic is to predominate and define, in law or regulation, what counts as "animal welfare"? The answer, of course, is that of society in general.

For virtually all of human history, animal agriculture was based foursquare in animal husbandry. Husbandry, derived from the old Norse word "hus/band," bonded to the household, meant taking great pains to put one's animals into the best possible environment one could find to meet their physical and psychological natures which, following Aristotle, I call *telos,* and then augmenting their ability to survive and thrive by providing them with food during famine, protection from predation, water during drought, medical attention, help in birthing, and so on. Thus traditional agriculture was roughly a fair contract between humans and animals, with both sides being better off in virtue of the relationship. Husbandry agriculture was about putting square pegs into square holes, round pegs into round holes, and creating as little friction as possible doing so. So powerful is the notion of husbandry, in fact, that when the Psalmist seeks a metaphor for God's ideal relationship to humans, he seizes upon the shepherd in the 23rd Psalm: 'The Lord is my shepherd; I shall not want; He maketh me to lie down in green pastures; He leadeth me beside still waters; He restoreth my soul'.

We wish no more from God than what the husbandman provides for his sheep. In husbandry, a producer did well if and only if the animals did well, so productivity was tied to welfare. No social ethic was thus needed to ensure proper animal treatment; only the anti-cruelty designed to deal with sadists and psychopaths was needed to augment husbandry. Self-interest virtually assured good treatment. The animals lived the life determined by their *telos.*

The modern, industrialized systems of agriculture – be they operative in producing chicken, pork, milk, or eggs -- no longer must meet or even respect the animals' natures or physical and psychological needs. With “technological sanders” – hormones, vaccines, antibiotics, air-handling systems, mechanization – we could force square pegs into round holes, and place animals into environments where they suffered in ways irrelevant to productivity. If a nineteenth century agriculturalist had tried to put 100,000 egg-laying hens in cages in a building, they all would have died of disease in a month; today such systems dominate.

With husbandry systems being as iconic as they are in the Western mind -- cows on pasture, pigs rooting on soft loam, chickens scratching in barn yards -- it is relatively easy to identify society's ethic of animal welfare. In the view of the average member of society, animals are well-off if and only if they are permitted to express their natural behavior as dictated by their *telos.* As the song goes, "fish gotta swim, birds gotta fly."

Does this mean that society expects a return en masse to pastoral agriculture? That is, of course, impossible if we are to feed a growing population at a cost that allows everyone to eat properly. But that does not mean that society will accept modern agriculture as currently constituted. What must occur in modern agriculture for it to be morally sustainable, is the vectoring in of meeting the animals'needs and natures into the design of modern systems, something which has not only not been done, but has not even been attempted until public concern and pressure threatened the existence of these systems; consider, for example, the mass rejection of gestation crates for pigs in the United States and Europe. Fortunately for the swine industry, welfare-friendly alternatives to sow stalls readily suggest themselves, in the form of pens and other group housing systems.

The challenge to the poultry industry is to find other socially acceptable alternatives to today's systems. In addition, the bruising and fracturing epidemic in the broiler industry is part of its having bred for a bird that reaches market growth in seven weeks, rather than the traditional 28 weeks. Also, reliance on massive amounts of antibiotics to control the negative effects of extreme crowding on bird health will no longer be tolerated as too, neither will the manure pollution of water and land. Nor will the cavalier attitude towards the welfare of individual animals resulting from their negligible economic value continue to be tolerated. All of these societal/ethical concerns are inimical to the industry's primary reliance on the values of efficiency and productivity. But, as I told the Animal Science Association during a recent speech, they should not see social concerns as a repudiation of their achievements, but rather as a challenge to add solutions to these concerns as part of the challenge of designing systems in today's world.

It is extremely wise for the industries to shoulder these burdens and clean up their own act before well-meaning but ignorant legislation is created by people who do not understand unintended consequences. An excellent example of this can be found in the US ban on horse slaughter. A well -intended movement directed against hurting an iconic animal has resulted in animals being turned loose in deserts and other hostile environments to die slow and prolonged deaths from starvation and dehydration. As I recently told 900 Cowboys at cattlemen's meeting, "cowboy up and deal with your issues before the public does via immutable legislative action."

THE ROLE OF ENFORCEMENT AND THE VETERINARY PROFESSION IN POULTRY'S SUSTAINABLE FUTURE

I.A.ROBERTSON

The notion of sustainability has evolved from simple strategies of maintaining renewable resources to a significantly politicized multidisciplinary and multifactorial issue involving an array of stakeholders with competing and conflicting interests. In the agricultural sector, sustainability encompasses global and national interests involving matters of food safety and supply, economic interests, and improved animal welfare. Amidst continued debates regarding whether industry or government lead development changes, there is increasing recognition of the need for collaboration to protect the interests of all stakeholders. Effective enforcement and innovative leadership by the veterinary profession will assist in future proofing the poultry industry by delivering a product and a process that is sustainable, humane, and trustworthy.

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INTRODUCTION

The biggest single global use of animals is as a source of food, and consumers increasingly want to know where their food has come from, and be reassured that their food has been produced using best practice animal welfare standards which naturally relates to concerns about both the animals interests and food safety for the human consumers.

Animal welfare is described as a multidisciplinary and multi-factorial issue. It is increasingly recognized by government, industry, and the public, that although animal welfare is not an issue in isolation, it remains a key component in any proposed solution to national and international issues regarding the environment, the economy, and matters of sustainability.

In spite of research illustrating that there is a disparity between the public's concerns regarding animal welfare and their purchasing decisions, it is nonetheless clearly evident that initiatives are constantly being implemented by stakeholders along the "farm to fork" process. Food labeling and traceability, international trade programs, legislative amendments, changes in supermarket policies, and debates on a range of topics from cage size and genetic modification, to the conflicts of interest for veterinary professionals, provide just a few examples which demonstrate developments in response to consumer concerns and related matters of sustainability.

Law has been described as a "house of words", and illustrates the importance of clarifying definitions of key terms from the outset.

DEFINING SUSTAINABILITY

The concept of sustainability occupies a prominent place in an increasing number of disciplinary, media, political, and consumer discussions. Originally, the concept of sustainability focused on strategies to maintain renewable resources in terms of production and consumption. Use of the term was broadened beyond a purely anthropocentric concern for human livelihood, to incorporate matters of conservation and preservation of animal species and ecosystems. As the concept of sustainability became politicized, the associated issues also increased. "Sustainability" expanded to incorporate discussions regarding matters such as distribution and benefit sharing between developed and developing countries; and different ecological, economical and social dimensions. Tools such as ecological footprinting and environmental accounting were also developed to measure sustainability.

Common definitions of "sustainability" reflect notions of management which avoid long-term depletion of natural resources. “Sustainable agriculture", as a subset of sustainability, requires a balance between social, economic and environmental goals, and is addressed in this paper. More specifically, this paper focuses on the animal welfare component of sustainable agriculture and provides perspectives on the role of enforcement law, and the veterinary profession, in future proofing a sustainable poultry industry.

THE LAW

Legislation is not a panacea for animal welfare issues but it must be a fundamental component of any proposed change or development because, as a prerequisite, all change, or proposals for change, must be "lawful".

Welfare not rights

As the name of the Act illustrates, the Animal Welfare Act is about animal “welfare” not animal “rights”. Not all animal interest groups are the same, and the terms “animal rights”, “activists”, and “animal welfare” have quite different meanings generically and in law, but misunderstandings about the distinctions is a frequent cause of confusion , contention, and/or bias.

Opinions regarding the role and treatment of animals obviously vary significantly. The law addresses animal “welfare” which provides a point of balance between the polarized views of purist inherent-value concepts versus those which view animals simply as a commodity to be used. Legislators have the task of balancing the multitude of opinions, and prioritising the competing and frequently conflicting interests of the many stakeholders involved in issues of animal welfare. It follows that animals are stakeholders who represent one, but not the only, group whose interests are to be represented. Subjective, emotive and anthropomorphic opinions clearly exist about how each stakeholder’s interests should be prioritized, and the democratic system provides an opportunity for each opinion to be expressed.

Legislative development

Consideration of existing and developing animal protection law across multiple legal jurisdictions exhibits progress from primarily animal "protection" to animal "welfare" law. There are broad similarities between jurisdictions which have contemporary animal welfare law. A hallmark of contemporary animal welfare legislation is the legal incorporation of the principles of "the five freedoms". Owners and/or persons in charge of animals have legal obligations described as "positive duties of care" to provide for the "physical, health, and behavioral needs" of animals in their care.

The positive duties of care require owners and/or persons in charge to provide animals with proper and sufficient food and water, adequate shelter, opportunity to display normal patterns of behavior, physical handling in a manner which minimizes the likelihood of unreasonable or unnecessary pain or distress, and protection from, and rapid diagnosis of, any significant injury or disease. Under the law, each need is considered, in each case, in light of what is appropriate to the species, environment, and circumstances of the animal.

Law is constantly evolving, and the New Zealand 2010 Animal Welfare Act Amendment Act which came into force in July 2010 is one such example. The amendment enables the court to set a minimum period of disqualification from owning an animal, and doubles pre-existing penalties for animal welfare offences. Additionally, the Legislature created a new offence of "reckless ill-treatment of an animal".

Case law illustrates that in circumstances where prosecution has been pursued in respect of animal welfare offences, defendants have submitted a variety of explanations in seeking to justify why the needs of animals in their care were not being met. While some of these factors have been viewed as matters relevant to sentencing, the courts have frequently emphasised that the overriding consideration is still the legal obligation of the owner and/or person in charge to provide for the animals in their care.

In *R v Dalmer* (2009) regarding animal welfare offences related to underfeeding of approximately 3500 sheep, Judge Neave stated "(it is) part and parcel of the nature of farming… that there needs to be consideration for all that the elements and the seasons and the economy can throw at you because you do have vulnerable animals in your care. They are entirely dependent upon the resources you provide for their survival and their welfare and that is one of the reasons behind the Animal Welfare Act itself".
Mr. Dalmer was convicted and penalties amounted to approximately $75,000.

in *MAF v. Peacock* Judge Rea in addressing circumstances where cows had not been adequately fed, said: "…The fact remains, Mr. Peacock, *that you were the man on the spot*. Your very job was to look after the stock. It was your responsibility both as the manager and under the law, to ensure that they were looked after and take whatever steps was required for you to do so….If you, at that time, considered that you were in a situation where the lack of resources was enforcing you to commit offences by not looking after these animals properly, *then it was up to you to do something about it* again, not only as the manager, but also because of your obligations under the law….It is easy at this stage to cast blame to others. The blame may well attached to others but it certainly does attach to you."

Each case naturally depends on its facts and applied law. The 2010 Animal Welfare Amendment Act provides improvements to animal welfare legislation by closing gaps for the minority of people for whom education and incentives do not provide sufficient motivation to comply with required animal welfare legal standards. While each case will obviously turn on the individual facts and circumstances; the Amendment enables the justice system to apply a penalty that is commensurate with the crime.

This has relevance for individuals and businesses who are directly, and indirectly, involved with animals. The legislative definition of an owner and "person in charge" is broad and "includes a person who has the animal in that person's possession or custody, or under that person's care, control, or supervision". It is frequently assumed in the first instance that this applies primarily to the immediate person in charge, but closer scrutiny and consideration illustrates that the definition has a wide ambit and, depending on the circumstances, may involve employees, animal service providers, contractors, and associated professionals including, for example, veterinarians.

Additionally, where there is evidence of a relationship of employment, agency, or management; principles of vicarious liability may be applicable. Vicarious liability has implications not just for the company or body corporate, but also for directors and "persons concerned in the management".

Prosecution is only part of enforcement

In legal terms, animals are classified as property, but describing animals simply as legal property similar to a chair in New Zealand, England, Wales, or any one of a number of jurisdictions which have contemporary animal welfare legislation, illustrates either an archaic or misinformed understanding of leading animal welfare law. Contemporary animal welfare legislation creates a form of “specialist property law” by recognizing the animate nature of animals that is distinct from inanimate objects as evidenced by the acknowledgment in legislation that animals, as animate property, experience pain and distress.

Although academic debates regarding the continued classification of animals as property are controversial and likely to continue, the fact remains that the law has historically demonstrated a clear focus and ability in protecting property. In turn, this means that in terms of *practical* protection of animals, and therefore practical benefit *for* animals, there are as many good legal arguments for retaining the property status as there are those who argue against it. Additionally, issues of animal welfare are frequently attached to significant national and international financial interests, so it should come as no surprise that these additional "property interests" should be protected under the "hammer" of the law. Animal protection law developed as a part of the process of balancing human and animal interests.

In 1822 one of the earliest advocates of animal protection law, MP Richard Martin, learnt two important lessons regarding enforcement. Firstly, legislation alone is not enough. It never is. The second lesson learned by Richard Martin almost 200 years ago, was that if legislation is to be effective, it must be adequately enforced.

Although there are those that consider "enforcement" as synonymous with "prosecution", the process of enforcement realistically encompasses much more than simply dragging alleged offenders to court and prosecuting them. Prosecution would more accurately be described as a segment, and ideally a "last resort", of enforcement. Addressing this matter, animal welfare lawyer Mike Radford has stated:

"It is simplistic to suggest, as is sometimes the case, that the effectiveness of animal protection legislation is to be assessed by the number of prosecutions which are brought before the courts. Indeed, prosecution is a reflection of failure in the sense that if regulation was working perfectly, there would be no need to prosecute. However, where there are serious or repeated contraventions, prosecution is clearly desirable, in part by way of punishment, but of equal if not more importance, as a means of safeguarding the animals concerned."

Those involved in enforcement are obliged to apply legal concepts of natural justice and, at the same time, be transparent and accountable for their decisions in the public policy arena demonstrating applied consideration to the wider impacts of their decisions.

The basics of the enforcement triangle illustrate that persuasion through education and the implementation of appropriate incentives is more efficient, and much more cost effective, for most people, than pursuing a prosecution.

Collaboration

The need to address consumer needs, practical economic considerations, resource limitations, and recognition of "common risks and interests", has prompted animal welfare initiatives which include the development of animal welfare plans, and projects aimed at encouraging collaboration, cooperation, and coordination between stakeholders in spite of current and future competing, and sometimes conflicting, interests.

The initiatives promote the idea of a partnership involving all those with animal welfare roles, working together to encourage voluntary compliance with animal welfare standards in the first instance, and secondly, where necessary, working together to ensure compliance through collaborative enforcement. Education, awareness and persuasion initiatives to drive desired behaviour change are provided by various government, industry, and nongovernment organizations. However, resource limitations and the lack of a cohesive "whole-of-system" approach are recognized as limiting the effectiveness of those these programs and initiatives.

Collaboration is promoted because no one organization can ensure animal welfare compliance on its own. In the spirit of promoted partnership, the objective is to ensure that all those involved with animal welfare, from corporates to individuals, are in possession of accurate information, have adequate support, and an understanding - and therefore the desire - to ensure that they personally and collectively take responsibility for the welfare of animals and the interests attached to them.

THE VETERINARIAN

Veterinarians, and the veterinary profession, are widely accepted as animal health experts by the public. Additionally, animal welfare legislation, across multiple jurisdictions, also commonly identifies veterinarians as experts in animal welfare matters. Leaders from the veterinary profession frequently comment on the role of the veterinary profession and make reference to what veterinarians "should" be doing in matters of animal welfare. Veterinarians have been promoted by the veterinary profession leaders as "animal health and welfare experts", correctly implying that welfare is something distinct and/or in addition to matters of animal health.

The involvement of veterinarians is frequently held out as a source of authoritative assurance when questions of animal welfare and/or lawful animal welfare practice are raised. Additionally, in circumstances where prosecution is pursued in respect of animal welfare offences, it is usual to find that a veterinarian has been, or should have been, involved. While most veterinarians are good-hearted individuals who genuinely care about the well-being of their clients and their patients, it stands to reason that veterinarians, like other professionals, vary in their professional abilities and attitudes. It also stands to reason that they are likely to be circumstances where there is a potential conflict of interest for the veterinarian between the animal's welfare, the client’s interests, or the veterinarian’s business interests.

The veterinarian's business interests can be broadly interpreted to include a wide range of circumstances from a veterinarian's personal clinical practice through to the veterinarian's engagement as an employee, agent, or consultant.

It follows that the existence, acknowledgment, and recognition of conflicts for the veterinarian by decision makers including the veterinary profession and courts, raises questions about potentially inaccurate assumptions that presume that the decisions and actions of every veterinary professional are always appropriate and/or lawful.

Although education and persuasion frequently results in understanding and consequent change on the part of most people, there are still those who change only after enforcement is instigated through court prosecution. Given the interests at stake, lawyers and organisations like MAF Enforcement are necessary to ensure that the interests of the many are not compromised by the unlawful actions of the few.

It is debateable whether every non-complying individual or corporate will be identified, but no one really wants to become the subject of an investigation, and common sense indicates that it is less trouble to comply than to face the stress, time and financial costs of criminal charges, lawyers, and court proceedings.

Recognition of potential conflicts of interest between an animal's welfare, the owner's interests and/or confidentiality, and veterinary business interests, has raised further questions about the evolving responsibilities, accountabilities, and liabilities of veterinarians. Does the farmer, producer, or employer contribute to this dilemma for the veterinarian? Sometimes, yes. However, in an environment where there is increasing risk of detection, and increased penalties then, on the basis that "prevention is *still* better than cure", it pays to ensure that all parties consistently, lawfully, and appropriately prioritise matters of animal welfare.

CONCLUSIONS

Future proofing a sustainable poultry industry involves more than resource management. Proactive leadership in industry requires collaborative development of law and its enforcement. It also requires its employees, its contractors, and especially its veterinary professionals, to be assisted, and compelled when necessary, to appropriately and lawfully prioritize issues of animal welfare.

These considerations constitute essential ingredients that result and deliverables that are not only sustainable from the perspective of resources, but are demonstratably humane and trustworthy as well.

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Disclaimer

This article is intended for informational purposes, and should not be construed as giving legal advice. Readers with questions regarding specific and/or personal situations should contact their legal adviser for assistance.

EGG QUALITY AND FOOD SAFETY

JULIET R ROBERTS

SUMMARY

The hen's egg is a very safe, nutritious source of food. The egg has many antibacterial properties which are designed to protect it from microbial invasion, in order to protect the developing chick. Human consumers benefit from these properties. A strong intact egg shell provides excellent defence of the egg's contents against the ingress of bacteria. Therefore, eggshell quality and the safety of table eggs are closely related. Even minor defects in the egg shell may make it easier for bacteria to penetrate the egg.

INTRODUCTION

The egg of the domestic hen is an excellent source of food as has been known by humans and other animals for a long time. The biological role of the hen's egg is for the production of a new chicken. In this role, the egg has many properties which are designed to provide the developing chick with all the nutrients that it needs and to keep it safe from microorganisms which might enter into the egg. Hen eggs contain a range of antimicrobial properties and these same features also protect the consumer from bacterial contamination of table eggs.

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Although the Australian Egg Industry has not experienced problems with *Salmonella enteriditis, Salmonella typhimurium* does cause food-borne illness from time to time. Therefore, the industry needs to be vigilant in monitoring the presence of bacteria such as Salmonella in flocks and ensuring that egg contents do not become contaminated.

Egg shell quality is of primary importance to the egg industry worldwide. Egg shells need to be strong enough to remain intact throughout the chain from the time that the egg is laid until it is used by the consumer. In addition, a strong, intact shell helps to keep the contents of the egg safe from microbial contamination. Egg shell quality is also very important in breeder flocks as one of the factors affecting hatchability.

FORMATION OF THE HEN'S EGG

Understanding the process of egg shell formation helps us to understand the many variables contributing to the integrity of the egg shell of the hen's egg. The yolk and associated ovum is ovulated from the ovary and is captured by the infundibulum where it remains for about 15 minutes. It is here that the perivitelline membrane and chalazae form and fertilisation occurs in breeder birds. The egg then moves into the magnum where it remains for about 3 hours while the albumen proteins form. The layer of albumen proteins provides mechanical and antimicrobial protection for the yolk as well as functioning as the template for the later formation of the shell membranes and shell. From the magnum, the developing egg passes into the isthmus where the inner and outer shell membranes are laid down over about one hour. Next the egg enters the tubular shell gland where plumping occurs and the formation of the mammillary cores commences over a period of approximately 5 hours. The egg then enters the shell gland pouch where it remains for about 15 hours during which time the plumping process is completed and the egg shell is formed. Finally, the egg is laid via the vagina and cloaca.

The quality of the egg shell is influenced by all stages of formation from the production of the albumen, the laying down of the shell membranes and the adherence of the mammillary layer to the shell membranes to the final deposition of the cuticle (Solomon 1991).

STRUCTURE OF THE HEN'S EGG SHELL

The structure of the egg shell is complex. The organic matrix of the shell consists of the shell membranes, the mammillary cores, the shell matrix and the cuticle. Details of the composition of the organic matrix and its importance in egg shell formation have been elucidated in the past decade (Arias and Fernandez, 2001; Nakano *et al.*, 2002; Nys *et al.*, 1999, 2001). The inorganic portion of the shell consists of calcium carbonate with the crystals of calcium carbonate normally being in the form of calcite. The different layers of calcium carbonate making up the egg shell are, from the inside to the outside: the mammillary knob layer, palisade layer, surface crystal layer. The details of the fine structure of the egg shell are contained in Fraser and Bain (1994), Fraser *et al.,* (1999), Nys *et al.* (1999), Roberts and Brackpool (1993-4), Rodriguez-Navarro *et al.* (2002, 2007), Simons (1971) and Solomon (1991). In recent years, it has been demonstrated that it is the formation of the organic matrix that determines the rate of formation of the egg shell and controls the size, shape and orientation of the calcite crystals comprising the inorganic portion of the egg shell (Nys *et al.,* 2001) and the organic matrix also determines the termination of formation of the egg shell (Nys *et al,*. 2004). The stage of formation of the egg shell correlates with a particular composition of the uterine fluid which is secreted by the distal portion of the oviduct (Dominguez-Vera *et al.,* 2000; Fernandez *et al.*, 2003; Gautron *et al.,* 1997; Lavelin *et al.,* 2000; Nys *et al.,* 2004; Panheleux *et al.*, 1999). The structure of the egg shell needs to be not only strong enough to prevent premature breakage but also of the correct porosity in the case of hatching eggs to allow for normal embryonic development.

METHODS OF MEASURING EGG SHELL QUALITY

Egg shell quality may be measured, experimentally, in a number of ways: destructive and non-destructive, direct and indirect (the latter sometimes called mechanical and physical properties, respectively). Direct methods include measures of shell breaking strength such as impact fracture force, puncture force or quasi-static compression. Indirect means include specific gravity, non-destructive deformation, shell thickness and shell weight. In commercial operations, eggs are either candled using light to detect cracks and other defects or they pass through an electronic crack detector for detection of cracks. Experimentally, egg shell quality may be measured by a number of means and there is some equipment available commercially to assist with these measurements, such as the egg quality equipment produced by Technical Services and Supplies that is used in the author's laboratory and the egg testing equipment marketed by Sanova Engineering, Denmark. Similar equipment can be found in the Quality Assurance laboratories of large egg processing and grading operations.

The specific gravity of whole eggs can be measured by immersing eggs in salt solutions of different specific gravity or by using Archimedes principle. Shell colour may be determined visually or it may be measured by shell reflectivity under controlled conditions. The intactness of the shell cuticle can be measured by immersing the eggs in a special dye (blue-green in colour) and then measuring the extent of the colour with a handheld spectrophotometer. The measurement of shell breaking strength and shell deformation (either destructive or non-destructive) requires the use of special equipment. Shell breaking strength is most commonly measured by quasi-static compression where the egg is compressed under controlled conditions until the shell cracks or breaks. The minimum force required to cause failure of the shell is then recorded. Shell deformation may be non-destructive where the deflection of the shell under a given force is measured, or it may be destructive and measured as the distance the shell is compressed before it fails. The amount and thickness of the egg shell have been found to be related to egg shell strength. Shell weight may be measured by breaking open an egg, carefully rinsing

the pieces of shell, drying them, measuring shell weight and calculating it as a proportion of egg weight to give percentage shell. Shell thickness may be measured by a suitable gauge, either custom made (e.g. a gauge based on a Mitutoyo Model 2109-10 Dial Comparator Gauge as used in the author's laboratory) or commercially available from suppliers such as AMES, U.S.A.

The strength of an egg shell is determined not just by the amount of shell that is present, but also by the quality of construction of the shell. Studies of the quality of construction are conducted by examining the ultrastructure of the egg shell under the scanning electron microscope, as described by Solomon (1991). In circumstances where shell weight, percentage shell and shell thickness are good but shell breaking strength is relatively poor, the explanation probably lies with the shell ultrastructure, or how well the shell has been constructed.

Even minor defects in the ultrastructure of the egg shell can potentiate the entry of food borne pathogens into eggs (DeReu et al., 2006a, 2008; Bain et al., 2006).

METHODS OF MEASURING EGG INTERNAL QUALITY

The interior of the hen's egg consists of the yolk and the white or albumen. Egg internal quality is measured in several ways. A good quality egg should be free from internal blemishes such as blood spots, pigment spots and meat spots. Some commercial grading machinery allows for detection of these defects. Yolk quality is also a component of the internal quality of the egg. There are two components to yolk quality, the colour of the yolk and the strength of the perivitelline membrane which surrounds the yolk. If the perivitelline membrane is weak (as in an old egg), the yolk will break more easily (Kirunda and McKee, 2000). Yolk colour preference varies considerably depending on the part of the world and pigments of either natural or synthetic origin may be added to achieve a desired yolk colour. In Australia, the preferred yolk colour is about 11 on the Roche scale. However, other countries prefer darker or lighter yolk colour. Some countries such as Sweden do not allow the use of synthetic pigments.

The quality of the albumen is usually measured from the height of the albumen at a distance of 1cm from the edge of the yolk. Albumen height is usually converted into Haugh Units, based on the calculation of Haugh (1937). However, the validity of the Haugh Unit has been questioned (Silversides, 1994; Silversides and Villeneuve, 1994; Silversides and Scott, 2001) because it is influenced by the age and strain of bird and is affected by storage.

COMPOSITION OF ALBUMEN

Albumen height and Haugh Units measure the viscosity of the thick albumen. However, current problems in Australia with internal quality often involve a very low viscosity of the thin albumen. Egg albumen is about 12% protein of which the main ones are ovalbumin (54%), ovotransferrin (13%), ovomucoid (11%), α- and β-ovomucin (1.5-3.0%) and lysozyme (3.5%) (Johnson, 2000). All except lysozyme are glycoproteins. It is known that there are many minor proteins in albumen but few of these have been identified. Robinson (1987) and Li-Chan and Nakai (1989) provide a comprehensive review of the components of egg albumen and changes that occur during storage.

MICRORGANISMS OF CONCERN FOR FOOD SAFETY OF EGGS

The most problematic organisms causing food safety problems in eggs are the salmonellae and all salmonellae that are associated with poultry are members of a single genetically defined species, Salmonella enterica. The motile serotypes are often referred to as paratyphoid (PT) salmonellae and include S. enterica serotype Enteriditis and S. enterica serotype Typhimurium (usually abbreviated as S. enteritidis and S. typhimurium). The paratyphoid salmonellae are often asymptomatic in avian species, but can cause food-borne illness in humans (Gast, 2008). There are two possible routes of contamination of eggs with food borne pathogens. It appears that only S. enteriditis is able to contaminate eggs via the transovarian route where the bacterium is present in the

ovary or oviduct and from there transmitted into the egg contents. For most bacteria, contamination occurs through the pores of the egg shell (or via cracks or other defects). Sampling along the egg production chain permits an evaluation of the most likely sources of contamination of eggs (de Reu et al., 2005). The ability of bacteria on the outside of the egg to penetrate into the egg contents can be investigated by use of egg shells filled with agar medium (Messens et al., 2007).

ANTIMICROBIAL PROPERTIES OF EGGS

Eggs possess a range of antimicrobial properties, designed to protect the developing chick. The cuticle on the outside of the egg provides a mechanical barrier to bacterial ingress (Berrang et al., 1991) and its removal can increase the penetration of the eggshell by bacteria (Board et al., 1979). The eggshell itself provides a significant mechanical barrier to bacterial entry into the egg contents. The organic matrix of the egg shell and the shell membranes possess antimicrobial properties. Egg albumen is well known for its antimicrobial properties and the perivitelline membrane provides a mechanical barrier to the entry of bacteria into the egg yolk.

In some countries such as Australia, it has been argued that refrigeration of eggs leads to condensation of moisture on the eggs and that this may enhance the ingress of bacteria into the eggs. However, research conducted by De Reu and colleagues (De Reu *et al,* 2006b,c) has shown that this does not occur in intact eggs.

RECOMMENDATIONS FOR PREVENTION OF FOOD SAFETY PROBLEMS IN EGGS

Preventative measures to reduce the incidence of food borne pathogens in eggs include regular monitoring of layer flocks for identification of Salmonella serovars present (some countries eradicate positive flocks), use of salmonella-free feed where possible (pelleting has been shown to kill bacteria), maintenance of good egg shell quality, removal of faecal materials from eggs as quickly as possible, maintenance of eggs at refrigeration temperature throughout the production chain.

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CURRENT ISSUES IN BROILER BREEDER NUTRITION

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BROILER BREEDERS on DIETS!

In North America, dieting shows like *The Biggest Loser* (US) and *X-weighted* (Canada) consume the attention of large audiences. In *The Biggest Loser*, contestants compete for cash prizes by losing the most weight. *X-weighted* is more about inspiring people to stick to difficult lifestyle decisions that will lead to a healthier body weight. Deep down I think we would all agree that full-fed couch potatoes don't have the best welfare. Why would it be different for broiler breeders? Rather than focus on feed restriction as a bad thing, it's time to convince consumers that feed restriction is essential for animal welfare. The degree is debatable, but the principle is sound. The hatching egg industry's challenge is to manage the diet of the broiler breeder to ensure sustainability both in terms of reproductive efficiency and animal welfare.

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BACKGROUND: A CASCADE OF CHALLENGES

The ultimate goal of broiler breeder nutrition is to maximize the production of high quality broiler chicks that will grow quickly and efficiently, and yield well. Decades of selection for high growth rates, efficiency, and yield in broilers has had unintended consequences for parent stocks. Allowed to express their genetic potential for growth, broiler breeders lose physiological control of their ovary. Reproductive output from over-fed broiler breeders is seriously compromised, both in terms of chick numbers and quality. Welfare of overfed hens is also a problem. To optimize chick production, feed restriction is practiced. However, since there has been little change in the target body weight (BW) profiles of breeder hens, the degree of restriction is continually increasing. Because the feed resource is increasingly limited, competition is also increasing. More aggressive pullets out-compete more passive pullets in the feeding rush, leading to poor flock uniformity. Poor uniformity is difficult to manage because non-uniform birds have unequal nutrient requirements, and BW greatly affects the process of sexual maturation in response to photostimulation. Management of feed composition and delivery is critical for equitable feed consumption and flock uniformity. Feed management in terms of both feed composition and allocation will be discussed, both in terms of uniformity and carcass conformation. Recent research suggests that target growth curves can be rethought. Strategies for precision management of individuals within flocks will be presented.

FEED MANAGEMENT

Feed management includes two major concepts: feed composition and feed allocation, or rationing the quantity of the feed. The main objective is "*don't let the bird's metabolism know you have changed the feed allocation*". In other words, maintain a steady energy balance. Meet the maintenance and egg production requirements as closely as possible, with an ever-so-tight excess which the birds will partition toward growth. Avoid over-correcting feed allocations, which results in 'frog-feeding' or the 'bullwhip effect'.

Recommendations for feed allocation decisions are:

1. Use BW gain as an indicator of a bird's metabolic status. BW gain is a much more sensitive measure than BW of what is going on under the current feed allocation and growing conditions. One of the key aims in broiler breeder feeding is to maintain a steady positive energy balance so the birds grow the target amount every day.
2. Weigh birds frequently. The shorter the feedback loop, the quicker any required corrections can be applied, resulting in a much more stable pattern of growth.
3. Take the weather into consideration. Broiler breeders in relatively good condition take care of their maintenance and egg production requirements first. At room temperature, birds lose heat to their environment at a certain, predictable rate. As the temperature increases, that rate decreases, and until heat stress becomes an issue, the net result is a decrease in energy required to keep the body warm. Since ideal broiler breeder pullet feed allocations are very slightly above maintenance, small changes in environmental temperature substantially affect the amount of nutrients available for growth.

FEED COMPOSITION

Feed composition is a tricky question for broiler breeders. Of course, the ultimate goal is to match nutrient intake to nutrient requirements, but defining nutrient requirements is a tricky task. Given what is expected of broiler breeders, current recommendations for protein intake may be too high. The target growth rate for Ross 708 pullets from 4-16 wk of age is around 13 g/d. The protein requirement for this amount of growth is very low. There is also a maintenance requirement for amino acids, which are used for synthesizing proteins for metabolic processes and tissue turnover, but relatively speaking, the amount of protein required by broiler breeders is decreasing as the gap between the target growth rate and potential growth rate continues to increase. We recently conducted an experiment to determine the effects of dietary energy (2650, 2800, or 2950 kcal/kg) and

protein levels (14 or 16%) on pullet conformation. By photostimulation, birds fed the low protein diet showed a 7% reduction in breast muscle, and a 40% larger abdominal fatpad. Evidence from our research program suggests that high yielding strains need a fatter body conformation to sustain high rates of egg production. Though metabolic rate suffers with skip-a-day feeding programs, a similar body conformation change was observed in a recent trial where birds fed every other day had an 11% reduction in breast muscle and an 11% increase in abdominal fatpad compared to an every-day fed control group.

UNIFORMITY

High body weight uniformity is important because BW affects the timing of sexual maturation, and the onset of lay affects the nutrient requirements of breeders. Small pullets may not respond immediately to photostimulation because they must reach a threshold of BW and carcass fat content. Therefore it is critical to manage the broiler breeder feeding system to maximize uniformity. Recently, we conducted a trial to test the effect of feed restriction management strategies on flock uniformity. Compared to a BW coefficient of variation (CV) of 15.5% in the daily-fed controls, uniformity at 22 wk improved with scatter feeding (CV=10.9%; a pelleted form of the diet was spread on the litter, forcing birds to forage through the litter to find their feed), and skip-a-day feeding (CV=12.7%). Sorting birds into three equal sized categories improved uniformity to the largest extent (CV=6.2%). Though this is not practical in regions with high labour costs, we recommend that producers segregate only the smallest birds and feed them more until they become ‘more average’.

This can be done by providing more feeder space in an area where the smaller birds are placed, or by supplementing their feed allocation with extra feeders. Recent work at the Poultry Research Centre suggests that it is most economically beneficial to increase feed allocations to underweight birds.

AGE AT PHOTOSTIMULATION

Though not strictly a nutrition issue, photostimulation age is a very important consideration because sexual maturation and production status affect nutrient requirements. Photostimulation should occur when the entire flock is of adequate BW and fat content to enter puberty in response to photostimulation.

Though early egg production increases with early photostimulation, we have shown that settable egg production (eggs > 52 g) actually increased when photostimulation was delayed from 18 to 22 wk of age (Figure 1).

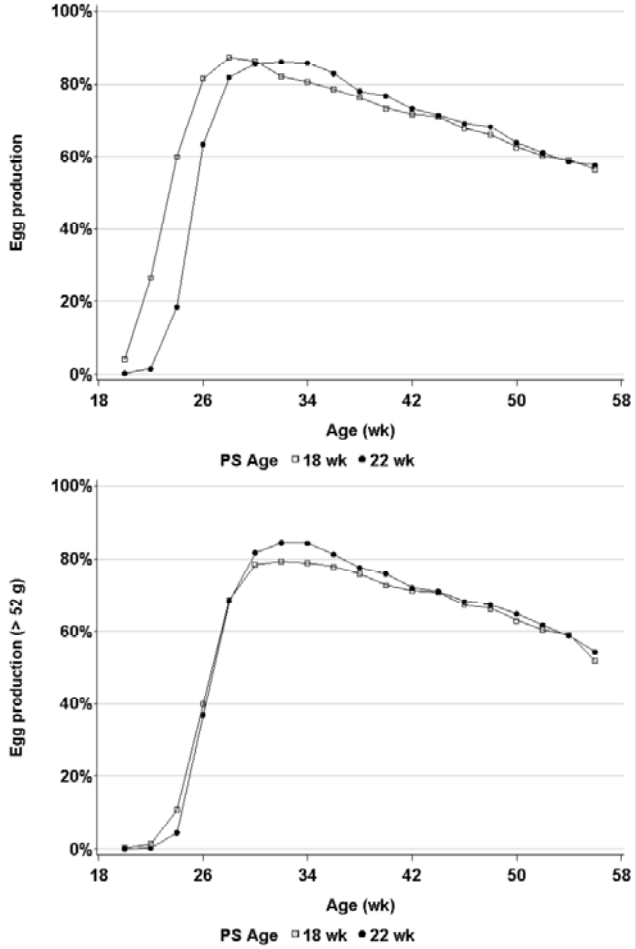


Figure 1. Total (upper panel) and settable egg production (lower panel) of birds photostimulated at 18 or 22 wk of age.

TARGET GROWTH CURVES

In the same study, we grew broiler breeders on 4 radically different BW curves that converged at 32 wk. The curves were: Standard: mean of breeder BW targets for strains used; Low: 12 wk BW target = 25% lower than Standard followed by rapid gain to 32 wk; Moderate: 12 wk BW target = 150% of Standard followed by lower rate of gain to 32 wk; and High: 12 wk BW target = 200% of Standard followed by minimal growth to 32 wk. With the exception of a high yield strain on the High BW curve, all treatments performed well in terms of egg production. This leads us to believe that there is considerable potential to manipulate BW curves in the future to address issues of welfare, carcass conformation, and early egg size.

ENVIRONMENTAL TEMPERATURE

As described previously, environmental temperature affects heat loss to the environment, and thus increasing environmental temperature in the range of 15 to 27°C decreases the maintenance metabolizable energy (ME) requirement of broiler breeders. Recent work in our laboratory indicated that the growth of a 1.3 kg pullet receiving the same amount of feed would be 15 g/d lower at 15°C than at 27°C. Once the maintenance energy needs are taken care of, 1 g of feed containing 2.8 kcal of ME will equate to approximately 3 g of BW gain in restricted fed pullets.

Heat stress conditions may exacerbate the problem of overfeeding protein. Excess amino acids relative to energy are deaminated, and the carbon skeletons are used as an energy source. This is an inefficient process, resulting in the release of heat. There is concern that broiler breeders receiving currently recommended levels of amino acids are at higher risk of heat-related mortality because of this.

THE FUTURE: PRECISION MANAGEMENT OF INDIVIDUALS

In our laboratory, we have been focusing more and more of our attention on the responses of individual broiler breeders to their environment and nutritional inputs. This has yielded insights that will be of great value for managing broiler breeder flocks in the future. One of the consoling trends we observed is that reproduction is a firmly entrenched biological priority.

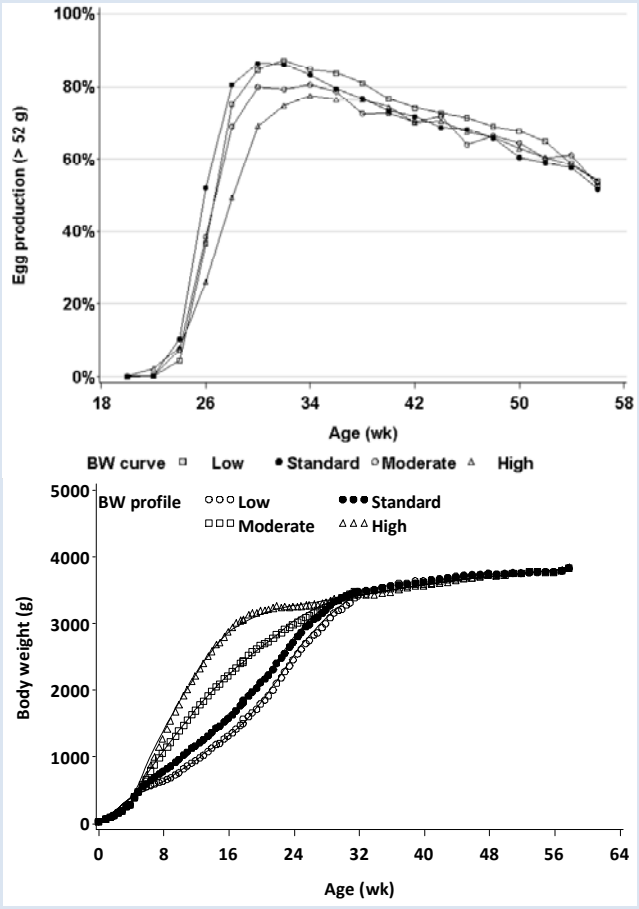


Figure 2. Settable egg production (upper panel) of birds grown on 4 BW profiles converging at 32 wk (lower panel).

In Figure 3, it is clear that the rate of BW gain drops around the time that egg production begins. There is clearly a biological shift in nutrient partitioning from growth to reproduction. Regardless of experimental treatments that have been applied, which range from BW profile to photostimulation age to strain to environmental temperature, this effect is highly persistent. This key biological priority suggests that BW profiles can be substantially altered with minimal impact on lifetime productivity. More research is needed to determine whether long-term increases in the BW profile (i.e. BW profiles that do not return to the current recommended target profile) are feasible.

Precision feeding of broiler breeders is still some time off, but a system that allocates feed to individual broiler breeders based on immediate feedback from individual body weights would be the ideal way to control weight gains, and to provide nutrients in quantities that precisely match nutrient requirement. Research on this concept has begun, and if successful, it will revolutionize the management of broiler breeders.

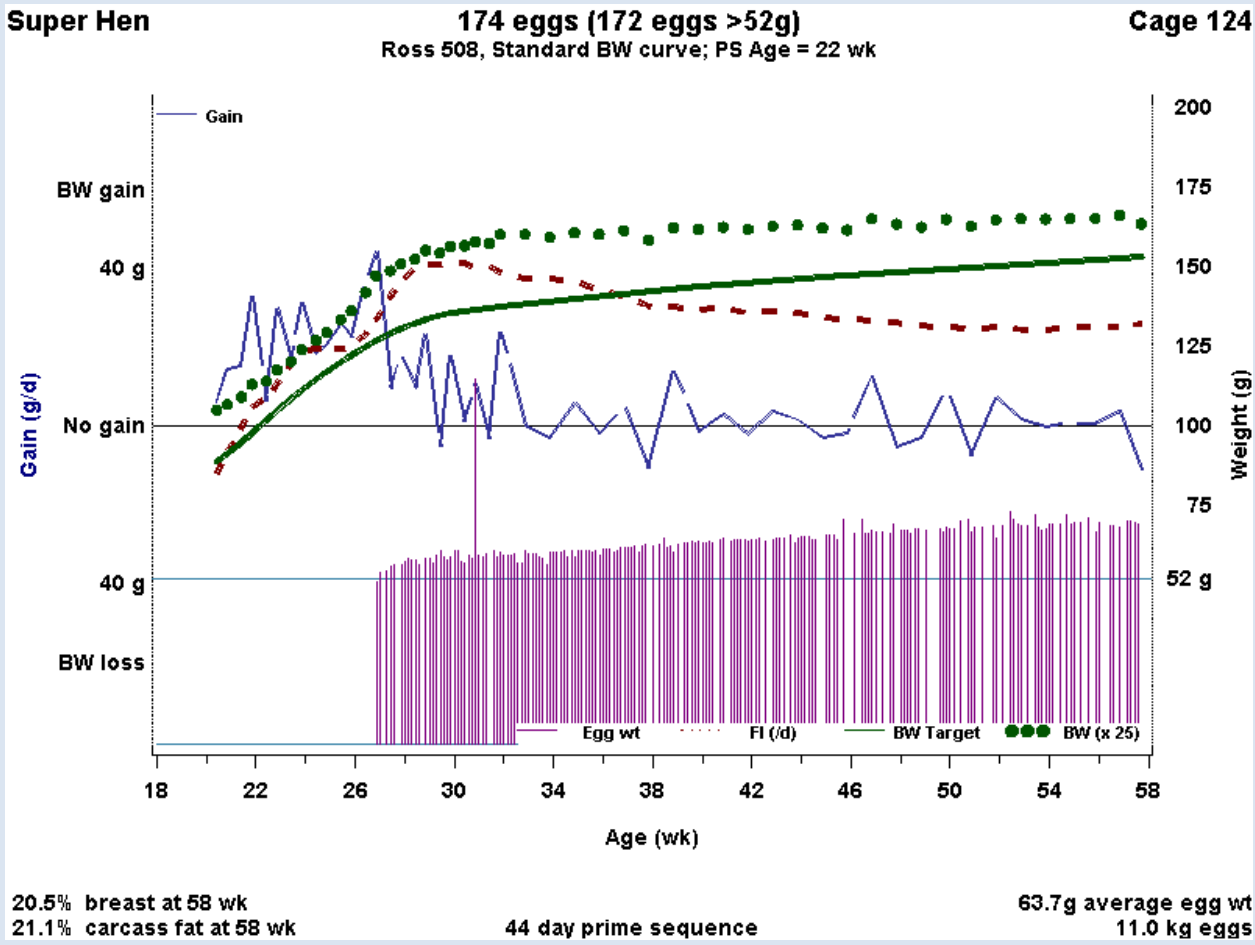


Figure 3. Analysis of individual hen records of performance has been instrumental in providing insights into individual responses to environmental and nutritional inputs.

CONCLUSIONS

Matching nutrient intake to the nutrient requirements of broiler breeders is a continuing challenge. More work needs to be done to determine how the changing genetic potential of broilers will in the future require manipulation of carcass composition of breeders to optimize chick production. We recommend allocating feed according to BW gains rather than BW, because BW gain is much more sensitive indicator of metabolic status. Feed broiler breeder so that their metabolism doesn't know you've made a change to their feeding level. This will be made more precise when temperature is considered. Consider sorting pullets according to BW to maximize BW uniformity. A labour saving way to achieve this is to visually identify small pullets when walking the barn, and place them in an area where the average feed allocation per bird is higher than for the rest of the flock.

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DISCOVERING NEW FRONTIERS IN GUT HEALTH – QUO VADIS AGP?

ANDREAS KOCHER

INTRODUCTION

The animal feed industry worldwide has been using antibiotics for over 50 years. To date antibiotics are widely used in farm animals at therapeutical levels to control actual disease and at subtherapeutical levels to promote growth and feed efficiency. Despite the fact that there is now an intensive debate on long-term sustainability of the use of antibiotics as growth promoters (AGPs) only a few countries have taken steps towards a complete ban of their use in animal production.

The most commonly used arguments in support of a total ban are the potential links between the use of antibiotics in animals and the occurrence of multi resistant bacteria in the human population. Possibly the most direct link between the use of AGP in animal production and the increase in resistance of human pathogen is the occurrence of vancomycin resistance enterococci (VRE) in hospitals and in the general population (Revington 2002). It has been established that the close relationship between a glycopeptide antibiotic used in animal production and the human antibiotic vancomycin has largely contributed to the rise and prevalence of vancomycin resistant enterococci. Other examples of potential links between the use of AGPs in animals and the potential threat to human health are the use of fluoroquinolones or macrolides, commonly used antibiotics to treat Campylobacter infections in people.

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It is postulated that the continued use or over-use of these compounds in animal feed will lead to increased selection pressure and subsequent transmission to human patients (WHO 2007). Despite this evidence, it remains debatable if a ban on the use of these AGPs in animal feed will actually be beneficial. Cox and Popken (2006) found that withdrawing antibiotics would significantly increase the illness rate in animals and as a result increase the risk to human health. The consequence would be an even greater demand for therapeutically use of antimicrobials to treat animal and human illness.

As a result of the uncertainty on the actual risk compared to the measurable benefits on the continuous use of AGPs, the debate on the future of antimicrobial growth promoters as become a more emotional rather than a scientific debate. This paper will attempt to discuss some of the factors which could influence the future use of AGPs in poultry production.

Why do we use AGPs?

The overall intention on the use of AGP's in poultry diets is clearly to improve animal performance. Ever since the first experiments over 60 years ago (Moore *et al.* 1946), antimicrobial components are used to improve the growth performance of animals as well as increase the overall net return in animal production. There are numerous studies in the literature which report significant improvements in bodyweight or feed conversion when AGPs are used. Reports on potential benefits of AGPs vary between 4-5% in weight gain and 3.5-4% in feed conversion ratio (Mordenti and Zaghini 1979) and (Centre for European Agricultural Studies 1991) cited in (Page 2003). However, more recent studies which investigated the potential losses after the withdrawal of AGPs found only a small decrease in performance 0.6% in weight gain and 0.8% in FCR (Graham *et al.* 2007) or no effect on weight gain and only a 2.3% increase in FCR (WHO 2003). Contradictory to the earlier studies Graham *et al.* (2007) concluded that despite the fact that the use of AGPs will increase broiler performance, using AGPs will result in a net loss to producers. It has to be pointed out that some of the benefits of using AGPs are difficult to capture in a simple economical analysis. Considering the increasing demand for feed for intensive animal production even a small reduction in FCR will have significant

implications on the overall availability of feedstuff for animal production and subsequently the cost of feed. Furthermore, it has been documented that the use of AGPs will lead to healthier animals, which will reduce the risk of contamination at processing as well as the potential risk of increased levels of foodborne pathogens entering the human food chain (Singer *et al.* 2007).

Although it is difficult to measure the BENEFIT of AGPs, it is equally difficult to predict the potential LOSSES as a result of a total ban of AGPs. Based on data from Holland it was estimated that the cost of intestinal disorders is in excess of €10 (Van der Klis 2010). As a result of the potential economical losses after the EU ban on AGPs, producers in the Netherland used increased amounts of therapeutic antibiotics to the extent that the total amount of antibiotics remained constant over the last 10 years (de Lange 2010). Despite the widespread use of AGPs and the general acknowledgment that AGPs have a positive impact on growth performance, the actual mode of action is still poorly understood.

Proposed mode of Action of AGPs in animals

The most common argument related to the mode of action of AGPs is the impact these compounds have on the intestinal microflora. This hypothesis is supported by the fact that most of the commonly used AGPs are not or very poorly absorbed after oral administration. Therefore it is concluded that their effect is predominantly on unwanted bacteria in the gastrointestinal tract.

The inhibitory effect of these compounds on growth and survival of bacteria is well documented (summarised in (Butaye *et al.* 2003; Page 2003). AGPs are predominately active against gram positive bacteria, however a number of studies did report against gram negative bacteria (Page 2003). However the fact that most of the current used AGPs are a mixture of various components makes it difficult to fully comprehend the impact of these antimicrobials on a diverse ecosystem.

The hypothesis that AGPs are directly targeting the intestinal microflora have stemmed from very early observations with germ-free chickens which showed reduced effects of antibiotics (penicillin) in the absence of an intestinal microflora (Coates *et al.* 1963). Based on this observation a number of authors postulated that AGPs reduce the competition for nutrients between the host and the microflora, reduce the load of pathogenic bacteria and reduce growth depressing metabolites,

which reduces nutrient availability to the host animal (Dibner and Richards 2005). This hypothesis assumes that at any stage in the life of an animal the microflora can be manipulated and directed towards a perceived optimal flora. It is curious to note that a number of authors attribute the growth promoting effect of antibiotic to a reduction in the abundance of lactobacilli and their metabolites and in turn this can contribute significant amounts of net energy to the animal as a result of changes in the bacterial carbohydrate metabolism (Gaskins 2002; Vervaeke *et al.* 1979).

The low inclusion level of growth promoting antibiotics, the wide varying classes of AGPs and with different spectrum and the significant changes in the microflora during growth and development challenges the theory of a direct anti-microbial effect of AGPs (Lu *et al.* 2008; Niewold 2007). These authors postulate that AGPs alter the inflammatory response and therefore reduce the impact of a too strong immune response and the associated waste of energy and nutrients.

One of the main arguments for a continuous use of AGP is the control of Necrotic enteritis (NE) caused proliferation and toxin production of some stains of *C. perfringens*. It is well known that mucosal damage caused by *Eimeria* infection can predispose birds to rapid proliferation of *C. perfringens*. The consequent of intestinal inflammation and mucosal damage would be the absorption of low molecular weight AGPs and an accumulation of these compounds in phagocytic inflammatory cells and that the changes in the microbial composition, and subsequently a reduction in pathogenic *C. perfringens*, is a consequence of altered immune status rather than a direct antimicrobial effect of AGPs (Niewold 2007).

Are there any credible alternatives to AGPs?

Together with a greater understanding of the mode of action of AGPs there is now an increase in the demand to find acceptable alternatives to AGPs. Despite the lack of strong scientific evidence, Sweden was the first country to implement a precautionary ban on the use of AGPs. A number of countries including the EU, Switzerland, South Korea and Bangladesh have since followed the Swedish example, whereas in other countries pressure from major retailers and consumers have led to a voluntary reduction in the use of AGPs. As a result research on alternative growth promoters have intensified over the past years, with a strong focus on finding a compound or

compounds which will have the same beneficial effects as AGPs in terms of growth promoting effect as well as disease control against NE for example.

The apparent lack of understanding of the true mode of action of AGPs and the lack of understanding what an ideal microflora is, has complicated the rapid emergence of credible alternative compounds. A recent update on alternatives of AGPs for broilers concludes that although some classes of alternatives have potential, there is also an urgent need to describe the mode of action in a more scientific way to meet standards and consistency set by AGPs (Huyghebaert *et al.* 2010).

Novel tools to defining gut health and the mode of action of feed additives

Classical nutritional studies which are commonly used involve a considerable number of individual animals and replication of treatments in order to establish statistical differences between individual treatments. Depending on the actual hypothesis nutritional studies require considerable time until a final conclusion can be drawn. The measured parameters are often closely interrelated; hence it is difficult to isolate the effect of specific dietary ingredients. The mapping of the genome of chickens have allowed for the development of microarray as a tool to research the effect of specific nutrients on functional gene network and regulatory pathways (International Chicken Genome Sequencing Consortium 2004; International Chicken Polymorphism Map Consortium 2004). Many changes seen at gene expression level within a specific organ or tissue are much more subtle than can be measured in animal growth and physiology. Nutrigenomics is the science which studies the relationship between nutrition, and the specific effects of nutritional additives on the response of genes. However, it is important to note that it is not always possible to directly correlate an increased present in mRNA in tissue samples, which is a reflection of the level of gene expression, phenotypic or protein changes in tissue (Moody 2001). Despite these limitations, Nutrigenomics offers a valuable screening tool to find expression patterns related to specific nutritional intervention which in turn could be used for a more scientific approach in the development of a growth promoter with equal efficacy to that of AGPs.

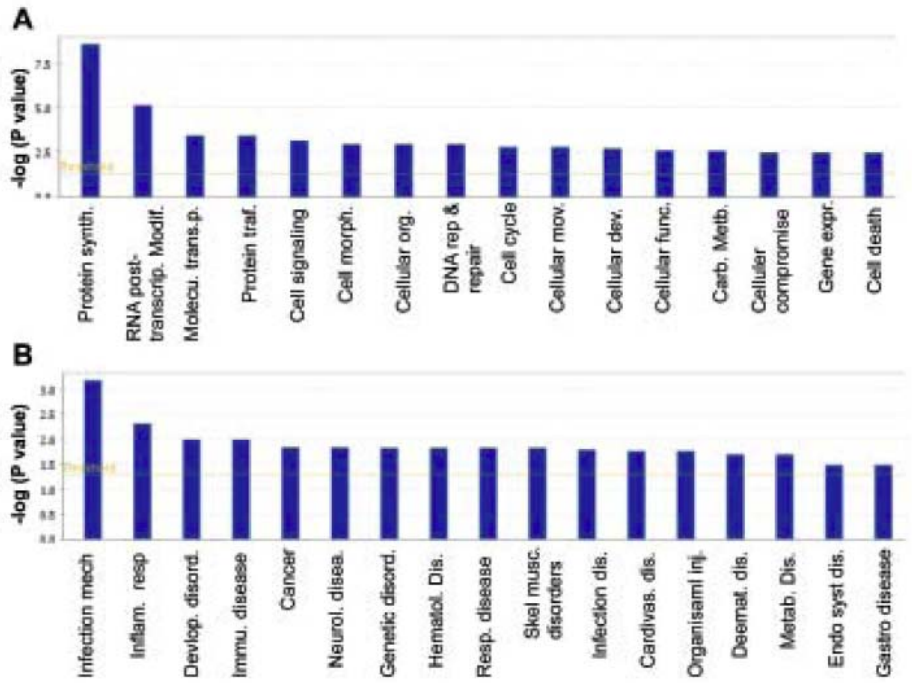
Nutrigenomics as a tool to finding an alternative to AGPs

Mannanoligosaccharides (MOS) and mannoprotein are one of the most widely studied alternative compounds to AGPs. Numerous publications have reported on aspects of their mode of action s well as their overall effect on the growth performance of production animals (Hooge 2004; Kocher 2006; Rosen 2007). The best known mode of action of MOS products is their ability to to inhibit pathogen colonisation by blocking the type-1 fimbriae which enables these pathogens to attach to the intestinal lining (Spring *et al.* 2000). More recent studies have investigated the changes in morphology, structure of the intestinal mucosa and changes in mucin production and composition (Chee 2009; Uni 2007). These studies suggest that the addition of mannanoligosaccharides reduce the bacterial colonisation and improve growth efficiency through a mechanism that alters structure and functional activities of tissue.

Until recently the identification of the composition and the structure of mannoprotein and mannanoligosaccharides in the cell wall has been hampered by the complex nature of the cell wall structure and its relative resistance to simple digestion and extraction. Yeast wall mannoproteins are typically highly glycosylated polypeptides, often 50-95% carbohydrate by weight that form extended structures on the exterior of the yeast cell wall (Lipke and Ovalle 1998). These structures are very similar to mannose-rich N-glycan chains associated with surface found mammalian cells. (Uni and Smirnov 2006) found that addition of a commercial MOS product (Bio-Mos) elevated gene expression of a number of brush border enzymes and transporters as well as increased the expression of the MUC2 gene, which is associated with mucin biosynthesis. These authors hypothesised that components found in the MOS product may interact with cell membrane lectins and affect intracellular signalling pathways. Furthermore it was found that a mannan-rich fraction isolated from the yeast cell altered the inflammatory response in macrophages (Singboottra *et al.* 2006). This process is likely to be mediated through (mediating) a transitory decrease in the expression of the toll-like receptor 4 (TLR-4), which binds to pathogen-associated molecular patterns stimulating NF-κB translocation from the cytoplasm to the nucleus where it activates genes encoding the inflammatory cytokines.

The combination of a better understanding of the structure of the yeast cell wall and the ability to separate specific components from the yeast cell wall together with the advances in the field of Nutrigenomics provide a powerful tool towards a scientific understanding of nutritional strategies for performance improvements and disease resistance.

Figure 1. Molecular and cellular functions (A) and diseases (B) associated with genes commonly regulated yeast cell wall factions



Early steps in this direction have been presented by (Xiao *et al.* 2010). This study looked at the molecular mechanisms comparison of two fractions from the yeast cell wall, a commercial product MOS (Bio-Mos) and a more specific carbohydrate fraction isolated from the yeast (Actigen). The study found that yeast cell wall fractions alter the expression of over 1500 genes in the jejunum of broilers compared to an unsupplemented control. In particular it was shown that genes related to pathogen defences were significantly induced whereas the expression of genes related to the inflammatory response were decreased (Figure 1 - above). These changes could

explain why these products have the potential to act in a similar way to AGPs which are currently in use.

Quo vadis AGPs?

Despite the lack of solid evidence on the negative impact on human health caused by the continues use of antimicrobial growth promoters, it is reasonable to expect that the increased pressure by consumer groups, supermarkets, the media and governments for a precautionary ban, will make it difficult to justify any increase in the use of these compounds. On the other hand, it is difficult to foresee that the poultry industry will agree to a voluntary ban of all AGP at this point in time. The main argument for the continued use of AGPs will be the lack of any credible – and more importantly - consistent alternative compound. Advances in the understanding of dietary interventions on disease resistance and production efficiencies as a result of developments in the field of Nutrigenomics will give scientists AND producers a more precise tool to differentiate and identify strategies to maximize not only animal performance but ultimately profitability. Whilst this science is still in its infancy, it can be expected that it ultimately will lead to the end on the use of AGPs.

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DETERMINATION OF AMINO ACID DIGESTIBILITY IN HEAT TREATED RAW MATERIALS BY EVONIK'S Aminored®

C. K. GIRISH, T. G. MADSEN, A. HELMBRECHT and M. REDSHAW

INTRODUCTION

Feed ingredients including soybean meal (SBM) and distiller's dried grain with solubles (DDGS) are subjected to heat treatment as a part of processing to destroy or reduce the anti-nutritional factors. The major concern about the anti-nutritional factors in the feedstuffs is their associated adverse effects on utilization of energy, amino acids and other critical nutrients affecting the performance of animal and poultry. These thermal processing methods, however also have negative effects on the amino acid contents and digestibility of raw materials if not processed properly. The destruction and loss of amino acids including lysine, cystine and arginine due to heat treatment was shown in SBM and DDGS (Fontaine et al., 2007). A significant reduction in digestibility of amino acids in DDGS to different heat treatment methods has been reported by Martinez-Amezcua and Parsons (2007). The alteration in the digestibility of all amino acids in DDGS and SBM were observed when heat treated at varying temperature and duration (Boucher et al. (2007a, b).

Parsons et al. (1992) showed that excessive heat treatment has a negative effect on total amino acid content, especially on the content of lysine which is referred as first or second limiting amino acid in most monogastric rations (Table 1). Excessive heat treatment not only decreased the total amino acid content but the digestibility was also affected to a greater degree compared to total amino acid contents. The contents of lysine and methionine were decreased by 16 and 10 %, respectively.

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Whereas the digestibility of both amino acids was decreased by 25 %, the effect on digestible amino acid content, the measure that is of true importance in formulation and ration calculations is thus partially additive with a decrease of 36 % in the case of digestible lysine and 31 % for methionine. This data indicates that although lysine is the most heat labile amino acid it is not the only amino acid affected by heat treatment. The objective of this paper is to evaluate the effect of excessive heat processing of SBM and DDGS on ileal amino acid digestibility in broiler chickens. An additional objective is to demonstrate the effect of feeding heat damaged SBM adjusted for amino acid digestibility using AMINORED® on performance of broiler chickens.

AMINORED® concept to predict SBM and DDGS quality

AMINORED® is a novel solution developed by Evonik Degussa to detect amino acid digestibility of feed ingredients which are thermally over processed. Detection of the amino acid digestibility is achieved through rapid NIR technology. This tool also allows for adjustment of amino acid digestibility depending on the degree of heat damage. The subsequent correction of the amino acid digestibility in the feed formulation prevents the risk of loosing animal performance. Total amino acid concentrations are usually estimated as one of the quality control program followed by application of standard digestibility co-efficient for each of amino acids. This is only used as an indication of the quantities of amino acids that are available to the animal. Thus formulating diets using table values for standardized ileal amino acid digestibility would overestimate the nutritional value of heat damaged ingredients which may result in reduced animal performance.

Table 1. Effects of heat treatment on amino acid content and digestibility of soybean meal in poultry (Adapted from Parsons et al., 1992).

Autoclaving time (minutes)	Content, %			
	Lysine	Methionine	Cystine	Threonine
0	3.27	0.7	0.71	1.89
20	2.95	0.66	0.71	1.92
40	2.76	0.63	0.71	1.87
	Digestibility, %			
0	91	82	86	84
20	78	69	86	86
40	69	62	83	80
	Digestible amino acid content, %			
0	2.98	0.57	0.61	1.59
20	2.30	0.46	0.61	1.65
40	1.90	0.39	0.59	1.50

The newly branded AMINORED® service predicts the effect of excessive heat damage within seconds during the normal analysis for proximate figures and amino acids. Because of the speed and cost advantages of AMINORED®, users can analyze not only suspicious raw material samples but actually they can implement the heat damage indication as a routine in their quality management system. This gives a much better position to identify low and high qualities of incoming raw materials. Additionally, the large number of sample information allows the purchasing department as well as the feed formulation department to differentiate processing quality by suppliers or even detecting variation of processing within one single crushing plant.

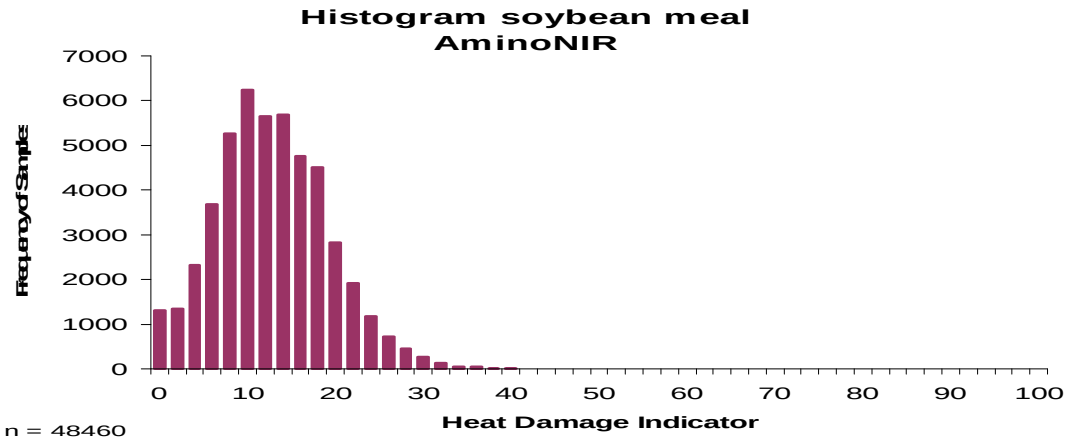
According to our current ranking the most typical soybean meal is represented by a HDI (Heat Damage Indicator) of 12. The reference value of 12 has been indentified as a standard in a series of close to 50,000 thousand samples (Figure 1).

Effect of excessive heat treatment on ileal amino acid digestibility of SBM and DDGS in broiler chickens

An experiment was conducted in the research facility of University Halle-Wittenberg, Germany, to evaluate the ileal amino acid digestibility of SBM (experiment 1) and DDGS (experiment 2) differing in pretreatment with heat.

Standard products of SBM, solvent extracted, and DDGS based on corn were purchased. Further, two batches of each standard product were treated at temperatures during the drying process. The first batch was obtained after 20 minutes ("20 min") and the second after 40 minutes ("40 min") autoclaving at 135 °C with steam. They were ground using a 3-mm sieve. All batches were produced by Deutsches Institut für Lebensmitteltechnik e.V., 49610 Quakenbrück, Germany.

Figure 1: Histogram for Heat Damaged Soybean Meal.



The contents of crude nutrients and amino acids for the different products of SBM and DDGS are summarized in Table 2. The crude protein (CP) content of SBM varied between 46.70 and 48.80 % which can be attributed to increasing dry matter content with increasing heat treatment, for DDGS the CP varied between 25.40 and 25.90 %. In both

products the contents of arginine and lysine were decreased with increasing time of heating from 20 to 40 min. Compared to SBM the decrease of these amino acids was higher in DDGS. Arginine and lysine were reduced by 36 and 42 %.

Table 2. Analyzed nutrient and amino acid content in SBM and DDGS without heat treatment (0 min) and after heat treatment with steam at 135°C for 20 minutes (20 min) or 40 minutes (40min), respectively

	Pure SBM			Pure DDGS		
Time of heat treatment	0 min	20 min	40 min	0 min	20 min	40 min
Nutrients in%:						
Dry matter	89.30	91.70	93.30	90.90	91.60	90.20
Crude ash	6.70	6.90	7.10	3.30	3.30	3.50
Crude protein	46.70	47.70	48.80	25.40	25.70	25.90
Crude fat	1.90	1.60	1.90	12.00	11.80	12.00
Crude fiber	5.60	5.70	6.00	6.50	6.70	6.60
Lysine	2.92	2.63	2.43	0.79	0.50	0.46
Methionine	0.63	0.67	0.69	0.52	0.50	0.51
Cystine	0.71	0.60	0.54	0.53	0.48	0.48
Methionine+Cystine	1.34	1.26	1.22	1.05	0.99	0.99
Threonine	1.87	1.97	2.06	0.98	0.95	0.96
Tryptophan	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Arginine	3.51	3.31	3.13	1.19	0.87	0.76
Isoleucine	2.18	2.29	2.34	0.92	0.90	0.91
Leucine	3.62	3.82	3.97	3.04	3.00	3.05
Valine	2.33	2.46	2.51	1.30	1.29	1.31
Histidine	1.28	1.32	1.36	0.78	0.73	0.72
Phenylalanine	2.47	2.59	2.69	1.23	1.21	1.23

Seven experimental diets were prepared for each experiment. The basal diet was based on corn, solvent extracted SBM, wheat gluten and corn starch. In six further diets, SBM or DDGS as untreated standard product and each of the two heat treated batches were included at levels of 10 and 20 % at the expense of corn starch (Table 3).

Table 3. Composition of the experimental diets containing different levels of SBM or DDGS.

Time of heat treatment	0 min	20 min	40 min
Corn	-	49.00	-
Soybean meal,	-	9.00	-
Wheat gluten	-	9.00	-
Soybean oil	-	5.00	-
L-Lysine·HCl	-	0.95	-
DL-Methionine	-	0.20	-
L-Cystine	-	0.24	-
L-Threonine	-	0.36	-
L-Tryptophan	-	0.04	-
L-Arginine	-	0.67	-
L-Isoleucine	-	0.33	-
L-Leucine	-	0.09	-
L-Valine	-	0.55	-
L-Phenylalanine	-	0.07	-
Premix*	-	1.00	-
Dicalcium phosphate	-	2.00	-
Limestone	-	0.70	-
NaCl	-	0.30	-
Titanium dioxide	-	0.50	-
Cornstarch	20.00	10.00	0
For experiment 1: SBM	0	10.00	20.00
For experiment 2: DDGS	0	10.00	20.00

*Premix supplied the following according to the supplier [BASU-Mineralfutter GmbH, Bad Sulza, Germany] (per kg of complete diet): vitamin A, 5,000 IU; vitamin D3, 2,000 IU; vitamin E, 30 mg; vitamin K3, 2 mg; thiamine, 2 mg; riboflavin, 3 mg; vitamin B6, 2 mg; vitamin B12, 15 mcg; niacin, 30 mg; folic acid, 1 mg; biotin, 100 mg; panthothenic acid, 10 mg; choline chloride, 500 mg; Zn, 100 mg; Fe, 20 mg; Co, 0.5 mg, Mn, 100 mg; I, 1 mg; Se, 0.5 mg.

Titanium dioxide (TiO2) was included as an indigestible marker. All dietary ingredients, with the exception of the test ingredient and corn starch, were mixed in one lot. This mix was divided into six portions and cornstarch and SBM or DDGS were added in the respective amounts. Diets were pelleted without steam trough a 3-mm die.

For each experiment, 504 day-old male broiler chickens (Ross 308) were obtained and allocated in groups of 12 birds to 42 pens. Wood shavings and chaffed straw were used as bedding. Birds had free access to drinking water from nipple drinkers and feed from one trough per pen. All data were recorded on pen basis.

During the first 14 days of life a commercial feed was offered. Each of the seven experimental diets was randomly allocated to six pens and experimental diets were offered *ad libitum* for five days. At the end of this period, all birds were asphyxiated with CO_2 and the intestine section between Meckel's Diverticulum and the ileocecolonic junction was removed (Kluth et al., 2005). The content of the two last third of this section was gently flushed with distilled water, pooled within each pen and immediately frozen. After freeze drying, the samples were ground through a 0.5 mm screen.

The digestibility of amino acids from the tested soybean meal and DDGS was assessed by linear regression analysis regressing daily intakes against digested (disappeared) amounts of amino acids in digesta (Rodehutscord et al., 2004). Daily intakes of amino acids and crude protein were calculated separately for the basal diet and diets including the test ingredients. The total daily intake was calculated as feed intake (g/d) × analyzed amino acids or crude protein concentration in the diet (mg/g). Daily intake of amino acids from the supplemented soybean meal or DDGS was calculated as the difference between the total intake and the intake responding to the basal diet. The slope of this regression line can be considered as a measure of the true digestibility of each amino acid from the supplemented protein sources because the slope of regression is independent of the endogenous losses.

Results of the linear regression analysis to calculate the amino acid digestibility are summarized in Tables 4 and 5. Digestibility of crude protein from the "40 min" heat treated SBM was 60 % and was thus significantly lower than the values found for the

standard product (83 %) and for the "20 min" heat treated SBM (65 %). Similar results were detected for digestibility of all amino acids. With the exception of cystine, digestibility of all other amino acids was significantly and gradually reduced with heat treatment. The mean digestibility of the essential amino acids arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine in the standard product was 82 %. Autoclaving for 40 min reduced the mean digestibility to 62 %.

The digestibility of crude protein in DDGS was not as strongly reduced by heat treatment as for SBM. It ranged between 83 % (standard product) and 72 % ("40 min" heat treated DDGS; Table 5). The mean digestibility of essential amino acids was 85, 80 and 79 % (standard product, "20 min" and "40 min" heat treated DDGS). The clear gradual negative effect of heat treatment on amino acid digestibility observed in SBM products was not detected in DDGS. Heating for 20 minutes reduced the digestibility only for arginine, histidine, lysine, methionine, cystine and tryptophan significantly ($p<0.05$). With the exception of histidine and leucine, a prolonged heating time of 40 min had no further effect on the digestibility of essential amino acids.

Validation of AMINORED®

To validate AMINORED® a growth experiment with broilers was conducted at Feedtest, Germany. In this project the first step was to produce a heat damaged soybean meal. This was done at the pilot plant for oil extraction (CREOL) the Technical Centre for Oilseed Crops, France (CETIOM), where both good quality and heat damaged SBM was produced under controlled conditions in quantities allowing for a feeding trial (Table 6). The expected heat damaging was confirmed by the wet chemistry analysis of amino acids as well as AMINORED®. Compared to Evonik Degussa's data base of amino acid profiles of raw materials a HDI of 11.7 represents the most frequent quality of SBM.

The experimental diets for the trial at Feedtest, Germany, were formulated to meet nutrient and energy requirements of broilers 10-28 days of age except for amino acids. Apart from SBM the experimental diets contained corn, wheat, oil and other ingredients including supplemental amino acids. The experimental design is shown in Table 7.

Table 4. Digestibility of crude protein and amino acids from SBM subjected without heat treatment (0 min) and after autoclaving with steam at 135°C for 20 minutes (20 min) or 40 minutes (40min), respectively (estimate of slope, standard deviation of estimate (SD), and fit of regressions (r2))

	0 min			20 min			40 min			p		
	slope	SD	r^2	slope	SD	r^2	slope	SD	r^2	0 to 20 min	0 to 40 min	20 to 40 min
Crude protein	0.83	± *0.02*	0.99	0.65	± *0.02*	0.98	0.60	± *0.02*	0.98	<0.001	<0.001	0.113
Lysine	0.82	± *0.02*	0.99	0.67	± *0.02*	0.99	0.59	± *0.04*	0.94	<0.001	<0.001	0.063
Methionine	0.84	± *0.03*	0.98	0.69	± *0.03*	0.97	0.67	± *0.04*	0.94	0.001	0.004	0.746
Cystine	0.72	± *0.04*	0.96	0.52	± *0.05*	0.86	0.56	± *0.09*	0.72	0.006	0.128	0.735
Met+Cys	0.77	± *0.03*	0.98	0.61	± *0.04*	0.94	0.61	± *0.06*	0.87	0.003	0.034	0.956
Threonine	0.75	± *0.02*	0.98	0.60	± *0.02*	0.98	0.55	± *0.03*	0.96	<0.001	<0.001	0.143
Tryptophan	0.80	± *0.02*	0.99	0.64	± *0.02*	0.99	0.56	± *0.03*	0.96	<0.001	<0.001	0.018
Arginine	0.86	± *0.01*	1.00	0.79	± *0.01*	1.00	0.75	± *0.02*	0.99	0.002	<0.001	0.116
Isoleucine	0.81	± *0.02*	0.99	0.69	± *0.02*	0.99	0.61	± *0.02*	0.98	<0.001	<0.001	0.017
Leucine	0.83	± *0.02*	0.99	0.67	± *0.03*	0.97	0.61	± *0.02*	0.98	<0.001	<0.001	0.086
Valine	0.80	± *0.02*	0.99	0.69	± *0.02*	0.99	0.63	± *0.03*	0.97	0.001	<0.001	0.080
Histidine	0.83	± *0.01*	1.00	0.65	± *0.02*	0.98	0.58	± *0.03*	0.97	<0.001	<0.001	0.055
Phenylalanine	0.82	± *0.02*	0.99	0.70	± *0.02*	0.98	0.65	± *0.02*	0.98	<0.001	<0.001	0.124

Table 5. Digestibility of crude protein and amino acids from DDGS subjected without heat treatment (0 min) and after heat treatment with steam at 135°C for 20 minutes (20 min) or 40 minutes (40 min), respectively (estimate of slope, standard deviation of estimate (SD), and fit of regression (r2))

	0 min			20 min			40 min			p		
	slope	SD	r^2	slope	SD	r^2	slope	SD	r^2	0 to 20	0 to 40	20 to 40
Crude protein	0.83	± *0.02*	0.99	0.76	± *0.02*	0.99	0.72	± *0.05*	0.95	0.031	0.046	0.500
Lysine	0.88	± *0.01*	0.99	0.83	± *0.01*	0.99	0.84	± *0.02*	0.99	0.018	0.200	0.633
Methionine	0.90	± *0.02*	0.99	0.85	± *0.02*	0.99	0.85	± *0.02*	0.99	0.028	0.066	0.965
Cystine	0.68	± *0.04*	0.96	0.57	± *0.03*	0.96	0.64	± *0.05*	0.93	0.044	0.532	0.246
Met+Cys	0.80	± *0.03*	0.99	0.73	± *0.02*	0.99	0.75	± *0.03*	0.97	0.058	0.301	0.606
Threonine	0.80	± *0.02*	0.99	0.76	± *0.02*	0.99	0.74	± *0.03*	0.98	0.124	0.128	0.686
Tryptophan	0.81	± *0.02*	0.99	0.72	± *0.03*	0.98	0.72	± *0.03*	0.97	0.024	0.056	0.942
Arginine	0.90	± *0.01*	0.99	0.87	± *0.01*	0.99	0.88	± *0.01*	0.99	0.048	0.253	0.670
Isoleucine	0.86	± *0.02*	0.99	0.80	± *0.02*	0.99	0.79	± *0.03*	0.98	0.055	0.066	0.763
Leucine	0.85	± *0.02*	0.99	0.80	± *0.02*	0.99	0.77	± *0.02*	0.98	0.052	0.015	0.410
Valine	0.86	± *0.02*	0.99	0.81	± *0.02*	0.99	0.80	± *0.02*	0.99	0.051	0.052	0.659
Histidine	0.81	± *0.02*	0.99	0.74	± *0.02*	0.99	0.73	± *0.03*	0.98	0.042	0.039	0.739
Phenylalanine	0.86	± *0.02*	0.99	0.80	± *0.02*	0.99	0.80	± *0.03*	0.98	0.063	0.090	0.848

Table 6. Total amino acids (%) and standardised ileal digestible (SID) amino acids adjusted by AMINORED® (%) according to the Heat Damage Indicator (HDI) of different soybean meal qualities produced out of the same batch of soybeans (standardised to 88% dry matter)

Soybean meal quality	Good		Heat damaged	
Dry matter		88.00		88.00
Crude protein		47.28		47.33
	Total	SID according to AMINORED®	Total	SID according to AMINORED®
Methionine	0.63	0.57	0.62	0.53
Methionine + Cystine	1.30	1.12	1.26	1.04
Lysine	2.84	2.56	2.60	2.14
Threonine	1.83	1.56	1.82	1.42
Tryptophan	0.64	0.56	0.64	0.50
Arginine	3.44	3.20	3.33	2.97
Isoleucine	2.06	1.83	2.06	1.69
Leucine	3.52	3.13	3.51	2.86
Valine	2.17	1.91	2.18	1.79
Histidine	1.26	1.16	1.24	1.03
Phenylalanine	2.32	2.07	2.32	1.93
HDI		11.7		48.2

Table 7: Experimental design of the two validation trials

Treatment	Good Quality SBM	Heat Damaged SBM	HD SBM + Analyzed AA	HD SBM + AMINORED®
Basis of formulation	AMINONIR analysis + SID coefficient published by Evonik	Replacement of the good quality SBM to reach the same CP Level	Analyzed total AA + SID coefficient published by Evonik	Analyzed total AA + SID coefficient according to AMINORED®

SBM = soybean meal; SID = standardized ileal digestibility; AA = amino acids; CP = crude protein

In **treatment 1,** the good quality soybean meal was used and the diet formulation was done on basis of analysed amino acid levels of the protein containing ingredients combined with SID coefficient published by Evonik Degussa. This treatment served as the positive control. In **treatment 2,** the good quality soybean meal was completely replaced with heat damaged soybean meal (negative control). However, due to a higher dry matter of the heat damaged material, the fraction of soybean meal was reduced in a way that heat damaged soybean meal contributed exactly the same amount of crude protein to the negative control as the good quality soybean meal contributed to the positive control. Thus, the inclusion of the other ingredients had to be adjusted. Apart from this dry matter issue no further nutritional adjustments were performed. This treatment should imitate a case in which heat damaged soybean meal is not identified and used like regular quality which may occur if not every single batch of ingredient is analysed. The next two treatments were designed to observe the effects of adjusting the diet formulation for total amino acids according to amino acid analyses and an additional adjustment for the effects on digestibility which is provided by AMINORED®. For **treatment 3** the analysed content of total amino acids from the heat damaged soybean meal was the basis to optimize the diet but still using table values for standardized ileal amino acid digestibility. As the inclusion level of the soybean meal was not changed the adjustment of amino acid supply in order to meet specifications was done by supplementing amino acids. Finally, the diet for **treatment 4** which also used the heat damaged soybean meal was not only corrected for total amino acids according to amino acid analysis but also the standardised ileal amino acid digestibility (SID) coefficients were adjusted according to AMINORED®. Once more, the inclusion level of soybean meal was maintained and adjustments were realised through amino acid supplementation.

Diet compositions are shown in Table 8. All diets were pelleted and analysis of compound feed confirmed accurate feed manufacturing.

Table 8. Diet composition and nutrients of experimental diets used in broiler trial at Feedtest, Germany

Treatment	Good Quality SBM	Heat Damaged SBM	HD SBM + Analyzed AA	HD SBM + AMINORED®
Diet composition, g/kg:				
SBM – good	311.84			
SBM – heat damaged		284.10	284.10	284.10
Corn	306.04	324.87	324.87	324.87
Wheat	250.00	250.00	250.00	250.00
Soybean oil	68.73	68.73	68.73	68.73
Corn starch	20.00	28.74	27.97	25.77
Calcium phosphate	23.26	23.43	23.43	23.43
Calcium carbonate	6.52	6.52	6.52	6.52
Sodium hydrogen carbonate	2.71	2.71	2.71	2.71
Sodium chloride	2.34	2.34	2.34	2.34
Premix****	5.00	5.00	5.00	5.00
DL-Methionine	2.15	2.15	2.20	2.48
L-Lysine HCL	1.09	1.09	1.86	2.91
L-Threonine	0.32	0.32	0.28	0.77
L-Valine				0.37
Nutrients, %:				
Metabolizable energy				
MJ/kg	13.20	13.19	13.20	13.23
Kcal/kg	3155	3152	3155	3162
Crude protein	20.1	20.28	20.35	20.47
Ether extract	8.84	8.87	8.87	8.87
SID Lysine	1.00	0.90	0.96	1.00
SID Methionine	0.47	0.46	0.47	0.49
SID Met+Cys	0.74	0.71	0.72	0.74
SID Threonine	0.65	0.62	0.62	0.65
SID Tryptophan	0.22	0.23	0.23	0.23
SID Arginine	1.20	1.06	1.06	1.06
SID Isoleucine	0.74	0.70	0.70	0.70
SID Leucine	1.41	1.37	1.37	1.37
SID Valine	0.80	0.76	0.76	0.80

* SBM = soybean meal

** Calculation based on analysed amino acid levels of heat damaged SBM

*** Calculation based on the AMINORED® concept for the heat damaged SBM

**** Premix composition: 12,000 IE retinol, 2,400 IE cholecalciferol, 50 mg dl-a-tocopherol, 1.5 mg menadione, 2.0 mg thiamine, 7.5 mg riboflavine, 3.5 mg pyridoxine, 20 mcg cobalamins, 35 mg niacin, 10 mg D-pantothenic acid, 460 mg choline chloride, 1.0 mg folic acid, 0.2 mg biotin; 80 mg iron, 12 mg copper, 85 mg manganese, 60 mg zinc, 0.40 mg cobalt, 0.8 mg iodine, 0.1 mg selenium, 125 mg anti-oxidant mixture

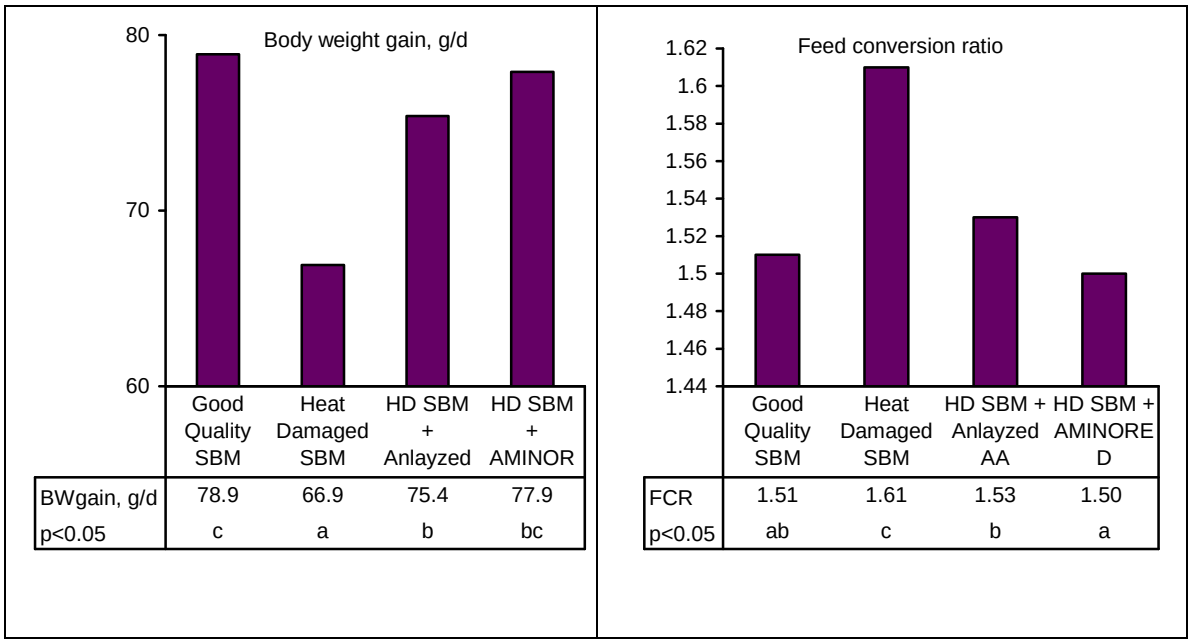
A total of 1200 male Ross 308 broilers 10 to 28 days of age were utilised in the trial. Each of the four dietary treatments was run with 15 replicates. One pen containing 20 birds was considered the experimental unit. For the first 9 days chicks were fed with commercial crumbled starter feed adequate in energy and all nutrients. Room temperature and lighting was in accordance to breeder recommendations. Body weights were recorded individually at day 10 and day 28 while feed consumption was recorded per pen. At day 29, seven birds per pen with body weight as close as possible to pen average were slaughtered. Carcass and breast meat yield were determined. Statistical data analysis for weight gain, feed intake, feed conversion, carcass yield and breast meat yield was conducted by analysis of variance (ANOVA). The probability of error $p<0.05$ was considered significant.

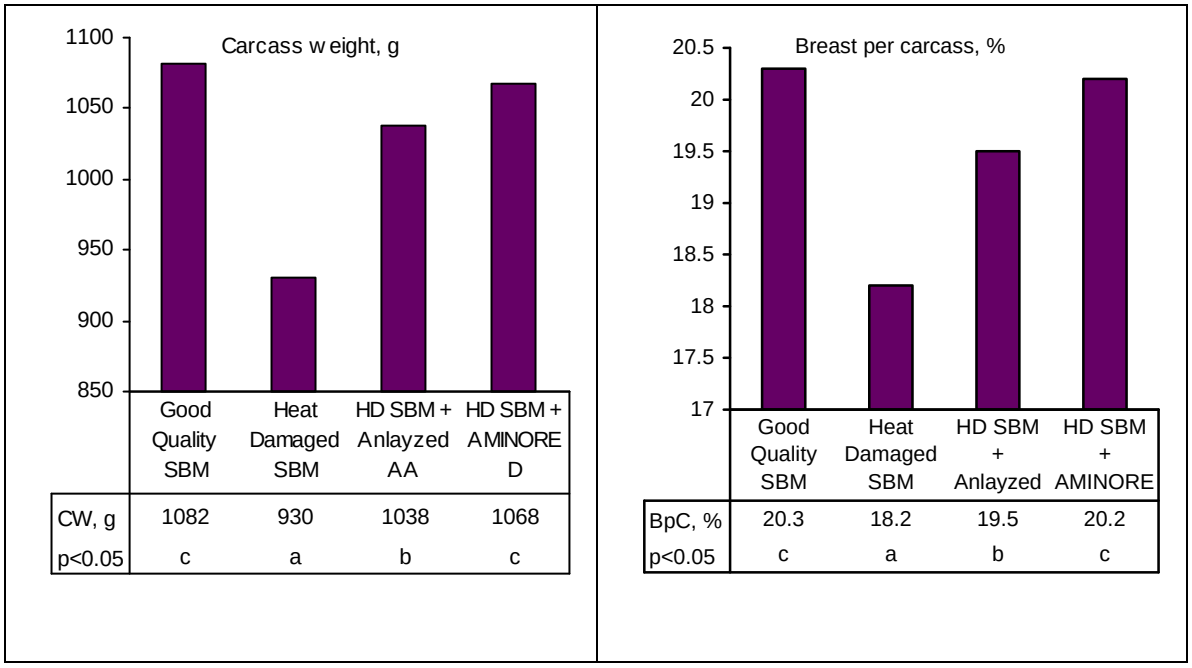
Trial results are presented in figure 2. Significant differences between treatments and thus the two SBM qualities were observed for body weight gain, feed conversion ratio, carcass weight, and breast meat yield.

Birds from the negative control (treatment 2) in which the good soybean meal was replaced by the heat damaged soybean meal, had the lowest final body weight and therefore the lowest body weight gain particularly compared to the positive control ($p<0.05$). Correction for total amino acids (treatment 3) and SID amino acids according to AMINORED® (treatment 4) gradually improved performance compared to the negative control up to the level achieved by the positive control. Similar effects were observed for feed conversion ratio, carcass weight, and breast meat yield expressed as % of carcass.

These effects clearly demonstrate that in case of heat damage, correction only for total amino acid loss only partially accounts for the reduced nutritional value. Additional correction of the digestibility coefficients via AMINORED® allowed performance to be maintained compared to the positive control with good quality soybean meal.

Figure 2. Effects of diets using good SBM, heat damaged SBM, heat damaged SBM with amino acid adjustment after amino acid analysis, and heat damaged SBM with dietary adjustment of standardised ileal digestible amino acids according to AMINORED® on various performance parameters in 10-28 days old broilers; figures with different letters a, b, c differs significantly ($p<0.05$)





The data set shown in figure 2 suggests that it is worthwhile not only to adjust the nutritional matrix of heat damaged ingredients in terms of total amino acids but also in terms of SID amino acid which can be done using AMINORED®. Thus, risks of losing animal performance can be minimised if such corrections are applied.

Economic analysis on feed cost

Higher concentrations of CP and amino acids might not indicate the optimal digestibility of the amino acids. Price of the raw materials including SBM based only on CP and amino acid concentrations would be misleading. The real value of the SBM may be overestimated. Utilizing over processed raw materials including SBM would lead to reduced performance and profitability will be negatively affected. SBM which is assigned a value of HDI 12 may be a more frequently occurring SBM which could be considered as a reference. If the price of the SBM with HDI 12 is 340 USD/Ton, then formulating the diet using the same SBM would cost 304 USD/Ton of feed. The shadow price of SBM which is heat damaged with HDI 47 adjusted for digestible amino acids according to AMINORED® can only be purchased at 311 USD/Ton. If the heat damaged SBM

purchased at the same price as normally processed SBM and when included in feed will increase the cost of feed by 11 USD/Ton (315 USD/Ton of feed). Identification of heat damage to SBM and adjustment for digestible amino acid concentrations by AMINORED® hence reduces the negative effects on performance of broiler chickens. AMINORED® also assists to determine the price of heat damaged SBM based on digestible amino acid levels.

CONCLUSIONS

Digestibility of amino acids could be negatively affected in over processed raw materials as can be seen in the reduction in amino acids digestibility in SBM and DDGS. The effect of heat treatment on the nutritional value with respect to amino acid contents and digestibility was affected to a greater extent in SBM compared to DDGS. Adjustment of digestibility coefficient for amino acids through AMINORED® for heat damaged raw materials including SBM results in similar performance compared to birds fed good quality SBM. Economic losses due to decreased performance hence could be reduced when feeding heat damaged feed ingredients.

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ORGANIC ACIDS AND ESSENTIAL OILS, A VIABLE ALTERNATIVE TO ANTIBIOTIC GROWTH PROMOTERS IN POULTRY PRODUCTION

R. GAUTHIER and DAVID MAIR

SUMMARY

A better understanding of the mode of action of organic acids and essential oils on bacteria and the discovery of a strong synergy between those two families of compounds, coupled with an appropriate processing technology adapted to the anatomy and physiology of poultry, has given rise to a new and more efficacious alternative to antibiotic growth promoters. In order to evaluate the real efficacy of this strategy, *in vitro* and *in vivo* experiments were conducted showing that, by applying the microencapsulation technology, the dosage of both organic acids and essential oils could be reduced substantially.

INTRODUCTION

In the late 80's and early 90's, strong regulatory actions have removed most of the antibiotic growth promoters from the European Union market, the last ones have been withdrawn in January 2006. The adjustments following the withdrawal of these products in animal production have been difficult at times and many replacement solutions have been proposed by the feed additive industry.

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It is not easy to replace products that have proven to be generally efficacious for the last 50 years. A consensus seems to develop among the scientific community concerned by this subject (Rosen 2005) and one approach is definitely standing out, for its efficacy, technological and economical feasibility, the organic acids. Another option is, under the generic name of "botanicals", essential oils (plant extracts or related compounds).

ORGANIC ACIDS

Organic acids have been used successfully in pig production for more than 30 years and continue to be the alternative of choice. Even if much less work has been done in poultry (Dibner *et al.* 2002), we can now confirm that the organic acids are very efficacious provided their use is adapted to the physiology and anatomy of poultry. Organic acids (C1-C7) are widely distributed in nature as normal constituents of plants or animal tissues. They are also formed through microbial fermentation of carbohydrates mainly in the large intestine (Partanen *et al.* 1999). They are also found in their sodium, potassium or calcium form.

Over the years, it was thought that a pH reduction of the gastrointestinal tract content was the mode of action, research has proven differently. The key basic principle on the mode of action of organic acids on bacteria is that non-dissociated (non-ionized) organic acids can penetrate the bacteria cell wall and disrupt the normal physiology of certain types of bacteria that are called "pH sensitive" meaning that they cannot tolerate a wide internal and external pH gradient. Among those bacteria we have *E. coli*, *Salmonella sp.*, *C. perfringens*, *Listeria monocytogenes*, *Campylobacter sp*.

Upon passive diffusion of organic acids into the bacteria, where the pH is near of above neutrality, the acids will dissociate and lower the bacteria internal pH, triggering mechanisms that will impair or stop the growth of bacteria. On the other hand, the anionic part of the organic acids that cannot escape the bacteria in its dissociated form, will accumulate within the bacteria and disrupt many metabolic functions and lead to

osmotic pressure increase, incompatible with the survival of the bacteria. It has been well demonstrated that the state of the organic acids (undissociated or dissociated) is extremely important to define their capacity to inhibit the growth of bacteria. As a general rule, we need more than ten to one hundred times the level of dissociated acids to reach the same inhibition capacity of bacteria, compared to undissociated acids (Presser *et al.* 1997).

Too often, *in vitro* assays showing the antibacterial capacity of organic acids are done at a low pH, to avoid the dissociation of the acids. At a pH below 3.0-3.5, almost all organic acids are very efficacious in controlling bacteria growth. This does not reflect at all what is happening in the gastrointestinal tract of poultry. Logically, organic acids added to feeds, should be protected to avoid their dissociation in the crop and in the intestine (high pH segments) and reach far into the gastrointestinal tract, where the bulk of the bacteria population is located. More likely, the organic acids in poultry might play a direct role on the intestinal bacteria population, reducing the level of some pathogenic bacteria (ex. *C. perfringens)* and mainly controlling the population of certain types of bacteria that compete with the birds for nutrients (Lee 2005).

ESSENTIAL OILS

Essential oils are any of a class of volatile oils obtained from plants, possessing the odor and other characteristic properties of the plant, used chiefly in the manufacture of perfumes, flavors and pharmaceuticals (extracts after hydro-distillation). Essential oils or plant extracts can be used as appetite stimulant, aroma, stimulant of saliva production, gastric and pancreatic juices production enhancer and antioxidant. However there is no clear demonstration of the importance of these factors on the chicken performance.

Plants contain hundreds of substances having different properties but essential oils composed mainly of nine groups (and many sub-groups) of molecules are of interest to us. There are many chemical constituents but no two oils are alike in their structure and effect. One must make a difference between non purified plant extracts containing numerous different molecules interacting and pure active compounds, either extracted

from plants or synthesized (nature identical). According to the plant chosen, one or more active compounds are dominant and the quantity found will differ according to factors like; plant variety, soil, moisture, climate, time of harvest etc. Almost all essential oils (EO) are based on isoprene (5C) frame.

Nutritionally, metabolically and toxicologically, we have a clear interest in using as low as possible levels of essential oils in animal nutrition. Essential oils are extremely potent substances, they can lead to feed intake reduction, gastrointestinal tract microflora disturbance, accumulation in animal tissues and products.

Most essential oils are GRAS (generally recognized as safe) but they must be used cautiously because they can be toxic (allergens) and potent sensitizers and their odor/taste may contribute to feed refusal (Lis-Balchin 2003, Lambert *et al.* 2001). They are also very volatile and will evaporate (sublimate) rapidly, leading to a large variation in concentration in the finished feeds. Encapsulation of essential oils could solve the problem (Lis-Balchin 2003).

It is extremely difficult to generalize on the mode of action of essential oils on bacteria and yeasts because each essential oil has different properties and each type of microorganism has a different sensitivity. Generally, $Gram^+$ bacteria are considered more sensitive to essential oils than $Gram^-$ bacteria (Lambert *et al.* 2001) because of their less complex membrane structure.

The consensus on the mode of action of essential oils on bacteria is now that these compounds influence the biological membranes of bacteria. The cytoplasmic membrane of bacteria has two principal functions (Ultee *et al.* 1999); a barrier function and energy transduction, which allow the membrane to form ion gradients that can be used to drive various processes and the formation of a matrix for membrane-embedded proteins influencing the ATP-synthase complex.

A VIABLE ALTERNATIVE

In our own experiments with organic acids, we have experienced very consistent results, both under research station and field conditions, our rate of positive response exceeded 90% for weight gain and feed conversion, using a blend of protected organic acids. Not only protected organic acids can act as growth promoter but also play a role in the prevention of necrotic enteritis and in the reduction of intestinal *Salmonella sp.* It appears that the amplitude of the response is often related to the level of contamination or intestinal disease challenge in the flock.

More and more, the concept of combining essential oils and organic acids is proving to be efficacious (van Wesel *et al.* 2004) because there appears to be a synergy between the two concepts (van Kol 2005, van Dam *et al.* 2005). Our own experiments in field trials, using a chicken necrotic enteritis challenge model, have shown a strong synergy between essential oils and organic acids.

TECHNICAL PROBLEMS WITH ORGANIC ACIDS AND ESSENTIAL OILS

The use of organic acids and essential oils in the feed industry is often a source of problems; corrosion, worker's safety, handling, vitamin stability in premixes, environmental concern, stability of products.

It has been demonstrated that when both organic acids and essential oils are protected in a triglyceride matrix, the quantity required to achieve maximum performance in poultry can be reduced drastically. The active ingredients can be delivered into the intestine, directly where the bulk of gastrointestinal bacteria are located (Piva *et al.* 2004). Without protection, organic acids are readily dissociated in the first part of the chicken gastrointestinal tract and are rendered useless (Dibner *et al.* 2002). Essential oils are very rapidly absorbed in the duodenum and cannot interact with the microflora (Lee *et al.* 2004).

CONCLUSIONS

There is a general consensus on the efficacy of organic acids as the best alternative to antibiotic growth promoters. Essential oils have a limited effect as a replacement of antibiotic growth promoters but they can act in synergy with organic acids both for their growth promoting effect and prevention of specific intestinal diseases. Now there is an encapsulation technology that enhances the efficacy of organic acids and essential oils, at a low inclusion level.

Table 1. Effect of essential oils and essential oils-organic acid combination on production parameters, no challenge farm trial, broiler chickens, 28 days of age, $P<0.05$ (Jefo Nutrition internal data).

	No of birds	Body weight (g)	Daily weight gain (g)	Feed conversion	% Mortality
Negative control	1198	1.406[a]	48.70[a]	1.605[a]	3.83
Essential oils (2)	1200	1.367[b]	47.31[b]	1.621[a]	3.00
EO-OA (1)	1198	1.436[c]	49.79[c]	1.557[b]	2.59
EO-OA (2)	1200	1.467[d]	50.90[d]	1.560[b]	3.67

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THE EVOLUTION OF POULTRY DISEASE

PETER GROVES

This year marks my thirtieth year of involvement with the poultry industry and it seems worth reflecting over the changes in disease issues which have occurred over that time. It is sobering to look at the epidemiology of many emergent and new diseases which have evolved over this relatively short time, all of which can be directly associated with changes in poultry management and husbandry system developments. While many diseases which had major effects on the industry have had major improvements in control (e.g. Mycoplasmata, Coccidiosis, Chronic Respiratory Diseases), quite a few "new" ones have arisen or re-emerged under new expressions.

The list of diseases of domestic fowl which have emerged, re-emerged or changed in their severity or expression in Australasia and globally over this time is extensive and will include: Infectious Stunting Syndrome (ISS), Chicken Anaemia Virus (CAV), Inclusion Body Hepatitis (IBH), Marek's Disease (MD), Newcastle Disease (ND), "Spotty Liver Syndrome" (SLS), Necrotic Enteritis (NE), Dysbacteriosis, Histomoniasis, Spiking Mortality, Broiler Ascites Syndrome, Broiler Leg Weaknesses, Femoral Head Necrosis and cellulitis. This list is by no means exhaustive. Most, if not all, of these diseases have shown changes in expression, incidence or severity related to changes in bird genetics and management. For this discussion I'll concentrate on genetic and management changes that have affected three of these diseases: namely Broiler Ascites, Marek's Disease and Infectious Stunting Syndrome.

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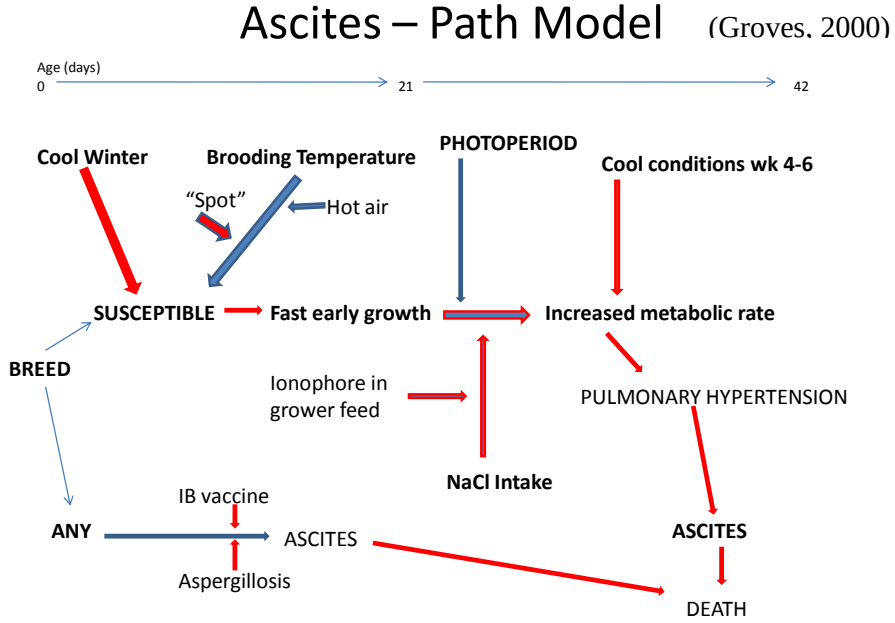
Broiler Ascites Syndrome (BAS)

First seen at high altitudes (>2000m) but then soon appeareing in broilers at sea level, this condition caused great difficulties in the late 1980's through to the late 1990's in rapidly growing breeds of broilers. In Australia in emerged in only two of the local breeds in the late 1980's and continued to cause problems in the imported broiler breeds thereafter. Initially it was problematic only in New South Wales, the same breeds not showing the problem in Queensland, Victoria or South Australia. The idea of "rapid growth" being involved was not maintainable as the Australian breed that did not see problems with BAS grew just as fast as the others. The difference though was breast muscle – the higher breast yield strains were those that were more strongly affected.

The major factor in the pathogenesis of BAS is pulmonary hypertension and, at lower altitudes, the major predisposing factor is cool temperatures. Wideman and Bottje (1993) describe the pathogenesis of BAS induced by increased metabolic rate as a result of hypothermia. The use of the term "hypothermia" by these workers refers to lower than optimum ambient temperatures, not necessarily low body temperature. Low ambient temperatures stimulate basal metabolic rate resulting in production of heat. This heat production comes from feed energy and is an oxygen requiring reaction. Van Kampen (1987) has shown that below the critical temperature, heat production in chickens increases as temperature decreases at a linear rate over a limited temperature range and that heat production is a function of oxygen consumption. Increases in basal metabolic rate require dilation of precapillary arterioles and hence an increase in cardiac output (CO). This results in an increased pulmonary arterial pressure. Coupled with a high muscle growth rate in an ascites-susceptible bird, the oxygen demand is dramatically increased by cold temperature and pulmonary hypertension is the result (Wideman and Bottje, 1993). Systemic pre-capillary arterioles dilate to allow increased tissue oxygen uptake. This response requires increased cardiac output which in turn further elevates pulmonary blood pressure.

Van Kampen (1987) noted that very young chicks go through a stage during which metabolic rate increases faster than bodyweight, and this was thought to be caused by differential development during growth. Genetic selection which has emphasised changes in relative differential organ sizes may have severely altered the magnitude of this metabolic rate "overshoot". Albers *et al.* (1990) also referred to this variation in the chick's ability to mobilise oxygen for oxidation per gram of feed intake with age, and noted that this is determined by the relationship of feed intake per unit metabolic weight. This ratio rises rapidly to a peak around 10 days of age and declines very quickly after 2 weeks of age.

Rapid growth requires increased blood flow (increased cardiac output = CO).Extra blood volume through a relatively small lung leads to pulmonary hypertension (PH).Cold temperatures increase oxygen demand and further increases CO leading to further PH. PH causes dilation of right ventricle and right atrio-ventricular valve insufficiency and ascites develops as a result of this right-sided congestive heart failure. The epidemiological progression of the syndrome is shown in the diagram below.



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We have been able to manage BAS to a large extent by modifying the bird's relative organ growth rate during the critical "metabolic overshoot" period between 5 and 10 days. This was initially accomplished by restricting photoperiod (providing a closer to normal scotoperiod abruptly on day 5-7). This temporarily decreased feed intake for a day or so and allowed the cardio-respiratory system to "catch up" to the rest of the body in this period. Also better attention to brooding temperature control throughout the entire brooding area also prevents the problem. Continued selection for higher breast yield will continue to put pressure on the bird from this condition in future.

Marek's Disease (MD)

The continued evolution of Marek's Disease worldwide has been well documented (Witter and Schat, 2003; Jenner, 1992). Witter's classic time line depiction of the increase seen in virulence with MD virus has been well appreciated, showing jumps in pathogenicity over time, pretty much in line with the development of the intensive poultry industry throughout the 20th century (Witter, 1998). The presence of a very virulent MDV strain was seen in Australia as early as 1987 (McKimm-Breschkin *et al*., 1990). In Australia we saw an interesting change in MD incidence and severity from about 1990 and this was coincident with management changes occurring in both the broiler and layer industries. The patterns seen exemplify the effects management changes can have on infectious disease, particularly highly transmissible diseases like MD. In Australia in the early 1990's, market influences encouraged the need to grow broiler chickens to a much heavier live weight than previously. This increased the final slaughter age of chickens from 48 days up to 60-62 days, with much higher proportions of the birds remaining on farm to later ages. At this time broiler chickens were not routinely vaccinated against MD and litter was often re-used without complete disinfection between broiler batches. MD is a relatively slow disease by chicken virus standards but this increase in the presence of unvaccinated birds to older ages allowed a significant increase in viral shedding into the poultry dense areas in New South Wales. MDV is shed in feather dander and is easily airborne, capable of being carried considerable distances (Groves, 1995).

In dense poultry areas this would have significantly increased the challenge levels to other broilers and also to the layer and breeder industries. Although distinct clinical MD was not observed to a large extent in the young broilers, the immunosuppression caused by this infection lead to substantial performance and mortality issues from other infections. This eventually lead to the need to institute vaccination of broilers against MD and resulted in a massive improvement in broiler performance and restoration of health from several other conditions. Concurrently, this time period was associated with the introduction of imported breeds of commercial chickens, in both the meat and egg industries. This was the first insurgence of overseas poultry genetic material in 50 years. While our splendid isolation in the antipodes had fostered peculiar viral strains, we had also developed our own vaccine strains to which our local breeds had been adapted and developed. The imported breeds however, reared for years under protection of stronger vaccines, did not respond well to our local MD vaccine types and , coupled with this higher existing field challenge at the time, folded under clinical and devastating outbreaks of MD. The only long term answer to this was to import an overseas vaccine type ("Rispens" CVI 988) which eventually settled bird health back to acceptable levels.

Infectious Stunting Syndrome (ISS)

Dr Rod Reece will present a thorough discussion of ISS at the AVPA meeting following this meeting and I would recommend anyone interested to attend his paper. Here I'll concentrate on the perceived management changes that have recently elevated this disease in Australia and in the possible underlying role this syndrome may be playing in overall poultry health.

ISS is a poorly understood group of syndromes. ISS was first recognised in Australia in the early 1980's. Although it is demonstrably transmissible, identification of the agent(s) involved has been problematic. It doesn't directly cause mortality but losses are high due to a high culling rate, poor growth and feed conversion efficiency. It seems to come and go and is sometimes associated with young breeder flocks (de Wit, 2008). It only clinically affects very young chickens and it is thought that it may be vertically transmitted and that maternal immunity arguably may play an important role in the expression of the disease (de Wit, 2008). It

has a viral aetiology (Reece, 2010) but many types have been incriminated without any being really proven to be the causative agent. There are three forms (see Reece, 2010) and these may be associated with different viruses. So far the virus types reported in association with the lesions include calicivirus, enterovirus, parvovirus, togavirus, rotavirus, astrovirus, reovirus and picornavirus. The condition is clearly multifactorial but the precise epidemiology has not been defined.

There have been no vaccines developed against ISS (although an autogenous vaccine is being tried at present in USA – T. Grimes, personal communication). There are no diagnostic tests available and confirmation of the diagnosis relies on histopathological examination. Control recommendations revolve entirely around environmental management, such as avoiding chilling, vitamin supplementation and rigorous farm hygiene (Reece, 2010).

The epidemiological appearance of the syndrome in time suggests that a natural population immunity develops which most likely includes maternally derived protection. As the exposure of the breeder flocks to the responsible virus(es) varies over time, this immunity cover waxes and a wanes. As field exposure changes in the face of variable immunity, the condition emerges or disappears.

One feature of the emergence of the disease recently has involved the placement of chicks into a broiler growing area derived from breeder flocks reared in a remote location. This is suggestive of lack of maternal protection aimed at the endemic virus population in the broiler environment.

While obvious outbreaks of ISS only occur from time to time, the viruses involved are ever present and their contribution to compromised broiler performance may be continuous at various discernable levels. Thymic degeneration is a feature of ISS and may demonstrate a considerable immunosuppression in some birds, even when the syndrome does not appear as a flock problem. An undercurrent of poor digestion from “sub-clinical” ISS viral infection may also show up as low level nutritional or development al issues. The chance that compromised nutrient absorption (particularly of calcium, phosphorus and fat soluble vitamins) may play a part in conditions like the so called “femoral head necrosis” needs consideration, as the latter condition is a major cause of bird lameness and mortality in most intensive broiler flocks.

In this respect, even without major ISS occurrences, the group of viruses involved in this syndrome may be a "sleeper" in the outward expression of several other common conditions that plague us these days. The lack of frequent outbreaks of ISS limits the interest of researchers and funding bodies in exploring this rather complicated and difficult condition further.

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SALMONELLA CONTROL IN NEW ZEALAND POULTRY: A SWOT ANALYSIS

EDUARDO BERNARDI

INTRODUCTION

Recent outbreak of *Salmonella* Enteritidis in commercial eggs in the USA have unfolded into serious consequences, among them a massive recall of eggs, dramatic reduction in consumption, raising of awareness, blame games, diverse conspiracy theories and renewed criticism on battery cages. The as the effects still roll, it is probably quite timely to look at Salmonella control in NZ and bring up the strengths, weaknesses and try to foresee threats and maybe the opportunities to take advantage of.

STRENGTHS

◆ Geographic isolation: We have a rather unique internal "flora" – bacteria in soil, grains, livestock, wildlife. There are no records of *Salmonella* Enteritidis in NZ poultry and, so far, mostly *Salmonella* Typhimurium has been the strain of concern. ◆ Strict control on imports – biosecurity. No live poultry imported – only eggs – and mostly of GP flocks – released into local facilities after supervised quarantine. All commercial flocks originated from locally produced eggs (immunised parents). Imports only for cooked, shelf-stabled poultry meat and eggs. Processing details required. ◆ NZ poultry still kept mostly indoors, in controlled environment sheds, with little contact with grain-eating birds such as sparrows and mynahs and little contact with wild waterfowl.◆ *Salmonella*-control treatment in feeds and raw materials for broilers and breeders. Use of organic acids, formaldehyde and temperature (pressure) treatment. ◆ RMP-Risk Management Programmes: Designing, Recording and Auditing, with a role of the NZFSA, and the industry - PIANZ/EPF.

Pacificvet, Christchurch

◆ Complete immunisation of breeders and commercial layers against *Salmonella:* Live vaccines against *Salmonella* Typhimurium, taking advantage of a complete programme and cross protection. Easy differentiation between vaccine strain and wild strain for surveillance purposes. ◆ Excellent consumption per capita of poultry and eggs. ◆ Excellent records in terms of Salmonella findings in poultry meat and eggs: Negative! (But, are we looking hard enough?) ◆ Active participation of EPF/PIANZ on representation of the sector, with broad coverage of communications and information throughout the country and immediate/strong action towards media attacks.

WEAKNESSES

◆ High cost of egg and poultry meat production: Raw materials – GE-free becoming costly and they are often (?) *Salmonella* positive. Multiple compliances are costly too, with little margins left for producers and retailers. ◆ Cold chain from farm to consumer not compulsory. Of course there is great debate on costs, shelf life, ideal temperatures for Salmonella growth. Complete cold chain may not be economically sustainable. ◆ Traceability systems could be improved: eggs. ◆ Temperature treatment on feeds may not be 100% effective: Different temperatures used – some are insufficient to kill *Salmonella*. Filtered air systems too expensive – risk of re-contamination. ◆ Frequent turnover of technical staff on farm and hatchery level: Precise measures of control may involuntarily lead towards a different direction, such as biosecurity, precise distribution of vaccine, use of public/chlorinated water. ◆ Normally, *Salmonella* Typhimurium does not make birds sick. Most *Salmonella* serovars will not make birds sick. An infected, healthy flock may carry food poisoning bacteria. It becomes a struggle between perception and correct detection; perception and appropriate emphasis. ◆ Flexibility of RMPs in terms of Salmonella control: Compulsoriness vs. Voluntariness. There is no perfect system. ◆ Import of poultry products based on cooking & processing details. Testing not routinely done.

◆ Misunderstanding of immunisation: Mistaking vaccines for "chemicals"; use of incomplete programme; reliance of maternal antibodies. ◆ Coverage of vaccine in terms of *Salmonella* serogroups. ◆ The industry has not yet developed a recognisable (by consumer) quality seal. The presentation of product can improve – as compared to some international standards. Consumer ignores quality traits to a very good extent, but at this stage there is no current public pressure to differentiate the products. ◆ There is still a residue of poor public perception of egg and poultry products in terms of association with Salmonella: Media, grocery stores, etc.

THREATS

◆ Excellent records in terms of Salmonella findings in poultry meat and eggs: Good results take the emphasis away from an area of focus - Complacency - Relaxation of programmes. ◆ Vectors are still out there: Sparrows, rodents. ◆ Cross contamination from other livestock (new strains): *Salmonella* Brandenburg, other serogroups. ◆ New strains of Salmonella popping up when others have been controlled – common perception (but real?) ◆ Increase on the number of free range operations: Increased contact with wildlife & grain-eating birds. ◆ Alternative methods not proven efficacious. ◆ Fragile supply chain from international companies – vaccines: NZ "not a priority" for large pharmaceutical companies; vaccine industry tending to concentrate on GM products for future developments; currently GM not accepted in NZ; trend of vaccines to become multi-agent. Some of these organisms not allowed in NZ. ◆ Constant threat of opening the NZ market for import products due to pressure from free trade alliances. ◆ Salmonella poisoning from other sector affecting poultry and eggs. ◆ Salmonella poisoning from poultry and eggs in other countries affecting the consumption.

OPPORTUNITIES

◆ Collective understanding the limitations of the best possible programme: The concept of the "*dijk*" (we can always build a higher and stronger dijk, but there is no guarantee against a massive wave or tidal surge breaking through it). Reinforcement of compliance; raising the height of the *dijk*; readiness for changes or adaptations. ◆ Information exchange throughout the alternative systems' network – preferably seeking science-based solutions. ◆ Preparedness against vectors – better awareness of pest control. ◆ Preparedness against new strains of *Salmonella*: better understanding of cross protection and serogroups; maybe new vaccines? ◆ Marketing: Excellent records in terms of Salmonella findings in poultry meat and eggs (NEGATIVE!). Talk about it - Poultry and eggs as a safe food – appealing! Make money with it - Collective labels, specialty labels. ◆ Raising the *dijk* against poultry imports. ◆ Use the same preparedness to combat other food safety organisms.

PRELIMINARY TRIALS OF IN-VITRO EFFICACY OF MITICIDES AGAINST THE CHICKEN MITE (Dermanyssus gallinae) IN NEW ZEALAND

N CHRISTENSEN[1] and M CHRISTENSEN[2]

INTRODUCTION

Variously known as the chicken mite, poultry mite or red mite, *Dermanyssus gallinae* (De Geer 1778) has become one of the most important impediments to efficient egg production in many countries around the world, especially in Europe. A measure of the effort being put into its control is the fact that in 2009 an entire issue of the journal Applied and Experimental Acarology was devoted to the biology and control of *Dermanyssus gallinae (*Sparagano 2009*).*

The red mite has three important characteristics

- Certain stages of the life cycle suck blood from the host.
- The mite lives in the structure of the poultry house rather than on the birds, emerging to feed from the birds at night.
- The mite can survive for months without feeding.

The mite has exploited two divergent trends in modern egg production to regain its former prominence:

- Modern high-rise multi-age cage systems with their manure belts, egg belts (especially woven ones), manure driers and complex supporting structures offer much more refuge to the mites than did the single tier cages they replaced; any move to furnished cages will further increase the opportunities for mites to become established. The economics of large cage houses make all in-all out stocking policies by shed the exception rather than the rule, which makes the mites very difficult to get rid of once established;.

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- The rise of free range egg production has increased the proportion of the national flock infested because of the open nature of free range houses, and the opportunities for contact with transport hosts e.g. sparrows, pigeons.

The problem has been exacerbated by a reduction in the availability of chemical controls due to decreased efficacy of some products or environmental concerns in some countries over others.

The Life cycle of D gallinae (Soulsby, 1968)

Adult females lay eggs 12-24 hours after first blood meal	(avg)	18 hrs
Eggs hatch in 48-72 hours when warm (>24^{o}C)		54
6 legged larva molts without feeding in 24-48 hours		36
8-legged blood-sucking protonymph molts in 24-48 hours		36
8-legged blood-sucking deuteronymph molts in 12 hours		12
Adult, females suck blood		**156hrs**

The mites can survive for up to 34 weeks without food, longer than the downtime of any commercial poultry house between flocks, so some form of chemical intervention is needed. The red mite is mainly a parasite of chickens but also infests pigeons, canaries, turkeys and some wild birds notably sparrows, which have a pre-deliction to line their nests with chicken feathers. They also attack humans biting them and/or causing allergic reactions.

TREATMENT OF MITES

Currently only Neguvon (98% trichlorphon) is registered for the treatment of mites in New Zealand, but the product is not currently imported. Other products that have been registered in the past are Malathion used at 5mg/ml and Sevin (carbaryl) 0.5%. The synthetic pyrethroids Ripcord (cypermethrin) and Sislin (deltamethrin) have also been widely used.

A review of miticides available in the USA 30 years ago was carried by DeVaney in 1986. Although she was concerned mainly with Northern Fowl Mite, the chemicals available were organophosphates, carbamates and synthetic prythroids. There have been few additions and a number of subtractions since. Other developments centre around natural products (oils, desiccants and pyrethrum extract) to meet organic egg producers' requirements for mite control products that do not compromise their status. Concerns about the development of resistance (pyrethroids) and environmental and human health concerns over the use of organophosphate and carbamate miticides has lead to the need for alternative products. Only very recently has a new chemical; active (spinosad) been approved in EU for red mite control. A number of candidates have been sporadically used and it was decided to carry out in-vitro tests on some of these.

SUPPLY OF MITES

Approximately 50g of red mites in various stages were collected from a local farm. The test mites had been exposed to Ripcord sprays a number of times over the past year.

Dilutions of the spray miticides were made as above and 1ml applied using a fine mist bottle (Arthur Holmes 30FLNWM) onto a Whatman filter paper inside a standard petridish. An initial trial was carried out with a selection of the above miticides, and then the whole group was tested in duplicate. The miticides were applied to named petri dishes; the names were randomly replaced by letters so that the observations were carried out blind. Approximately 150 mites were sprinkled over the center of each petri dish. The dishes were stored at 20-23^{o}C with the covers on to maintain a humid environment.

In the case of the powdered miticides, 1g was sprinkled evenly over a filter paper in a petri dish, and the mites applied to the powder. These were not scored blind as the powders were easily identifiable.

Table 1. Potential miticides tested

Spray miticides	**Active**	**Use rate**	**Active/L**
Control	Water	n/a	n/a
Ascend	fipronil 20% (Holmes 2005)	1ml/L, 0.5ml/L (+pulse)	2mg/L, 1mg/L
Ripcord	cypermethrin 15g/L	4ml/100ml	600mg/L
Elector /Extinosad	spinosad 25mg/ml (Allin 2010)	30ml/L	750mg/L
Organic	blend of pyrethrum extract and natural essential oils	12ml/L	12ml/L
Neguvon 98%	98% trichlorphon	1.5g/L	1.5g/L
Carbaryl	80% carbaryl powder	1g/160ml	625mg/L
Partna	400g/L trichlorphon + 20g/L cypermethrin	3.75ml/L	1.5g/L trichlorphon + 75mg/Lcypermethrin
Neopredisan 3%	Preventol CMK (p-Chloro-m-cresol)	30ml/L	30ml/L
Powder Miticides			
Carbaryl dust	1g 80% carbaryl + 25g talc	3% dust	1g/plate
Mitex	Diatomaceous silica desiccant	15-30g/m2	1g/plate
Stalosan -F		50g/m2	1g/plate

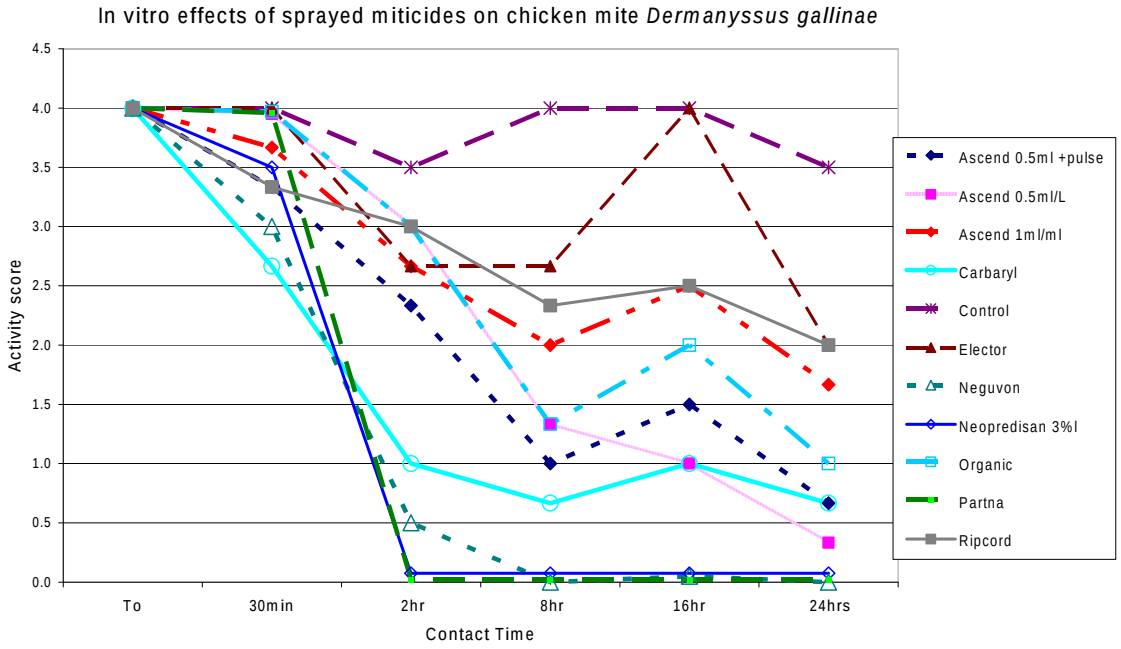
The numbers of mites seen to be active at ½, 2, 8, 16 and 24 hours exposure were recorded using the following scale:

Activity	**score**
No activity detected	0
1-4 mites seen moving	1
5-16 mites seen moving	2
17-64 mites seen moving	3
65-256 mites seen moving	4

Results were averaged across the number of replicates. These are shown in the table below

Mite activity score at times

Spray Miticides	***Replicates***	**To**	**30min**	**2hr**	**8hr**	**16hr**	**24hrs**
Control	*2*	4.0	4.0	3.5	4.0	4.0	3.5
Ascend 0.5ml +pulse	*3*	4.0	3.3	2.3	1.0	1.5	0.7
Ascend 0.5ml/L	*3*	4.0	4.0	3.0	1.3	1.0	0.3
Ascend 1ml/ml	*3*	4.0	3.7	2.7	2.0	2.5	1.7
Carbaryl	*3*	4.0	2.7	1.0	0.7	1.0	0.7
Elector	*3*	4.0	4.0	2.7	2.7	4.0	2.0
Neguvon	*4*	4.0	3.0	0.5	0.0	0.0	0.0
Neopredisan	*2*	4.0	3.5	0.0	0.0	0.0	0.0
Organic	*3*	4.0	4.0	3.0	1.3	2.0	1.0
Partna	*2*	4.0	4.0	0.0	0.0	0.0	0.0
Ripcord	*3*	4.0	3.3	3.0	2.3	2.5	2.0
Powdered miticides							
Carbaryl dust	*1*	4	1	0	0	NT	0
Mitex	*1*	4	3	0	1	NT	0
Stalosan	*1*	4	4	3	0	NT	1



Discussion

These results, presented in the next page, are of a preliminary nature. More replication of the trials is required, with more exact control over the volumes applied to the filter paper, as some of the papers had dried more than others.

Control	3.5	
Ascend 0.5ml +pulse	0.7	Fipronil is the active ingredient in Frontline spray used for control of fleas in dogs. Frontline was taken up by fancy poultry keepers, from where the idea came. I believe these results were affected by drying out. Ascend has been used in the field with some success at both 0.5ml and 1ml per litre. There is considerable data available about this active, which holds considerable potential.
Ascend 0.5ml/L	0.3	
Ascend 1ml/ml	1.7	
Carbaryl	0.7	Variation between replicates reflects desiccation
ElectorExtinosad	2.0	Elector has been approved for control of red mites in poultry facilities in EU, so these results are disappointing; they also reflect limited field trials in NZ. The trials used Extinosad at a dilution rate equal to that recommended for the 17.5x more concentrated Elector available in Australia and EU.
Neguvon	0.0	Uniformly effective
Neopredisan	0.0	The most consistent performer across all replicates; whether the wetting ability played a role in this is open to question.
Organic	1.0	Less effective in 2/3 replicates
Partna	0.0	Uniformly effective
Ripcord	2.0	Ripcord showed poor efficacy across all replicates, interpreted as a result of resistance due to previous repeat exposure.
Powdered miticides		
Carbaryl dust	0	Very rapidly effective when applied as a powder
Mitex	0	Mitex and Stalosan both showed limited effect on motility of mites for at least 8 hours, when the viability of mites fell off; issues to be considered is the high concentration of powder used (175g/m^2)
Stalosan	1	

Comments on these results will be expanded on in the oral presentation.

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THE PROBLEM OF WET LITTER

STEPHEN R. COLLETT

INTRODUCTION

A recent surge in food safety awareness, concern for the environment and compassion for animals has changed the expectation of animal protein consumers. This is particularly so where the affluence of post industrial economies has allowed the predominantly urban populous to become far more demanding as consumers; a situation that is in stark contrast to the developing markets where the consumer is still primarily price-driven.

Urbanization and economic stability has allowed people to lose touch with the realities of food production. This ignorance has created fertile ground for sensational reporting of food borne illnesses, product recalls, antibiotic resistant infections in humans and animal welfare violations, to tarnish the perception of animal agriculture. The resulting distorted and unrealistic view of animal rearing practices and the perceived health risk associated with food in general is, however, a "reality" that must be addressed.

There is no doubt that the responsibility of supplying food products that are *perceived* by the consumer to be safe, wholesome and derived from animals that are treated humanely at all times, lies squarely on the shoulders of the producer. Transparency and traceability have become prerequisites to doing business and this should not be viewed negatively. At last the producers will be seen for what they are, animal husbandry experts striving to achieve maximum productivity by ensuring optimum health and welfare.

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Bedding material is, for example, used in poultry production to enrich the rearing environment and enhance bird welfare. This bedding material, most commonly pine shavings, cushions the birds from the hard floor and helps to keep them dry and comfortable. Even the most ardent sceptic would agree that vibrant young chicks on a fresh bed of pine shavings are the epitome of health and welfare. Wet litter is, in contrast, not only a welfare concern but a threat to the sustainability of the poultry industry because of its impact on bird productivity. Once the moisture content of the litter gets much above 25% it starts to lose its cushioning capacity, it is less effective in helping to keep the birds dry and bacterial emission of ammonia increases. The ensuing discomfort reduces bird productivity and raises concern for the bird's welfare.

The success with which the poultry producers have balanced bird welfare with intensification and productivity is obvious, but there is an increasingly fine line between normal and wet litter. Wet litter is arguably one of the most important emerging conditions in the poultry industry of today. This is particularly so in countries where the moratorium on the use of in-feed growth-promoters has compromised gut health, increased faecal moisture and exacerbated *the problem of wet litter*.

Defining Wet Litter

Litter or bedding becomes wet when the rate of water addition exceeds the rate of removal. Litter management involves balancing water addition through spillage, condensation, urine and faecal water, with removal by evaporation and ventilation. Wet litter can thus be the result of inappropriate house environmental management, disease or physiological perturbation. All too often it is disease that is assumed to be the cause.

Litter moisture content is not homogeneous across the house which makes the term "wet litter" rather nebulous and difficult to define. Water spillage occurs under the drinkers while condensation tends to occur against the walls, thus raising the moisture content of the litter in these areas. In addition, birds evacuate cloacal content shortly after eating, presumably because of a gastro-colic reflex (Denbow, 2000). Since they drink after feeding, excreta (urine, faeces and caecal content) will most often be deposited in close proximity to the drinker-line. Even in a well managed house, the moisture content

of litter under the drinker lines will exceed the popularly stated ideal of 25% while litter in the centre of the house, between feeder-lines is likely to have a moisture content of well below 25%. While this may seem pedantic, a 30 cm (1ft) band of wet litter under each drinker line equates to 5-10% of total floor space, while a one meter (3ft) band of wet litter under the drinker-lines equates to 20- 25% of the floor space in a broiler house. Birds spend a lot of time standing at the drinkers and may, at high stocking densities, be forced to lie down on the relatively wet litter around the drinker-lines. Foot pad scalding and hock burns are a real possibility, even in relatively well managed houses.

Any elevation in litter moisture will first be noticed under the drinker lines and when this occurs it is an indication that the rate of water addition exceeds the rate of its removal. Litter moisture content is difficult to determine in a field setting but an estimate can be made by observing the response of a handful of litter to compression. If the litter is too dry it will not take any form on compression. If it is around 25% moisture it will hold its form for a few seconds after compression and if it is too wet it may exude water and will hold its form indefinitely after compression. While this method of litter evaluation gives a useful estimate of litter moisture at a specific point in the house, it is probably more pragmatic to evaluate the litter "wetness" by determining how far on either side of the drinker-line the litter moisture exceeds 25%. Anything over 30cm (a foot) on either side of the drinker line should be cause for concern.

In many instances the bedding material becomes caked after being wet. This makes evaluation difficult because there is invariably a layer of watery excreta on the surface, while the litter under the impervious "cap" is often quite dry. Under these conditions the litter moisture content *per se* may be within acceptable limits but the birds suffer because they are subjected to the wet surface. This is more of a problem when the litter surface is sticky or greasy as would occur when there is excess lipid (steatorrhea) or mucus (enteritis) in the faeces.

What Causes Wet Litter?

Since litter moisture is a balance between the rate of water addition and the rate of water removal there are environmental, house management and bird related causes. It is not within the scope of this paper to discuss in detail the non bird related causes. Suffice it to say that relative humidity, temperature, ventilation, and litter material/condition will influence the efficiency with which moisture is removed from the litter, and drinker management, relative humidity and temperature control will determine the rate of water addition to the litter.

The bird's contribution to litter moisture is primarily through faecal and urinary water, although evaporative loss can influence litter moisture indirectly by elevating relative humidity and the propensity for condensation. Daily urinary and faecal water loss is slightly less than daily feed intake, on a weight for weight basis. This means that a 2kg bird will deposit around 150g of water into the litter on a daily basis. At the top end of current or proposed EU stocking density limits, this equates to approximately 5 litres of water being deposited onto each square meter of litter surface daily (Horgan, 2006). At this rate even a minor increase in water excretion, spillage or condensation can rapidly exceed the capacity for removal by evaporation.

In the avian species urine and faeces are evacuated together via the cloacal opening, making it difficult to distinguish increased urine output (polyuria) and frequent evacuation of increased watery faeces (diarrhoea). Nutritionally induced wet litter problems are usually the result of a physiological diarrhoea or polyuria. In contrast, infectious cause is more often than not the result of enteritis (inflammatory induced diarrhoea) although; nephropathogenic infectious bronchitis virus (IBV), avian nephritis virus (ANV) and infectious bursal disease virus (IBDV) can cause a primary polyuria by compromising renal function (Cavanagh, 2000; Imada and Kawamura, 2003; Lukert, 2000). To complicate matters further once the intestinal environment is altered by aberrant nutrition, changes in the intestinal microbial community (dysbacteriosis) can itself induce enteritis (Ley, et al., 2006).

Polyuria is a relatively frequent occurrence in both broiler and breeder flocks. It may occur simply because the rate of water intake exceeds requirement as occurs with broiler breeders on restricted intake. More commonly however, it occurs because electrolyte intake (feed or water) is excessive or unbalanced. Sodium, potassium and chloride intake is particularly important in this regard. High salt (NaCl) diets, high potassium diets (soybean), and acid/base imbalance can induce sufficient diuresis to cause wet litter (Goldstein and Skadhauge, 2000). It is becoming increasingly important for the nutritionist to balance electrolyte intake as feed and water intake increases, particularly when using all-vegetable diets (Leeson and Summers, 2005; Oviedo-Rondon, et al., 2001).

Excess calcium in the diet can and frequently does induce polyuria. This is because the capacity for calcium recovery from the renal filtrate runs close to its limit so even a minor excess spills over into the urine thus creating an osmotic diuresis, polyuria and in some cases wet litter (Wideman, et al., 1985). High dietary calcium also predisposes to increased faecal moisture (diarrhoea). Once calcium in the diet exceeds 1% the propensity for interaction with dietary lipid increases and soap formation in the intestinal tract can cause lipid indigestion, steatorrhea, low grade intestinal irritation, and in some cases diarrhoea (Leeson and Summers, 2005).

Steatorrhea is itself seldom a primary cause of wet litter. However although the consequential increase in faecal moisture is usually slight, its significance is exacerbated by the fact that excreted lipid causes “capping” of the litter. By compromising the absorptive capacity of the litter, capping reduces evaporative loss of litter moisture. Steatorrhea is most likely to occur in young birds, when the diet contains a high level of unsaturated free fatty acids and especially if the fat is rancid (Engberg, et al., 1996; Leeson and Summers, 2005; Mossab, et al., 2000). Since broiler diets are frequently fortified with relatively high levels of lipid, any factor that reduces digestion and absorption will also manifest as a degree of steatorrhea. This can occur in both vegetable based and animal protein based diets. Animal protein increases the proportion of bile-salt

inactivating bacteria in the intestine, thus compromising lipid digestion and absorption (Drew, et al., 2004; Knarreborg, et al., 2004; Knarreborg, et al., 2002). Although these organisms are a lot less prevalent in the intestinal tract of birds fed vegetable diets, the high level of non starch polysaccharides in these diets may interfere with bile-salt recirculation thus reducing lipid digestion and absorption (Meng, et al., 2004). In such cases the addition of exogenous dietary enzymes is essential in order to avoid the problem of wet litter.

In contrast to nutritional effects on water balance, infectious agents cause wet litter problems by damaging the lining of the intestinal tract and thereby reducing its capacity for digestion and absorption. Since water is the medium by which molecules move across the intestinal membrane, any reduction in nutrient absorption manifests as an increased water loss. In addition to increasing faecal water, disease of the intestinal tract causes inflammation which results in, amongst a host of other things, increased mucus production. The increased excretion of faecal water, non-digested nutrient and mucus is highly hazardous from a wet litter standpoint. Litter moisture content rises rapidly because of the increased water loss, and evaporation of this moisture from the litter is prevented by the formation of an impervious mucoid cap on the litter surface. In addition, the undigested feed in the faecal material is rapidly converted into noxious products by the microorganisms in the litter, having now been provided with the three critical ingredients: nutrients, water and heat. Under these conditions bird comfort and productivity rapidly declines.

In addition to altering litter conditions, undigested and non absorbed nutrients cause a shift in the composition of the intestinal microbiota. This can have both a short and long term effect. If digestion and absorption inefficiencies are severe enough it will manifest as poor performance immediately. In contrast, even low grade changes can alter microbial communities gradually through replacement and displacement and the negative effect of this developing dysbacteriosis on bird productivity thus escalates over time. The development of this aberrant microbiota is relatively easy to recognise because microbial fermentation of undigested nutrients causes gas to accumulate in the caeca.

In the modern high producing birds of today, the caeca are not considered to make an important contribution to feed conversion efficiency. The caeca do however play a critical role in the process of water and electrolyte balance (osmoregulatory) (Goldstein and Skadhauge, 2000). Most of the urine entering the cloaca passes retrograde up into the caeca where post renal water recovery in the caeca occurs. Dysbacteriosis in this part of the intestinal tract can significantly impair post renal water and electrolyte recovery and thereby cause wet litter.

Anti-nutritional factors and toxins can also cause renal damage, intestinal inflammation, dysbacteriosis, enteritis and ultimately wet litter problems. While anti-nutritional factors are ingredient specific and addressed by feed processing or exogenous enzyme addition, toxins are a little more difficult to tackle because they can be ingredient or intestinally derived. Mycotoxins are probably the most common ingredient derived toxins that cause wet litter. There are three mycotoxins, ochratoxin, citrinin and oosporein that can cause enough renal damage and polyuria to result in wet litter problems (Hoer, 2000). Mycotoxins such as the trichothecenes, that cause ulceration in the lining of the digestive tract, and the aflatoxins, that have an immune suppressive effect, may also predispose to the development of wet litter problems (Hoer, 2000). Low grade contamination of feed with mycotoxins is seldom recognised as a problem. However since one of the functions of these fungal metabolites is to help them compete with bacteria, they can even at low doses, change the composition of the intestinal microbiota.

With respect to intestinally derived toxins, exo-toxins produced by *Clostridium perfringens* are of most concern. These toxins have been reported to cause anything from low-grade (sub-clinical) enteritis to acute life threatening necrotic enteritis (Ochiai, et al., 2003; Wise and Siragusa, 2005). This organism is well adapted to compete in the modern poultry production system. It survives well in the caecal environment, is able to endure even the most stringent house clean out and is capable of extremely rapid division and multiplication (Wages and Opengart, 2003). Although it is frequently present in the caeca of most commercial poultry, it seldom causes overt disease because it only produces toxins when it is dividing rapidly. It can however create a very serious problem when

inflammation in the upper intestine reduces the efficiency of digestion and absorption and stimulates the production of excess mucus (Collier, et al., 2008). When this mucus and undigested nutrient makes its way into the caeca, resident *C. perfringens* starts to divide very rapidly and consequently produces copious amounts of toxin.

Addressing the problem of wet litter

The first step in addressing any problem is to understand the process by which it developed. As outlined above, this is a multi factorial condition and consequently requires a multi facetted corrective approach. During every production cycle there are going to be periods when avian osmoregulation is challenged and the rate of water excretion increases. The constant and careful control of the house environment and the availability of additional ventilation and heating capacity to cope with any increase in excreted water are fundamental. It is also important to identify what, within the production system, is actually changeable before proposing an intervention strategy. There might for example be marketing or economic constraints that preclude the implementation of certain control strategies.

Dietary, environmental and primary infectious diseases are relatively easy to diagnose and correct/treat. Non-specific enteritis or dysbacteriosis is in contrast more of a challenge to deal with since the cause is ill defined and multi factorial. Even this situation can be corrected by implementing a methodical approach to rehabilitation of the gut flora. The process begins with seeding the gut with favourable flora (probiotic/competitive exclusion) and nurturing their development and establishment with a suitable organic acid in the drinking water. The simultaneous inclusion of selective exclusion products in the feed to make the unfavourable organisms less competitive is very advantageous at this point in time. Antibiotics have been used to achieve this for decades but recently several alternative approaches (prebiotics) have gained popularity. This is especially effective if the selective exclusion product has an anti-inflammatory effect, as this reduces the negative effect that any gut health challenge has on digestion and absorption efficiency.

Since much of the gut flora disturbance arises from digestible and non-digestible nutrients passing through to the distal part of the intestinal tract, there is merit in using exogenous enzymes to enhance digestion (Choct, et al., 1992). This allows the nutritionist the opportunity to drop the nutrient density of the diet and reduce the chance of nutrient passage without affecting the available nutrient profile.

CONCLUSIONS

The economic, health and welfare connotations of elevated litter moisture are likely to make wet litter problems first limiting in broiler production. The margin for error in litter moisture control will diminish as broiler growth rate improves, especially if the process of intensification continues to respond to economic pressure. As this margin for error narrows wet litter problems are likely to become more common and attract a lot more attention in the future. In order to keep pace with the broiler's constantly improving capacity for growth rate, and to avoid compromising bird welfare, there is a need for a significant change in the way these birds are housed.

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MODELS IN BROILER NUTRITION: A QUEST FOR OPTIMA[1]

MARTIN J. ZUIDHOF

SUMMARY

Many factors interact and many objectives compete in the optimal production of broilers. This paper summarizes the nonlinear effects of dietary balanced protein and dietary energy on feed intake, growth curves, and yield dynamics for one strain of broilers. Sex, prestarter nutrition, and subsequent dietary energy and protein levels had significant nonlinear effects on broiler feed intake, growth rates and yield dynamics. These effects have been quantified using previously available and novel nonlinear models. Feed is the largest single cost in broiler production, but predicting intake has proved challenging for the animal science community. Therefore modeling growth profiles has received much attention in recent years. In this paper, a nonlinear mixed model that describes scenario-specific growth curves, crucial for the timing of processing, is presented. Yield dynamics are explored under various nutritional scenarios aiming at the prediction of carcass value. This paper provides an integrated generalized nonlinear model that can be applied to a wide range of supply chain optimization problems. Data specific to strain, production conditions, or particular environments, will improve the value of the model in commercial applications.

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INTRODUCTION

Broiler growth and development are dynamic processes. During the first week of life, development of the gastrointestinal (**GI**) tract is a high priority. Around 25% of the total BW gain during the first week is accounted for by the GI tract, corresponding to a 4-fold increase in GI weight during that time. Conversely, even though the breast increases 16-fold in weight during the first 7 d, it accounts for only 10% of the total BW gain of the first week. As the broiler grows to market weight, these priorities reverse dramatically (Figure 1).

As BW increases, so does the absolute value of the carcass. However, since not every portion of the carcass has the same value, and because carcass proportions change both with both age and nutrient intake, the value of the carcass changes nonlinearly as a bird develops. Nevertheless, the portion that depends on nutrient intake can be manipulated to a significant degree through diet formulation.

Different tissues have different nutrient and energy requirements, both for deposition and for maintenance. Retained energy differs for muscle tissue (4 kcal/g) and adipose tissue (9 kcal/g). The maintenance requirements of tissues relate to a large degree on the cost of protein turnover and ion transport. Gill et al. (1989) reported that in growing lambs the GI tract and liver accounted for almost two-thirds of the ion transport energy expenditure. For protein turnover, the relative contributions of various organ systems to the total energy expenditure were approximately 25% each for the GI tract, skin, and muscle, and only 0.5% for adipose tissue. Thus, the energetic cost of gain depends on the composition of gain, and the energy cost of maintenance depends on the current body composition.

In order to optimize the process of commercial production, accurate models of feed intake, growth, and carcass yield dynamics are of crucial economic importance. To be of value to the supply chain, a model must take into consideration the natural physiological processes as well as the nutrition-induced dynamics that affect growth and development.

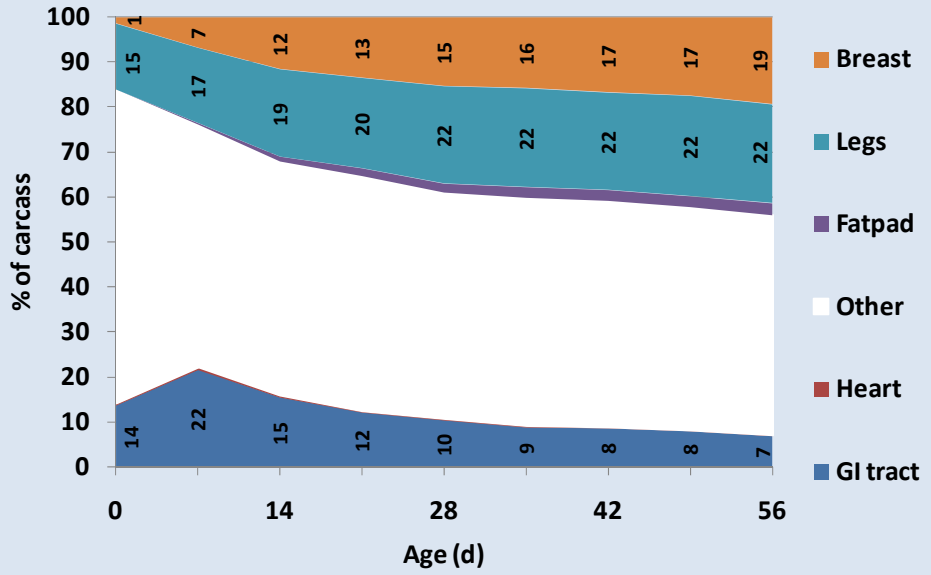


Figure 1. Development of the broiler carcass is dynamic. Early in life, development of supply and structural components is a priority. By 3 wk of age, priority shifts to muscle growth (meat yield). Source: Zuidhof, unpublished data.

Given that the value of a carcass can be manipulated through diet formulation, the optimization of a particular end product may be associated with specific nutrient requirements that require a different dietary formulation. The cost implications of situations that demand variable nutritional inputs are probably the most frequent challenge of optimization processes. The objective of this paper is to provide a decision making tool that takes into account the impact of diet on carcass value and enables supply chain optimization through improved nutrition-related decisions.

EXPERIMENTAL DESIGN

A study was conducted to investigate the simultaneous interactions of dietary energy and dietary balanced protein (**DBP**) on performance of broilers to 56 d of age. At hatch, 3,424 Cobb x Avian 48 chicks were randomly assigned to one treatment within a 2 x 2 x 3 x 5 factorial arrangement of treatments. The experimental design consisted of 2 sexes; 2 levels of prestarter; 3 dietary ME levels; and 5 DBP levels. The prestarter was fed from 0 to 11 days of age, and the different levels of ME and DBP from 11 to 56 days.

The dietary ME levels were 94, 97, and 100% of the breeder's dietary recommendations for maximum growth rate and feed efficiency (**E94**, **E97**, and **E100**, respectively; Cobb Broiler Nutrition Supplement, 2004, Cobb-Vantress, Inc., Siloam Springs, AR, 72761). Target ME levels for the E94, E97 and E100 treatments, respectively, were 2,960, 3,055, and 3,150 kcal/kg in the starter phase; 3,010, 3,105, and 3,200 kcal/kg in the grower phase; and 3,055, 3,155, and 3,250 kcal/kg in the finisher phase.

The DBP levels were 85, 92.5, 100, 107.5, and 115% of the same recommendations (**P85**, **P92.5**, **P100**, **P107.5**, and **P115**, respectively), with Met, Met + Cys, Trp, Thr, and Arg on a total amino acid basis in constant proportions to Lys. Target %CP (%Lys) levels for the P85, P92.5, P100, P107.5, and P115 treatments, respectively, were 17.9 (1.02), 19.4 (1.11), 21.0 (1.20), 22.6 (1.29), and 24.2 (1.38) in the starter phase; 16.2 (0.94), 17.6 (1.02), 19.0 (1.10), 20.4 (1.18), and 21.9 (1.27) in the grower phase; and 14.9 (0.85), 16.2 (0.93), 17.5 (1.00), 18.8 (1.08), and 20.1 (1.15) in the finisher phase. The prestarter nutrient densities were based on breeder recommendations for maximizing growth rate and feed efficiency (**HighPS**), or reduced feed cost (**LowPS**). Sixteen pens (n=4 per treatment) were used for the prestarter phase. At 11 d of age, birds were redistributed to 60 pens (n=2 per treatment). Since after 11 days of age the birds on the prestarter treatments were assigned to the different ME and DBP treatments, it was possible to estimate the effect of prestarter on overall growth, but not on specific feed efficiency after 11 days of age.

Nonlinear models were developed to describe BW, feed intake, and carcass yield dynamics. A total of 1,200 broilers were individually weighed weekly, and at redistribution. These longitudinal BW data were subjected to nonlinear mixed Gompertz model analysis to estimate growth curves for each treatment (Wang and Zuidhof, 2005). The model accounted for individual variation in growth rates, and provided treatment-specific predictions of growth. A total of 1,920 broilers were dissected twice weekly from 21 to 56 d of age to evaluate the effects of sex and diet on the allometry (yield dynamics) of breast meat, legs, wings, and abdominal fatpad (Huxley, 1932). Paired F-

tests were used (Motulsky and Ransnas, 1987) to test for significant differences between treatment-specific growth and yield curves. A nonlinear model based on a Cobb-Douglas form (Griffin et al. 1987) was developed using a stepwise procedure to estimate feed intake as a function of BW, ME, Lys, gain, and sex.

RESULTS AND DISCUSSION

Feed Intake

The final form of the feed intake model incorporated significant components of BW, nutrient composition of the feed, sex, and BW gain. The feed intake model, with the final estimated coefficients was:

$$ME\ intake = 0.14BW^{0.456}(ME/Lys)^{1.227}(1\text{-}0.013 \times Sex) + 0.67ADG^{1.44}\ (1\text{-}0.17 \times Sex)$$

where *BW* was average body weight (kg) of the broilers during the time period during which feed intake was measured, *ME/Lys* was the ratio of metabolizable energy content of the feed to the lysine content of the feed provided in the same period (kcal/g), *sex* was a dummy variable for sex of the birds (0 = female; 1 = male; 0.5 = mixed sex), and *ADG* was the average daily BW gain for the period. The model predicted ME intakes with reasonable accuracy.

Figure 2 illustrates sex-related differences in feed intake. At higher BW, females grew at a slower rate, and thus consumed less ME per unit of BW than males. The model predicted lower intake with higher dietary ME levels, which was confirmed by analysis of variance (data not shown). Similarly, the analysis of variance indicated that ME intake was slightly higher at low BW, which the current feed intake model predicted. Analysis of variance indicated that feed intake was maximized at recommended (P100) DBP levels. The main difference was increased feed intake in P100 compared to P85 from 28 to 42 d; this effect was predicted by the current nonlinear model. These differences in feed intake are for supply chain optimization, as feed is the single largest contributor to the cost of raising broilers.

The coefficients of the ME intake model reflect underlying biological mechanisms associated with feed intake. The maintenance component of the model (intake as a function of BW) infers that the maintenance component of males was lower (1.3%) than that of females. This is somewhat surprising since males have a greater proportion of lean tissue, and thus would be expected to have lower maintenance requirements than females. Shalev and Pasternak (1998) reported a 5 to 9% higher theoretical maintenance requirements in male broilers compared to females. In contrast, Samadi and Liebert (2006) found 1.5 to 11% higher nitrogen maintenance requirements in female broiler chickens than in males. The latter finding is consistent with the inference of the current model, though it is worth noting that the 1.3% difference in maintenance requirements of males predicted by the current model is significant but relatively small.

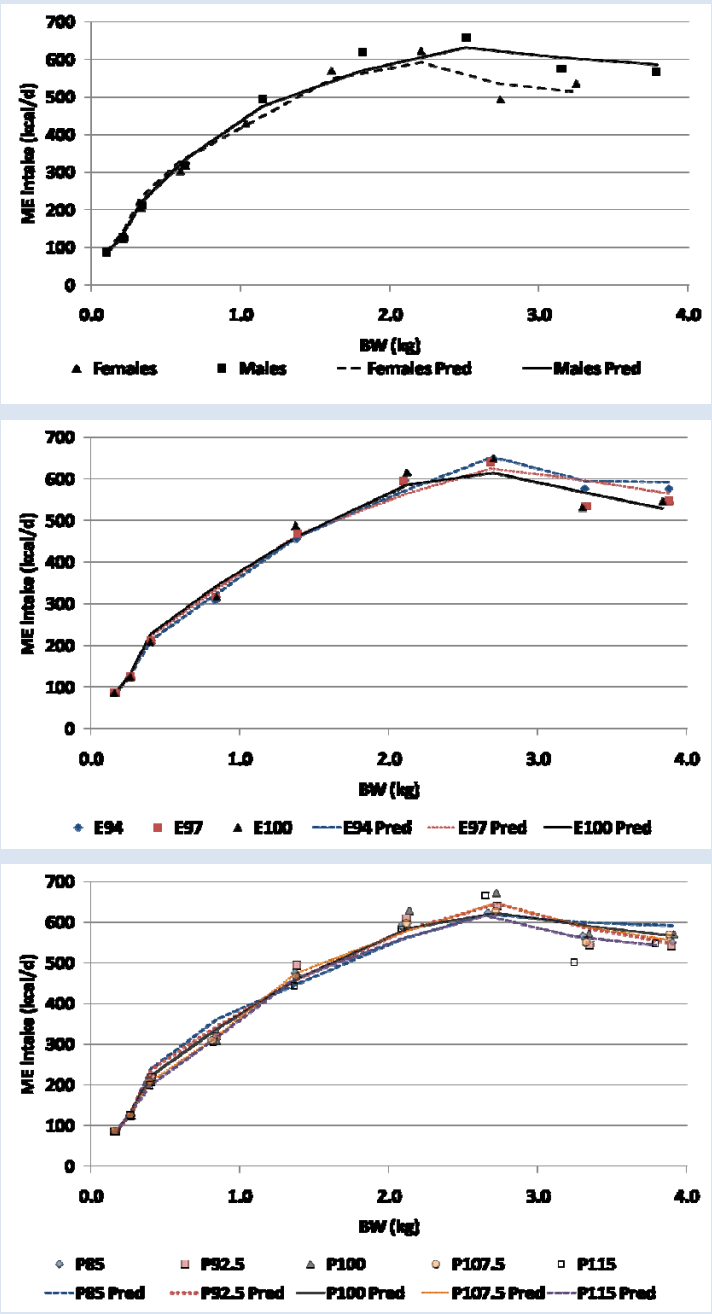


Figure 2. Actual and predicted ME intake for sex (top panel), dietary energy content (middle panel) and dietary balanced protein (bottom panel). See text for model description.

The exponential coefficient (1.44) on average daily gain indicates that the energy cost of growth increased with increasing growth rate. This was likely due to the differences in fat deposition as broilers mature. The energy cost estimate for average daily gain was 17% lower for males than for females. This was reflected the fact that females in deposited more fat than males. Comparison of a linear model analysis using the current data set and carcass composition data from the same trial inferred that the estimated energy requirement was 1.52 kcal/g for breast muscle, compared to 5.22 kcal/g for fatpad.

Growth

The Gompertz growth model and the coefficients estimated for all of the main treatment effects are presented in Table 1. These can be used to predict BW at any age for each

Table 1. Coefficients for a nonlinear mixed Gompertz model[1] describing the growth of male and female broilers provided diets with varied ME and dietary balanced protein (DBP) levels: main effects.

Effect	Treatment	W_m	B	σ^2_u	ε
PS [2]	PSHigh	5.964	0.0435	0.512	0.073
	PSLow	6.165	0.0425	0.564	0.071
Sex	Female	5.235	0.0439	0.175	0.060
	Male	6.837	0.0425	0.330	0.074
DBP [3]	P85	6.116	0.0424	0.449	0.071
	P92.5	6.025	0.0432	0.503	0.071
	P100	6.113	0.0432	0.530	0.073
	P107.5	6.164	0.0429	0.645	0.071
	P115	5.892	0.0434	0.556	0.075
ME [4]	E94	6.224	0.0423	0.579	0.071
	E97	6.039	0.0430	0.576	0.072
	E100	5.921	0.0437	0.466	0.073

[1] The nonlinear mixed model was $W_{it}=(W_m+u_i)exp^{-exp(b(t-t^*))}+\varepsilon_{it}$ where W_{it} was the expected BW (kg) of individual i at age t (d); W_m was the average mature BW of all birds within a treatment; u_i was a random deviation of mature BW of the individual i from the average mature BW of its genotype [$u_i \sim N(0,\sigma_u^2)$, and independent of ε_{it}]; b was a maturation rate (d^{-1}); t^* was the time (d) at which growth rate was maximum [$t^*=ln(-ln(W_0/W_m))/b$; initial chick weight,W_0, was measured]; and ε_{it} was the residual error of individual BW measurements.

[2] Prestarter nutrient levels were based on Cobb-Vantress recommendations for maximizing growth rate and feed efficiency (PSHigh), or for reduced feed cost (PSLow).

[3] Five protein treatments (P85, P92.5, P100, P107.5, and P115), balanced for 6 amino acids were provided, at 85, 92.5, 100, 107.5, and 115%, respectively, of Cobb-Vantress dietary specifications for maximum growth rate and feed efficiency.

[4] Dietary ME treatments E94, E97, and E100 were 94, 97, and 100% of Cobb-Vantress dietary specifications for maximum growth rate and feed efficiency.

treatment. Statistical comparison of Gompertz growth curves inferred that male broilers grew faster than female broilers (P<0.0001).

In males only, each decreasing dietary ME treatment resulted in an upward shift of the BW curve (P<0.05). The shape of the BW curves indicates that the differences in BW were realized after 42 d of age. There were no ME effects on female BW curves. The only significant BW curve difference due to the main effect of dietary DBP was an upward shift of the P85 treatment BW curve relative to the P115 treatment (P=0.02). Predicted BW of the P85 broilers was higher than the P115 broilers from 42 to 56 d of age.

The statistical curve comparisons demonstrated with a high level of confidence (P=0.0002) that the BW curve of broilers fed HighPS were shifted significantly higher compared to the LowPS treatment (Figure 3). The statistical analysis (confirmed with ANOVA) clearly demonstrated clearly that higher nutrient density during the first 11 d resulted in persistently higher broiler BW.

Yield

The allometric function describing yield was of the form $y=ax^b$, where y was the weight (g) of the carcass part (i.e. breast, legs, fatpad, etc.); x was eviscerated BW (g), with head, neck, and feet removed; and a and b were coefficients. The allometric coefficient b is of particular biological interest, since b=1 is a linear function, meaning the part grows at the same rate as the body as a whole. If b<1, the part matures early, and if b>1 the part matures later.

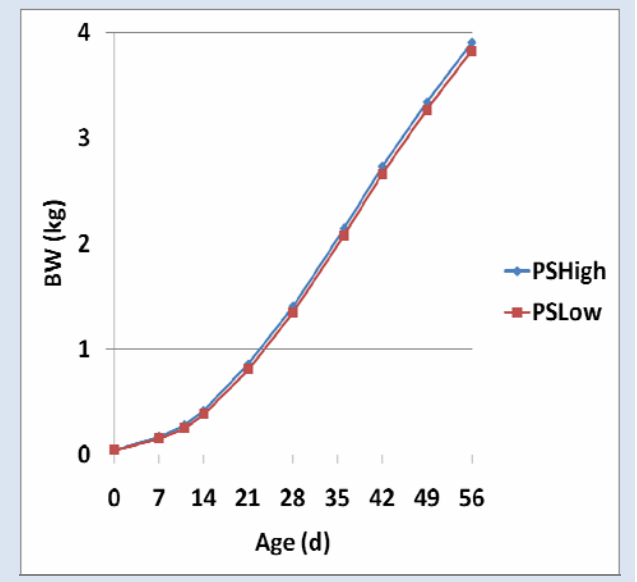


Figure 3. High nutrient density in the prestarter phase resulted in a persistent BW increase.

The breast muscle yield curve was shifted upward for females relative to males (P<0.0001). That is, at the same BW, females produced a higher proportion of breast meat. Increasing sex differences in breast muscle yield with increasing age have been observed in previous studies (Gous et al. 1999; Kidd et al., 2005; Zuidhof, 2005). The equations describing breast yield for females was $y=0.135x^{1.112}$, and for males was $y=0.166x^{1.081}$. The higher allometric coefficient for breast meat of females indicates that as the bird grows the rate of breast muscle growth in relation to the whole body increases at a higher rate in females than in males. Thus, at higher BW, the difference in breast muscle size between males and females is larger. In contrast, development of leg muscle (drum + thigh) was almost linear, and lower in females than in males ($y=0.374x^{0.979}$ and $y=0.321x^{1.002}$, respectively; P<0.0001). Wing yield was also lower in females than in males ($y=0.368x^{0.848}$ and $y=0.292x^{0.882}$, respectively; P<0.0001). The low allometric coefficient for wings indicates that they develop early relative to the rest of the body.

The effect of DBP in relation to breast yield in male and female broilers is summarized in Figure 4. Each reduction in DBP decreased breast meat yield in males as well as in females. Increasing DBP above recommended levels did not improve breast yield of females, while in males only a moderate increase in DBP (107.5% of recommended) shifted the breast yield curve upward. A further increase, to 115% of recommended DBP, did not further improve breast yield of males.

The LowPS diet, which was formulated with lower nutrient density, resulted in a downward shift of the breast yield curve relative to the HighPS treatment ($y=0.176x^{1.075}$ and $y=0.155x^{1.092}$, respectively; P=0.0378). Low dietary energy (E94) caused an upward shift in the breast yield curve relative to both the E97 and E100 treatments (P<0.0001). This is likely due to an increase in protein intake with reduced dietary energy, as the birds in the E94 treatment increased their feed intake from 35 to 56 d of age; their ME intake did not differ during this period (data not shown).

In both sexes, fatpad weights increase exponentially with age. Fatpad yield was higher in females than in males($y=0.008x^{1.488}$ and $y=0.0026x^{1.269}$, respectively; P<0.0001). This is caused by differences in hormone balance related to preparation for egg production in females (Gous et al., 1999).

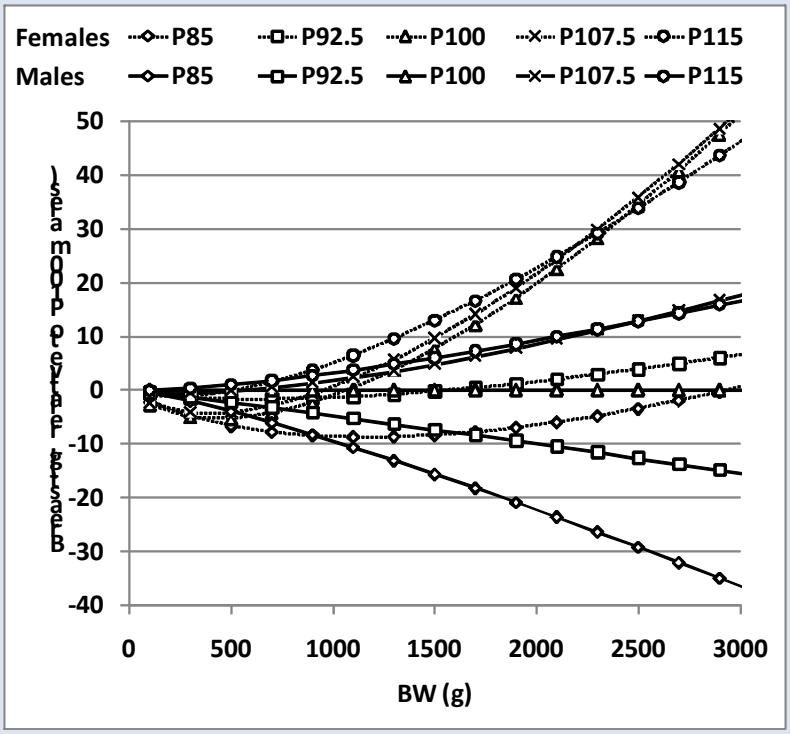


Figure 4. Breast yield relative to P100 males. In males and females, each reduction in dietary balanced protein (DBP) decreased breast meat yield. In females, increasing DBP above recommended levels did not improve breast yield. In males, a moderate increase in DBP (107.5% of recommended) shifted the breast yield curve upward. A further increase to 115% of the recommended level did not further improve breast yield.

Zuidhof (2005) assigned allometric coefficients for fatpad yield ranging from 1.23 to 2.10 in females, and 1.09 to 2.17 in males, depending on the strain, with average values of 1.59 for females, and 1.53 for males. These coefficients are in agreement with the results of the current trial in which fatpad yield was higher in females than in males ($y=0.008x^{1.488}$ and $y=0.0026x^{1.269}$, respectively; P<0.0001).

CONCLUSIONS

Sex, prestarter nutrition, and subsequent dietary energy and protein levels had significant nonlinear effects on broiler feed intake, growth rates and yield dynamics. To aid the process of optimizing nutritional programs, these effects have been quantified. Modeling feed intake is important because feed is the largest single cost in broiler production. Modeling growth profiles is important for the timing of processing, while models of yield predict the value of the cut up carcass. This analysis provides the most valuable insight

for the specific strain that was used. Although data specific to strain, production conditions, or particular environments will improve the value of the model in commercial applications, this paper provides an integrated generalized nonlinear model that can be applied to a wide range of supply chain optimization problems.

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MANIPULATING FAT DIGESTION AND ABSORPTION TO IMPROVE EFFICIENCY

R.R.CARTER

INTRODUCTION

Fat is insoluble in water which enables it to form the structural lipid found in cell membranes. However, this insolubility in water necessitates quite complex physical and chemical steps in digestion and absorption. This paper describes various factors affecting the utilization of fat by poultry and provides suggestions to improve its utilization. Dietary fat triglycerides are glycerol linked with three fatty acids which contain an even number of carbon atoms. The saturated fatty acids in commonly used feed fats (Table 1) are mostly palmitic (C16:0) and stearic (C18:0) with the unsaturated fatty acids being mainly oleic (C18:1 double bond) and linoleic acid (C18:2 double bond).

Table 1. Approximate % of fatty acids in fats and oils

Fat/oil	C16:0	C18:0	C18:1	C18:2
Beef tallow	35	36	24	1
Pork tallow	29	20	41	9
Poultry oil	22	7	42	23
Soy oil	11	4	27	50
Canola oil	5	2	61	19
Sunflower oil	6	5	23	54
Cottonseed oil	25	3	19	48
Palm oil	38	5	42	9
Maize oil	14	3	27	53
Rice bran oil	15	2	42	39

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Digestion and absorption

Due to insolubility in water, fats and oils require emulsification before they can be hydrolysed by pancreatic lipase in the duodenum. The emulsification process results in small droplets of dispersed fat. The products of enzymatic hydrolysis (fatty acids and monoglycerides) aggregate into micelles which then pass through the unstirred water layer adjacent to the absorptive epithelium where the fatty acids and monoglycerides are absorbed. The fatty acids and monoglycerides are then re-esterified in enterocytes. Key steps in this process are adequate emulsification and micelle formation.

Bird age and fat description

Oil and fat sources of plant or animal origin are routinely included in diets fed to broiler chickens, however there is evidence that the young bird's capacity to digest and absorb dietary fats is limited. Bile secretion is considered to be the rate limiting factor in fat utilization in the first weeks after hatching (Nitsan *et al*, 1991; Krogdal & Sell, 1989). Limitations in digesting fats with a higher content of saturated fatty acids have been demonstrated in younger chickens (Fedde *et al*, 1960; Carew *et al*, 1972; Wiseman & Salvador, 1989). Younger chickens have also been shown to have a limited ability to absorb fats with a higher proportion of palmitic (C16:0) and stearic (C18:0) acids (Renner & Hill, 1960). The effect of age on fat digestibility of the diet and apparent metabolisable energy (AME) of an 'animal' fat (Table 2) were demonstrated by Scheele *et al* (1997) supporting the use of different AME values for fats and oils for different aged birds.

Table 2. AME of added fat and total diet fat digestibility in broilers and adult cocks

Age	**Fat AME (MJ/kg)**	**Total fat digestibility, %**
Week 2	27.96[a]	62.5[a]
Week 4	29.02[b]	66.9[b]
Week 6	32.40[c]	72.0[c]
Week 8	33.19[d]	73.4[c]
Adult cocks	36.47	85.0

(different superscripts within a column are significantly different, $P<0.05$).

The issue of fat type and bird age was re-examined by Tancharoenrat *et al* (2009) who also found that the AME of the fat sources tested (tallow, soybean oil, 50:50 blend of tallow and soybean oil, poultry fat and palm oil) was significantly lower in the first week of life compared with weeks 2, 3 and 5 with tallow having the lowest AME value.

Animal fat sources are generally considered to be less well utilized than plant sources which have a higher proportion of unsaturated fatty acids. The more polar unsaturated fatty acids exhibit higher solubility in the micellar phase of digestion than saturated fats. The lower digestibility of acid oils is thought to be due to the reduced level of monoglycerides available for micelle formation with the effect less pronounced with acid oils high in unsaturated fatty acids. Scheele *et al* (1997) demonstrated relationships between fat/oil AME, PUFA content (poly-unsaturated fatty acid) and palmitic (PA) + stearic (SA) acid content (Table 3). The equations describing the relationships calculated by regression analyses are:

$$\text{AME (MJ/kg)} = 36.4 - 0.26(\text{PA+SA}) \qquad r^2 = 0.85$$

$$\text{AME (MJ/kg)} = 28.0 + 0.10(\text{PUFA}) \qquad r^2 = 0.60$$

Table 3. AME values of fats in 4 week old broiler chickens, PUFA and PA+SA content

Fats/oils	**AME, MJ/kg**	**PUFA, %**	**PA+SA, %**
Soybean oil	35.4[a]	60.0	15.3
Safflower oil	35.0[a]	76.2	10.0
Grapeseed oil	35.0[a]	69.9	9.3
Linseed oil	34.0[ab]	74.7	8.4
Rapeseed oil	33.5[abc]	32.7	6.9
Olive oil	32.5[bc]	18.3	15.8
Coconut oil	31.6[bc]	10.2	4.0
Groundnut oil	31.5[cd]	33.5	15.7
Poultry oil	30.1[d]	16.4	23.3
Mixed animal fat	28.1[e]	9.3	31.6
Palm oil	25.8[f]	11.0	45.6
Tallow	24.5[f]	7.9	39.9

(different superscripts within a column are significantly different, $P<0.05$)

Early research showed synergistic effects of combining unsaturated fats with saturated fats on digestibility of the saturated fats (Young and Garret, 1963; Lewis and Payne, 1966). The absorption of stearic acid (C18:0) was improved when blended with linoleic acid (C18:2) (Renner and Hill, 1961). Sibbald (1978) showed that the ME of a soybean oil-tallow mixture was higher than the sum of the ME values of the component parts with this result supported by Scheele and Versteegh (1987).

Wiseman (1999) combined the ratio of unsaturated fatty acids to saturated fatty acids (U/S), the free fatty acid content of the fat/oil (FFA), and bird age (1.5 weeks and 6 weeks of age) into equations to predict the AME of a fat/oil. This analysis showed that –

- fat AME increased curvilinearly as the U/S increased from 0.9 to 4.1
- fat AME was higher for a 10% FFA fat than a 40% FFA fat until the U/S reached around 3 when the AME values for a 10% FFA fat in young birds overlaped with the AME values for the higher FFA fat in older birds
- otherwise, fat AME was higher in 6 week old than 1.5 week old broilers

However, Wiseman (1999) cautioned that the U/S ratio should be based on adding myristic (C14:0), palmitic (C16:0) and stearic (C18:0) acids but should not include lauric acid (C12:0) which responds like an unsaturated fatty acid due to its shorter chain length.

Oxidation & fat AME

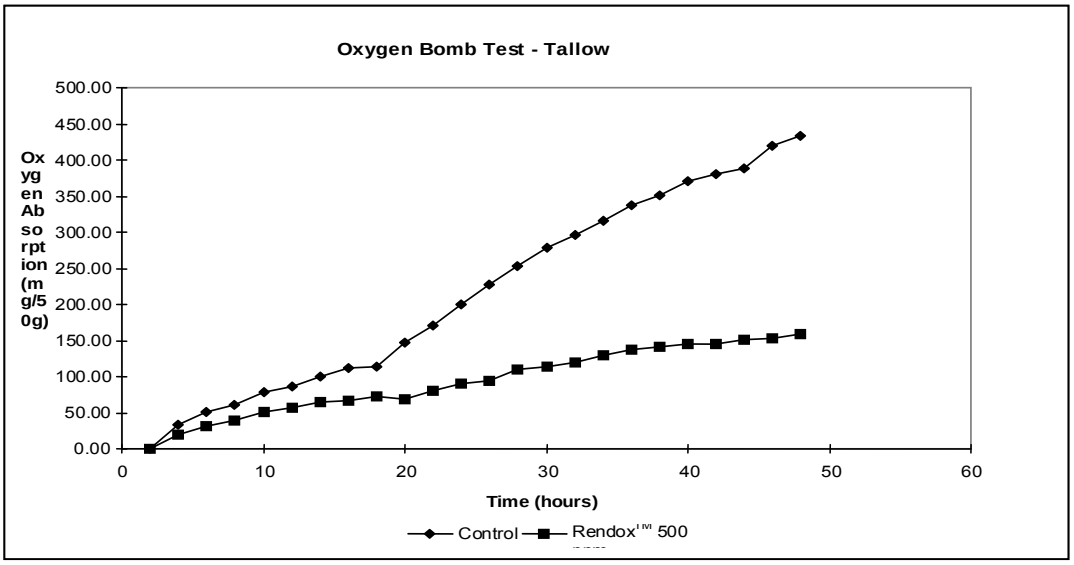
In a study involving poultry grease, waste frying oil, choice white grease, an animal-vegetable blend, palm oil, yellow grease and soybean oil, Pesti *et al* (2002) found that the AME of the fat source in broiler chickens was significantly correlated to:

- 20 hour AOM stability (Active Oxygen Method measures peroxide value after 20 hours of bubbling air through the sample)
    - r = 0.92520 (P=0.0010)
- iodine value (grams of iodine absorbed by 100g of fat – a measure of the number of double bonds)
    - r = 0.92147 (P=0.0011)

Racanicci *et al* (2004) fed poultry fat with peroxide values of 0.78 or 4.17mequ/kg to 31-34 day old broilers and determined the AME of this fat to be 38.7 and 32.5MJ/kgDM respectively (P<0.001), ie. a 16% reduction in AME for a moderate change in peroxide value. This indicated the importance of ensuring the oxidative stability of fats and oils which can be done by adding an antioxidant to the fat/oil. The effect of including an antioxidant into tallow on its accelerated oxidative stability is shown in Figure 1 with the control sample exhibiting oxidation induction at around 18

hours compared with the antioxidant treated sample showing no induction point and a much reduced rate of oxygen absorption indicating effective stabilization of the tallow.

Figure 1. New Zealand tallow response to liquid antioxidant in the oxygen bomb test



Feed enzymes and antibiotics

Removing antibiotics from broiler diets could contribute to a higher degree of deconjugation of bile salts by intestinal microflora which could have a negative impact on fat digestion as conjugated bile salts are needed for micelle formation. Indeed a lower intestinal concentration of conjugated bile salts was observed in broiler chickens receiving a diet without an antibiotic compared to birds that received the antibiotic (Knarreborg *et al*, 2002). The lower level of conjugated bile salts was associated with a higher number of *Clostridium perfringens* which express high levels of bile salt hydrolase activity. Hence broiler diets without antibiotics may constrain lipid digestion unless alternative intestinally active anti-bacterial agents are included in diets.

Nutrient digestibility can be impeded with diets containing non-starch polysaccharides which induce elevated intestinal viscosity. Van der Klis *et al* (1995) and Scheele *et al* (1997) showed that fat digestibility and AME decreased with increasing ileal viscosity. This is most commonly associated with diets based on wheat and barley and can be overcome with the addition of appropriate enzymes (eg. xylanase and β-glucanase, Fig. 2 shows viscosity response to Kemzyme® W) which enables an increase in fat digestibility and an overall increase in diet AME (Table 4).

Figure 2: New Zealand wheat (2000) extract viscosity response to enzyme treatment: temperature, pH and pH exposure times adjusted to simulate gut conditions

(Crop & Food Research, New Zealand)

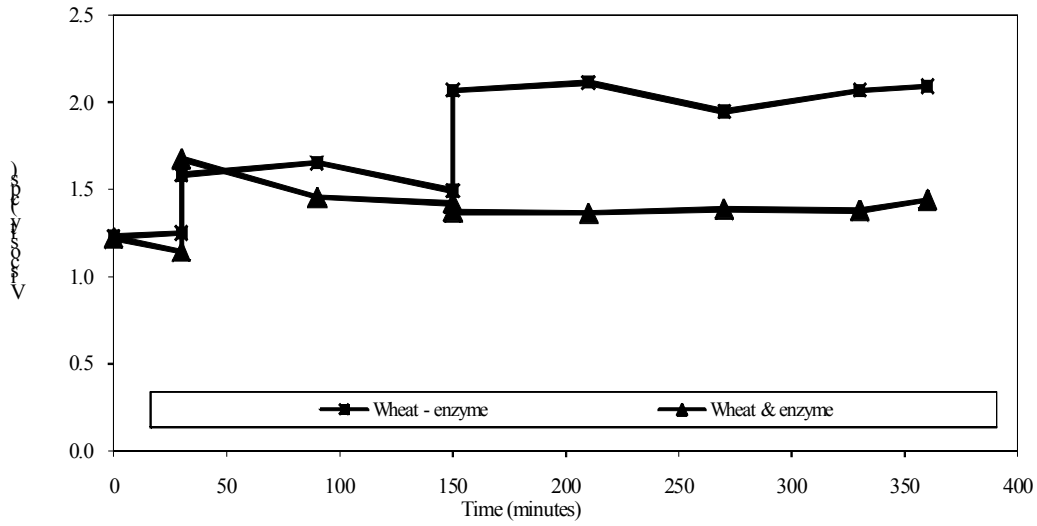


Table 4. [1]Dietary fat digestibility and diet AME response to enzyme addition to the diet of 35 week old laying hens (Institut de Recercai Tecnologia Agroalimentaries, Spain, 2005); [2]diet AME response to enzyme addition to the diet of broiler chickens (Massey University, New Zealand, 2003).

Bird	**Treatment**	**Fat digestibility, %**	**AME, MJ/kg**
Laying hens[1]	Control	75.5[a]	10.78[a]
	Enzyme[3] (500g/t)	79.1[b]	11.04[b]
Broiler chickens[2]	Control	-	13.49[a]
	Enzyme[4] (150g/t)	-	14.14[b]

[3]Kemzyme® W Dry; [4]Kemzyme® W Liquid;

values in cells with different superscripts are significantly different, $P<0.05$

The relationship between intestinal viscosity and lipid digestion was also examined by Maisonnier *et al* (2003). The addition of 0.5% guar gum to broiler diets increased intestinal viscosity and decreased dietary fat digestibility. However, this negative effect on fat digestibility was reversed with the addition of 0.3% sodium taurocholate (a bile salt).

Gut active emulsifiers

The duodenal secretion of bile salt components increased 8 to 10 fold from 4 days post-hatch to 21 days of age in broiler chickens (Noy & Sklan, 1995). Increasing the overall emulsification capacity of the bird's small intestine can assist with the utilisation of dietary fat in the broiler chicken. Recent research has demonstrated increases in diet AME by the addition of a (lyso-)phospholipd to broiler feed due to its lipophilic and hydrophilic properties which facilitate emulsification in the digesta. AME bioassays in 28 day old broilers fed diets containing 3.8% tallow, 3.2% palm oil or 3.5% rice bran oil were conducted at Massey University with standard diets formulated to 12.76MJ/kg,

reduced AME diets with 1% less of each added fat source, and these reduced AME diets plus an emulsifier. The results are shown in Table 5.

Table 5. Effect of emulsifier on AME of diets containing tallow, palm oil & rice bran oil

Diet	AME, MJ/kg		
	Tallow	**Palm oil**	**Rice bran oil**
Standard diet	12.91[a]	12.86[a]	12.87[a]
Reduced ME diet	12.48[b]	12.29[b]	12.40[b]
Reduced ME diet + emulsifier[1]	12.84[a] (+0.36)	12.70[a] (+0.41)	12.74[a] (+0.34)

[1]Lysoforte®.
[a,b] means in same column with different superscripts are significantly different (P<0.05)

The removal of 10kg/tonne of the added fat/oil source significantly lowered the diet AME. However, this was restored by emulsifier inclusion with no significant difference in AME compared with the standard diet.

Lyso-phospholipids (eg. lyso-phosphatidylcholine) are more hydrophilic than their phospholipid origin (ie. phosphatidylcholine) because only one fatty acid residue remains per molecule instead of two in the phospholipid. This property confers strong emulsification action on the lyso-phospholipids, making them very useful for oil in water emulsions such as what occurs in the gastro-intestinal tract. Mine *et al* (1993) demonstrated that lyso-phosphatidylcholine with linoleic acid formed very small and stable emulsions of ovalbumin protein compared with phosphatidylcholine. The diffusion of micelles across the unstirred water layer depends on micellar mass and mobility and so small, stable emulsions with protein would promote absorption of protein as well as fat. Indeed, ileal amino acid digestibilities were significantly increased in 45kg pigs with a (lyso-)phospholipid emulsifier supplemented diet (van Barneveld *et al*, 2003). This may also be due to enhanced enzyme access to protein due to increased digestion and clearance of fat from the digesta. The gut mediated effects of this emulsifier have also improved the growth performance of weaner pigs when tallow of pork origin was

added to the diet (Carter & Henman, 2003) and improved the efficiency of weight gain in broiler chickens (Othman *et al*, 2008,Table 6; Carter & Perez-Maldonada, 2007, Table 7).

Table 6. Main effects of fat type and emulsifier on male broiler performance; each value is the mean of 6 replicates (8 birds/replicate)

	1-21 days		**1-35 days**	
Main effects	**Weight gain**	**FCR**	**Weight gain**	**FCR**
Fat type				
- tallow	965	1.46	2415	1.57
- soybean oil	1022	1.37	2440	1.51
Emulsifier[1]				
- with	997	1.39	2433	1.51
- without	989	1.44	2422	1.57
Probability, ≤				
- fat type	0.01	0.01	0.01	0.86
- emulsifier	0.61	0.01	0.96	0.03

[1]Lysoforte® main effect, ie. each fat type with/without Lysoforte®

These data show better bird performance with soybean oil compared with tallow and also demonstrate the feed conversion efficiency benefits of the emulsifier. This can also be seen from the data shown in Table 7 with the reduced excreta fat results supporting the mode of action of the emulsifier.

Table 7. Broiler 0-21d & 0-42d responses to emulsifier: weight gain (g), FCR & excreta fat (g/kgDM; single value from pooled & mixed excreta from treatment replicates)

Measure	0-21 days		0-42 days	
	Control	**Emulsifier[1]**	**Control**	**Emulsifier[1]**
Weight gain	862	860	2836	2863
FCR	1.296[a]	1.266[b]	1.656[a]	1.618[b]
Excreta fat				
- males	66.4	45.7	66.1	56.9
- females	79.9	41.7	53.6	55.3

[1]Lysoforte®; [a,b] means within same time period with different superscripts are significantly different ($P<0.05$)

CONCLUSIONS

Digestion and absorption of dietary fat and the factors affecting it have been quite well researched and so are reasonably well understood. This knowledge has been used in practical ways to help ensure efficient utilisation of fat added to poultry diets. Examples include the use of more digestible fat/oil sources for younger birds, blending animal fats with vegetable oils, ascribing different AME values to fats according to bird age, including antioxidants in fat/oil sources to ensure against the negative effects of oxidation, using enzymes to ensure fat digestion is not impeded by digesta viscosity, inhibiting the activity of gut microflora with antibiotics or bacteriocin producing probiotics to prevent bile salt deconjugation, and adding gut active emulsifiers to feed with existing levels or reduced levels of added fat.

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