Lohmann Information

Cuxhaven, October 2007

Editorial

Ladies and Gentlemen, colleagues and friends,

the Nobel Peace Prize for Al Gore is likely to put additional pressure on politicians around the world to take the prospect of global warming seriously and to develop effective guidelines to limit the rate of an ongoing trend. As everybody in feed and food production is noticing, the use of grain for bio-fuel production has increased food prices significantly, and experts are expressing serious doubts that goals announced by politicians can be achieved with conventional methods of land use. For animal agriculture this means the pressure to increase the productivity per animal and the efficiency of feed conversion will continue, while consumers realize that the years of unlimited food supply at low prices are over. In this issue, we offer our readers as “food for thought”:

(1) **Prof. John Hodges: “Sustainable Agriculture and Food at Risk”**. The author has been responsible at the FAO for conservation of biodiversity and food production in developing countries after a career in Agribusiness and education at the University level. Since his retirement, he continues to publish and lecture extensively with focus on undesirable side effects of the concentration in the global food chain. Politicians and global players in the food industry are challenged to develop conditions for food production, in which agriculture finds its appropriate position.

(2) **Dr. Ken Laughlin: “Poultry Genetics – Anticipating Industry Requirements”**. To remain competitive, primary breeders have to predict industry requirements well in advance, and it takes many years from anticipated needs to advanced measurement techniques and finally the appropriate product profile at the time the industry asks for it. The improvements documented are impressive, but unlikely to be acknowledged by “fundamental” opponents to modern farm animal agriculture.

(3) **Dr. Hans-Heinrich Thiele: “Management Recommendations for Rearing Pullets for Alternative Housing Systems”**. As head of the Lohmann Tierzucht service team, the author coordinates the publication of management guides for breeding stock and commercial layers. Due to his extensive previous experience in duck and broiler breeding and management, he has a keen eye for bird behavior in connection with the transition from conventional cage management to alternative floor systems in Europe. This review should help to minimize avoidable mistakes.

(4) **Dr. A. Petri** and **Dr. A. Lemme: “Trends and Latest Issues in Broiler Diet Formulation”**. Increasing feed prices force nutritionists to take a closer look at the price of available components in order to minimize feed cost per unit edible meat. Balancing rations in terms of energy and amino acids is a key to minimize feed cost. This paper is reproduced from Degussa AMINONews, covers extensive world literature and is designed to check current standards for broiler feed formulation. Obviously, nutritional needs are changing with genetic improvement of growth potential.

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(5) **Prof. H. H. Swalve: "Crossbreeding in Dairy Cattle – International Trends and Results from Experiments in Germany".** The superiority of crossbreds compared to their purebred parents has been observed and documented in different animal and poultry species since at least a century ago. Plant breeders were pioneers in developing theories to explain "heterosis" and in designing long-term breeding plans to make maximum use of general and specific combining ability. Poultry breeders were first to follow plant breeders, and pig breeders soon followed poultry breeders. Terminal crosses of different breeds of beef cattle are also not uncommon, but systematic crossbreeding in dairy cattle on a larger scale is still the exception. In this article, the author examines under which conditions crossbreeding in dairy cattle may become more widely practiced in the future.

(6) **Prof. G. Flachowsky: "Iodine in Animal Nutrition and Iodine Transfer from Feed into Food of Animal Origin".** Many people suffer from insufficient iodine in their diet, while excessive intake presents another equally serious risk. On the basis of results from the literature and own experiments, the author reviews possibilities to optimize daily intake by consuming iodine-enriched food of animal origin. The high transfer rate in milk and eggs has led the EU Commission to reduce the maximum level from 10 to 5 mg/kg iodine in feed for dairy cows and laying hens. Increasing the iodine level in meat would be a very inefficient alternative.

We hope you find valuable information in these articles. Please feel free to pass this issue to colleagues and send us their e-mail address if they like to receive "Lohmann Information" directly.

With kind regards,

Prof. Dietmar Flock,
Editor

Sustainable Agriculture and Food at Risk[1]

John Hodges, Mittersill, Austria

Agriculture and food face both bright prospects and life threatening risks. These hazards have an entirely new origin. They result from human activity – not from the identifiable decisions of any individuals but from the system under which Western agriculture is now managed. That system poses real threats to sustainability.

Agriculture reshaped

Agriculture is being restructured at an incredibly fast pace as we enter the 21st century. The pace has been and continues to be higher in the West where innovations during the 20th century, especially during the last 50 years, have changed farming from the oldest, even the original, human activity of civilization into a new world of economic drivers and values. The process involves not only technological change but also the sociological movement of millions of people from rural to urban lifestyles. This massive migration continues in the developing world and in the New Independent States (NIS) of the former USSR. In the West it has already resulted in a strange isolation of farmers who are now numerically a very small minority of national populations. The contrast is shown by the former 15 country member and the new 10 country member states of the European Union. In the 15 member EU, where only about 5% work on farms, few city dwellers were born on a farm and very few have any relatives who farm today. In the 10 new EU countries, the rural population is still around 25% and many people come from a farm background. Further east in the states of the former Soviet Union, the percentage is higher at 30-50%.

In the West farmers are becoming an endangered species as intensification and scale are driven by the large public companies which now control the up-stream and down-stream flow of resources and income to farmers under the banner of Cheap Food. What are the prospects for the next 10, 20 or 50 years? Most obvious is a growing level of unsustainability.

Unsustainability

The present pattern of continuous change in farming and food production cannot go on indefinitely without serious consequences. All thoughtful people, both inside and outside agriculture, acknowledge that the current pace of change is a high risk process. Naturally, the hazards are not so obvious to those who control the economic drivers. They appear to be unaware that they are on a collision course with reality and that collapse and maybe calamity are strong possibilities. One reason for their blindness is that lack of sustainability creeps up slowly and is therefore less evident to those who are within the system. A second reason is that those who drive the system are focussed primarily upon economic returns which continue at present. Corporate executives express frustration with those who talk about unsustainability, sometimes calling them prophets of doom who are out of touch with the realities of the market – which is still doing very well. The profits of the large supermarkets and the upstream suppliers of seeds and chemicals to farmers are thriving. They feel that opposition comes from uninformed minorities who have limited, marginal or personal agendas. A third reason is that the decision-makers in the up and down stream power centres provide themselves with moral arguments for their existing ideology of increasing intensification, scale, cheap food and global trade in food. The view commonly expressed from the Boardrooms of the large and economically successful food chain companies in the West is that the world needs more food and therefore it is imperative to pursue economic and biological efficiency in food production. They seem able to ignore the fact that the West already has over-capacity for food production and, despite over-consumption and growing obesity under the pressure of massive advertising, the fantasy that they are feeding the poor provides a feel-good factor for their business success.

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[1] Adapted from an Editorial published in Livestock Production Science 98, 225-231. Any quotation should acknowledge the Author and Livestock Production Science.

But the system is unsustainable. The pursuit of ever cheaper food to the Western consumer is driven primarily by competition among a small clutch of large supermarkets in the West who seek market dominance and are not called to account for the effects of their agenda on the agro-resources, the farming community, the commons, and the environment which are the foundation resources for agriculture. Consequently there are many external costs which are carried by society through taxation, health, reduced environmental standards and depleted rural life.

What are the longer-term risks of continued unsustainability?

We are not speaking of tragedies of natural origin like hurricanes Katrina and Rita nor the Tsunami in the Indian Ocean on 26 December 2004. We are thinking rather of tragedies which have their origin in human behaviour. Progress in human society is imperative. Everyone would agree that, in principle, it should be progress which improves the quality of life for all, builds community on a foundation of respect for universal human rights, acknowledges the integrity of the biosphere and the dignity of sentient species and pays positive attention to the inanimate resources of the earth. However, despite these high aspirations, human history records that the perverse nature of mankind, particularly those who seek and then use power for selfish ends, has repeatedly marred the achievement of those high ideals. The human story is a sorry one – full of noble aspirations and goals and short on fulfilment. The tragedies of man's inhumanity to man is well documented in the archives of centuries past and resides in the living personal memories of millions alive today who suffered at the hands of other men in the 20th century. But even in the recent past of the 20th century the abuse of other humans, though horrific, was limited in time and space.

The prospect for damage in the future is far greater. The world is shrinking. Globalization makes the earth a village. The scope for petty dictators is still restricted even though they may have global ambitions. But the threats we describe here have a new origin and dimension and they are frighteningly powerful and wide in their effects. They will come from an error, lack of foresight, mistaken judgements, inadequate scientific understanding, sheer greed or collapse of the economic system. Because the food chain is going global their impact will be enormous.

Climate change is a current example of such a world-scale tragedy which is already upon us. Largely caused, to date, by the economic and lifestyle behaviour of the West, climate change is affecting the whole world population. Who is responsible? It is a collective responsibility because the tragedy which is still building derives from the system of economic lifestyles embraced by millions – mainly in the USA and Europe. In such a global situation everyone is a stakeholder and liable to suffer. Similarly, tragedies in the global food chain will also impact everyone. The unsustainability of our lifestyle of excessive energy usage will increasingly affect future generations in many unpleasant ways some of which are unforeseen.

Risks to the agriculture and food systems

Risks of three types threaten agriculture and food as we enter the 21st century. The origin of each risk lies within the economic system now being pursued in the West with singleness of purpose for immediate benefits. The three likely causes of potential tragedies are briefly discussed here without full details which are available elsewhere.

1. Environmental damage
2. Gene-technology in food production
3. Capitalist economic system for agriculture and food on a global scale

Environmental damage

The damage to the natural resources of the earth is overstretching the ability of the environment and its complex life-supporting systems. The recent Millennium Ecosystem Assessment (MEA, 2005) is the result of 1,200 scientists studying the global ecosystems over four years. Their conclusions are devastating. They issue a stark warning that irreversible damage is being imposed upon the biosphere, that the natural machinery which recycles life processes is being degraded, and that the planet will no longer be able to sustain future generations. The UN Environment Program (UNEP), (1995), reported to the Convention on Biodiversity that there are 1.7 million known species of plants and animals and, including all other lower forms of life such as insects and micro-biological species, there are an estimated 12 million not yet identified. All species, classified or not, are disappearing at an accelerating rate. UNEP also gave the following expected loss of species: mammals (25%), reptiles (20%), amphibians (25%) and fish (34%). Wilson et al., (2005) are so concerned at the rate of extinction of mammals and primates that they wrote to the US Senate asking for the Endangered Species Act to be strengthened rather than weakened.

The conservation of agro-bio-resources has become a major activity of biological science in the last decade. Part of this concerns the increasing loss of the diversity of livestock used for food. Loss of livestock breeds is a measurable benchmark of other irreparable damage being inflicted upon our capacity to produce food. The loss of breeds is serious for they have been thousands of years in the making and their unique adaptation traits are valuable. Because there are no detailed records it is not possible to know the precise numbers of breeds that have gone but at least 1,000 breeds have disappeared in the last 100 years. The rate is accelerating with 300 breeds gone in the last 15 years. Today 2,000 breeds are at risk (FAO, 2000). Those who suffer most from this long-term threat of lost biodiversity are the four billion rural poor people in developing countries, 50% of whom are dependent upon livestock to maintain basic quality of life. The lives of these people are being placed at risk by the Western agricultural system as domestic markets in their mega-cities are targeted by Western food exports (Hodges, 2005a). So far the programmes for conservation of animal genetic resources have not stopped the loss as shown by three successive editions of the FAO World Watch List from 1995-2000. Even from an economic point of view it is foolish to discard unique genotypes which may have commercial value in the future. These examples are but an indication of how the environment and biodiversity in general are being eroded by human activity and how the resilience of the natural cycles is overloaded. There is a certain risk that if we continue as we are going we will destroy the capacity to farm effectively (Hodges, 2005b).

Gene-technology in food production

The topic of Genetically Modified plant foods has been discussed in previous Editorials in some detail and will not be repeated here (Hodges, 1999, 2000). However there is one new aspect to the threat of great moment for animal scientists and for livestock production. The new issue is the use of transgenic animals in the food chain. To date genetically modified food has been of plant origin. But scientists and the large multinational companies in this area have been working for some years to produce and eventually market genetically modified meat and milk and eggs from genetically modified animals. Symptoms of this policy can be seen, for example, in the vast investment in gene-transfer technologies creating transgenic seeds and soon transgenic domestic animals. These products are accompanied by patent applications which will eventually turn staple foods into proprietary products with royalties. An example of this type of business is shown by the pending multiple applications made by Monsanto in many countries in 2005 for patents affecting pig production (Monsanto, 2005). These patent applications are very extensive covering some aspects of pig management systems as well as genetic material. If granted they will give Monsanto rights over some genetic breeding and selection tools that have been developed over many years by scientists supported by public funds and that are currently in the public domain, for example Marker Assisted Best Linear Unbiased Prediction. Monsanto argue that their application to patent their particular approach to the use of these algorithms is made together with some specific genes for which they claim patent right because they have developed a particular approach in applying many of these elements together with other innovations. Monsanto blandly state that their primary interest is in protecting their freedom to practise these approaches in the particular way described by the applications.

This Monsanto approach raises some new issues for animal scientists, for livestock production and for the consumption of animal products. On the issue of conservation, patented transgenic farm animals will hasten the demise of the traditional breeds and the issue of conservation of animal genetic resources will be completely reshaped. Although some consumers may now eat crop plant GM food without concern, the issue of transgenic livestock products will raise a new and negative image in the public mind about animal products and probably turn more people off eating meat altogether or to eating organically produced animal products.

These business intentions to create monopolistic trade within the food chain, protected by intellectual property rights, are already becoming plain to farmers, small processors and retailers whose survival is threatened. Gene-transfer technology, like all technologies, has potential both for good use and for abuse (IAEA, 2005). Doubtless it can make contributions to improved food production under the surveillance of independent scrutiny where Due Process is practised and all stakeholders are represented. The problem is that gene-technology has been launched into the staple foods of the world food chain, without public consultation, by a few private interests who take unethical legal protection and a proprietary stance over major components of agriculture and food.

Many may be comforted by the attractive but false argument that gene-technology is only doing more quickly what breeders have been doing for a long time. That statement is, of course, untrue. Gene technology moves genes across the boundaries of widely separated species which is an entirely novel technique for breeders to use. The threat of risks arising from this technology are evident in principle since species have been millions of years in the making and have achieved a remarkable level of genetic homeostasis within the reproductive boundary of each species. Abnormalities caused by mutations (natural analogues of transgenes) are usually negative and have been ruthlessly culled from the population genome by natural selection. When mutations are created artificially by human intervention using gene transfer technology, the process of natural selection is changed. The modified genome, chosen by human rather than natural selection, is multiplied by massive and rapid breeding programmes and released on a large-scale into the natural gene pool of the food chain. Although the immediate effect may appear to be benign, the longer term results are uncertain and risky. Later, when an unexpected and negative genetic consequence occurs in the modified genomes of the food chain, the impact will be wide-spread, even global, and containment will be impossible. We now have glimmerings of new knowledge about the potential dangers now emerging from recent research into BSE, vCJD and CJD (Hodges, 2005c). There are unsuspected genetic interactions between the genomes of cattle and humans, and experimentally with mice, which affect the health and survival of individuals.

When genetically modified food, plant or animal becomes the normal fare in the diet of the global population, which is clearly the business plan of some multi-national companies, the occurrence of a genetic error with deleterious effects upon the human populations or upon the agro-resources used for food will be awful. It will be too late to stop the tragedy which may be a global epidemic or kill-off. The terrible experience of BSE is a warning of the enormous difficulty involved in tracking down the mechanisms of a new and unsuspected aberrant genetic process which silently insinuates itself into the human food chain and is already established in the animal and human populations before recognition and continues to defy diagnosis.

Capitalist economic system for agriculture and food on a global scale

The intention to globalize the world food market is clear. It is a major item on the agenda of the World Trade Organization (WTO) as well as the business plan of the multi-national companies that are currently building control of the staple food market using intellectual property rights (IPR) associated with Terminator Gene Technology to give themselves near monopoly rights. The risks associated with this approach are clear. Based upon self-interest, capitalism quickly responds to the inevitable economic fluctuations, unpredictable cycles and variation in interest rates, exchange rates and returns on investment. Multi-national companies trading in the large food markets of the developing world will quickly stop activities to avoid losses when the world economy changes against their interest. Their prime contract is to their shareholders, not to feed their customers. Cutting supplies of non-essential manufactured goods is not fatal. Cutting supplies of food when local agricultural capacity has been diminished can be tragic. Future large-scale wars and terrorism will also disrupt world food trade leaving hunger in large urban populations who have neglected their local resources for growing food.

There is no world government to ensure poor people are fed when the international trading system collapses. Division of labour offers no remedy for these inevitable tragedies. The West knows from experience that capitalism is volatile. World food supplies cannot be subject to such uncertainty any more than food in the West. In 2007, for the first time, 50% of the world population are living in urban areas. Prudent global socio-economic policy for feeding both the urban and rural halves of the world population is needed to supply affordable food in cities and ensure market access and a viable life-style for the billions of small-scale farmers in rural areas. Steinfeld et al. (2006) considered the pollution released by livestock in large-scale intensive units and by small-scale farming. It is clear that, in addition to the socio-economic factors, endless expansion of intensive systems is not a feasible option to supply livestock products for the whole world.

Question

How can the risks confronting agriculture and food be averted? The power-structures are fully committed to the idea of progress through the present system of intensification, scale and cheap food. The three risks of environmental collapse, of gene-technology producing large-scale tragedy, and of starvation following a severe economic recession all flow from the same source. The threats come from the ideology of capitalism which is a superb system for creating new wealth but which lacks any inbuilt mechanism to avoid excess and abuse by those who own the capital. Today most of the world's capital is held by the West. Vast sums of capital are largely owned by share-holders who are remote from the technical and economic management of the business and whose only interest is in profit and increased equity. The use of the capital is in the hands of a relatively small group of anonymous business executives who, unlike politicians, are neither elected nor accountable to the stakeholders and communities affected by their decisions about the food chain. Customers are the only group with power to influence these executives' decisions and most customers are lulled into a sense of ignorant contentment and complacency about what is happening to the food chain by intensive advertising and the low price of food.

So what can be done? We may take encouragement from what happened once before in the West when the industrial capitalist barons of the 19th century were practising slavery and exploiting their workers ruthlessly (Hodges, 2005b). The system was modified by a small group of individuals, many motivated by their Christian values, who changed the socio-economic shape of Western culture by pressing for the abolition of slave trading and then of slavery itself. During the 19th century in the UK these few men and women of high moral conviction and social concern inside and outside parliament confronted the hard face of capitalism that grew under the influence of the British Empire. They include William Wilberforce, Lord Shaftesbury, Elizabeth Fry and others. Over a period of a few decades, against the prevailing economic interests of business, these few individuals led parliament to ban child labour in the mines, stop the exploitation of women in factories, limit the length of the working day, introduce prison reform, start compulsory and free education and make it illegal for ships to be loaded beyond the Plimsoll line painted on ship sides and named after the Member of Parliament who fought for it in 1876. Outside parliament these individuals pioneered the first care homes for the elderly and opened free hospitals for the poor. These proposals to improve the quality of life, to introduce equity and justice and to facilitate community activities were opposed by many of the owners of factories and mines who argued that these changes should be decided by the market and that the costs of such radical legislation would cripple the economy. As a result of much new legislation, ethical behaviour appeared in the market place. Changes in the socio-economic system were thus introduced which would never have been promoted by economic forces alone. Slowly life changed for the better.

Answer

The only answer is for Western society to stop treating agriculture and food as though they are normal manufactured products driven only by market forces. Prudent new legislation is needed for agriculture and food to provide freedom to the food industry to work on intelligent solutions to benefit everyone and freedom for each society and individual to choose their own lifestyle within the constraints of sustainability. The food chain must be recognized as a very special sector of socio-economic activity. Food and agriculture are not part of the Commons which might be regarded as a resource to be made available to all without charge. The Biblical view is that food is not free and people unwilling to work have no claim upon being able to eat. But there are many ways of ordering the economic production of food without allowing farmland, farmers and their products to be treated solely as disposable resources by unregulated capitalism. Short of war, that is the quickest and surest way to destroy both the resources and civilized life. Today the over-abundance of cheap food in Western society has blinded the sensibilities of the present generation to the precarious nature of a society that fails to guard its ability to produce food.

A fundamental change is needed in the philosophy of national food production and supply. Such a change will not come top down from the leaders of the multinational companies now taking ownership of food nationally and globally – their larger vision of life is besotted by the dominance of profit and shareholder value. It is equally unlikely to spring upwards as a large-scale grass-roots movement from consumers who, with minority exceptions, are currently victims of massive advertising and incentive campaigns to buy food that is allegedly ever-cheaper – but which actually is costing society dearly through indirect and unseen costs.

A cultural swing is needed based upon the reality of looming tragedy. Such a cultural change, that reverses current economic trends and limits vested interests, needs men and women of vision with deep moral concern for the future of society who also have courage to initiate legislative change to reshape the food chain. If such legislative changes seem unlikely one may be encouraged by recalling the 19th century reformers. Or, in the 20th century, one may reflect upon the remarkable cultural change in smoking habits brought about by legislation even against vested business interests and in the face of a populace largely dependent upon tobacco.

The open question is whether today there are such people of high moral character and social conscience, inside and outside parliament, who have an informed grasp of what is happening. And are they willing to act to ensure a future for agriculture and food supply? Regrettably, in recent years Western governments have preferred to listen to business leaders in the food chain. The only route is for reformers to act in parliament and in government to take up this challenge in the way that rare and courageous legislators have done in the past.

Zusammenfassung

Nachhaltige Landwirtschaft und Ernährung in Gefahr

In seiner Analyse von Entwicklungstendenzen in der Landwirtschaft und Humanernährung setzt sich der Autor mit drei konkreten Gefahren auseinander: (1) Zerstörung der natürlichen Umwelt durch rücksichtslose Landnutzung und Umweltbelastung durch überhöhten Tierbesatz; (2) Anwendung der Gentechnik in der Pflanzenzucht ohne ausreichende Prüfung der Konsequenzen; und (3) kapitalistische Strukturen in einer globalisierten Nahrungsmittelproduktion.

Der Anteil der Bevölkerung, der sein Einkommen aus der Landwirtschaft bezieht und somit auch noch ein natürliches Verständnis für nachhaltige Bodennutzung und intakte Umwelt hat, wird mit zunehmendem Wohlstand immer kleiner. In westlichen Ländern ist der Bauernstand vom Aussterben bedroht, und der preisbewusst Lebensmittel einkaufende Verbraucher begreift kaum, welche Konsequenzen dies mittel- und langfristig haben kann.

Da die Entscheidungen führender Köpfe in der Lebensmittelindustrie in erster Linie darauf ausgerichtet sind, Gewinne aus dem eingesetzten Kapital zu erwirtschaften und die meisten Verbraucher damit zufrieden sind, dass dieses System ihnen preiswerte Lebensmittel liefert, appelliert der Autor an eine Bewusstseinswandlung bei Verbrauchern, die weitsichtige Politiker darin bestärken, für Rahmenbedingungen zu sorgen, die bessere Lebensqualität für mehr Menschen in intakter Umwelt nachhaltig ermöglichen.

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Poultry Genetics – anticipating the Industry Requirements*

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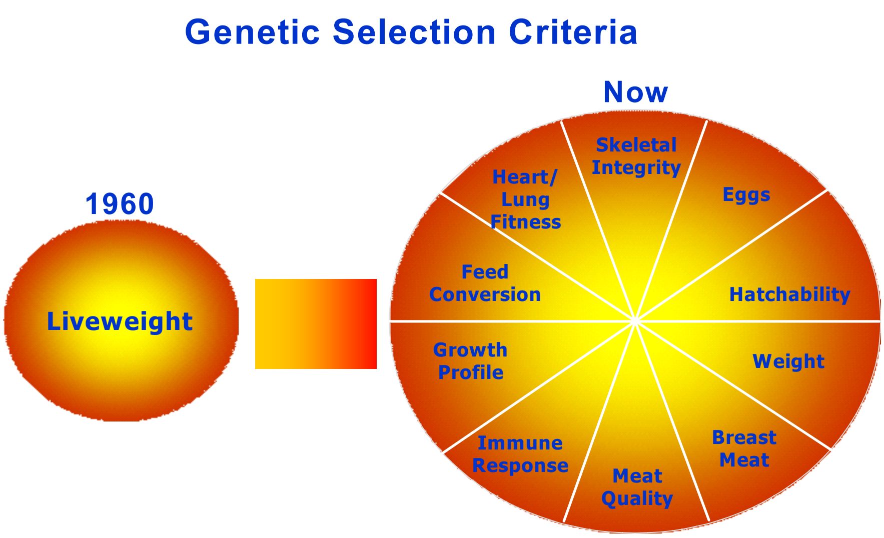
Scientific reviews and the introduction to papers frequently repeat and regenerate old, misunderstood or incorrect views regarding the nature of poultry breeding, particularly if they support the reasons for the research. In this regard a failure to acknowledge the long term attention to traits associated with health and welfare is often repeated with the implication that breeding companies have only recently addressed welfare issues in breeding programmes. The major economic traits receive most attention due to their historical commercial importance and because progress in their selection has been most significant. The more difficult traits, both in terms of measurement and in heritability have thereby seen slower progress but these gains are no less significant to the breeders and for the industry.

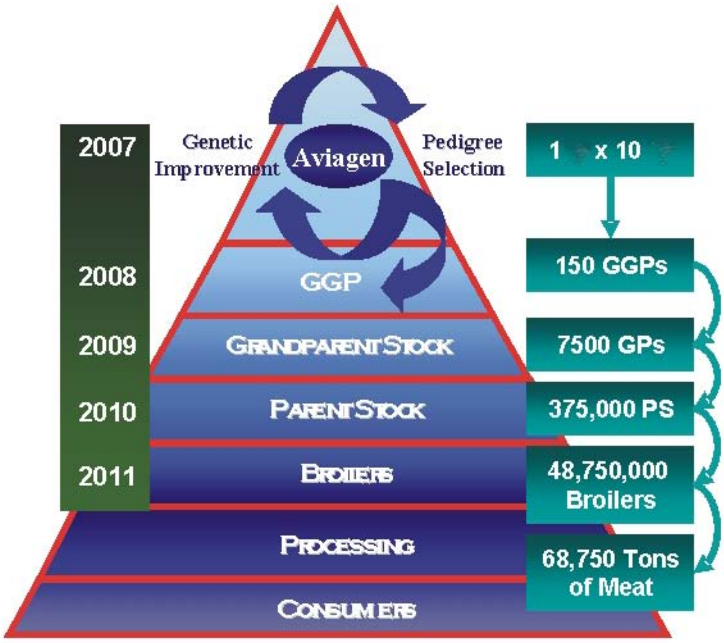
In order to understand why changes and improvements may take a long time let us consider the nature of poultry breeding and how breeding programmes have evolved. In the beginning of the broiler industry 50 to 80 years ago the "breeds" were produced by many different small breeders and most were single lines. Once the concept of hybridization was understood some breeding companies began to develop multiple lines and sell commercial crosses but, particularly in the United States, some single line breeders remained and the customers were free to buy males and females from different sources to create their own "cross". At a time when there were many breeders this "lottery" genetics could frequently produce good products which on occasion were better than those supplied as a package. Additionally the scale of operations meant that very small differences could be realized economically in specific feed or housing environments. Relatively quickly the breeding companies realized that the end product should be a planned combination of traits from lines with known characteristics. Initially however this was confined to putting broiler characters in the male and reproductive characters in the female. From the 1960's breeding programmes have moved from very simple mass selection for liveweight to include ever more traits as the technology to measure these and the computing power and programmes to analyse them developed. At least ten sectors can now be identified in the "pie" of genetic selection criteria and several of these are composed of multiple traits such that at least 40 traits would be considered at the time of each final selection. Although the diagrammatic representation of this is necessarily very simple it has evolved over many years as technologies facilitated change and traits were added.



*Based on a talk at 6th World Poultry 2007 Conference, 22-23 May 2007, Meridien Piccadilly, London

The two ends of the spectrum of selection traits over time

The modern breeding programmes have traditionally been represented as a pyramid with the primary breeding (genetic) section sitting on top of the production chain delivering genetic material. These diagrams can also display the time frame from pedigree to broiler production of around 5 years and a multiplication such that one male and ten females at the pedigree level generate almost 50 million broilers or nearly 70,000 tonnes of meat.



Traditional breeding Pyramid with timelines and volumes

Such a diagram highlights an important fact. The breeding company must correctly anticipate the needs of the industry at least 5 years ahead. However being realistic it could take at least five years to develop a new line to be available for the great grandparent level of the production process which moves the timescale from identified need to availability at broiler level closer to 10 years. This of course means that the breeding companies must be incorporating considerable feedback into their breeding programme strategy and the sources of this feedback include all levels of the production chain through to the consumer plus interest groups, regulatory matters and developments in science. The weighting and analysis of the feedback is critical to the success of the programme.

To return to the specific issue of welfare and one aspect which receives considerable attention – leg health – I would like to use this as one example of the biological time frame necessary to effect significant changes in a selection trait at the commercial level.

Almost 30 years ago I “inherited” a breeding programme in the UK which already included selection for leg condition scores recognizing the importance of this to bird health and welfare. Next, UK breeding companies collaborated in a program of work carried out by John Mercer at the University of Edinburgh assessing the opportunity to select specifically against Tibial Dyschondroplasia (TD). This was published as a PhD thesis in 1983 and showed the clear opportunity to select for reduction in this condition. The positive indications from this work led to the first use of the “Lixiscope” as a selection tool in the late 80’s, a procedure which has continued to the present day. Clearly therefore addressing welfare issues is not a recent trend in Poultry breeding. Aviagen’s specific data relating to eradication of TD shows both a reduction in the variability of this trait and also its incidence.

The data from the breeding programme have recently been supported by a commercial study in Denmark reported at the Nordic Poultry Conference (Petersen 2005). In this study the field incidence of TD was shown to reduce from 57% to 0.7% between 1999 and 2005. In addition to the genetic changes over this time we are also aware of changes in the nutrition which aided the reduction in

TD. These nutritional changes had resulted in part from recommendations from the breeding company – highlighting the importance not only of making genetic improvements but also supporting these with technical advice in the field. In addition to the specific improvements in TD score there was an associated overall improvement in leg health.

Taking this specific example shows the importance of dissecting and separating the various components which contribute to an industry "problem". To solve the problem, a trait or condition has to be identified which can be measured reliably and routinely and has been demonstrated to be heritable. Only at this point can it be incorporated successfully into the breeding programme and translated into an improvement in commercial stock in the field. Such improvements are essential for a breeding company to remain in business, but throughout the process of genetic improvement the overall characteristics of the product must remain acceptable to the customers in the industry who buy them.

A subject which highlights the difficulties facing geneticists in anticipating industry concerns is skin lesions on the legs. During the 1980's in the UK (one of the few countries to leave hocks on the ready to cook carcase) hock burn became a major issue. This was also linked to perceived welfare conditions of bird rearing. We initiated a process to address this in the breeding programme and considerable reductions in hock burn can be demonstrated at pure line level. Subsequently in regions which sold feet (paws) to the Chinese market absence of foot pad lesions (pododermatitis) became economically important. This was then proposed as a measure of welfare status for the EU Broiler Welfare Directive. Our historical data and trial work indicated a negative relationship between hock burn and foot pad dermatitis. The birds with better initial leg condition also spent more time moving and standing than sitting down and hence presented their foot pads to the litter, thereby reflecting litter condition. Considerable work to understand the causes and hence potential for reduction of this problem has been carried out. The final version of the EU Broiler Welfare Directive does not contain the same emphasis on (or routine measurement of) pododermatitis. Our programme will continue to address this issue because it is important.

In the last five years we have been given new tools and techniques from the science of Genomics. Aviagen has made a major investment in this area which will allow us to identify genetic markers which can be used to enhance the existing assessments particularly in traits related to health and welfare. Historically these have been difficult to examine without the use of complex and difficult challenge studies which are not suitable for use in routine breeding programmes. Using data from case studies in a field environment we expect to identify markers which can further broaden the range of selection traits.

Initial comments referring to only a limited number of major traits when appraising the broiler breeding industry presupposed that growth rate is the only issue driving a breeding program and that it is automatically negative for welfare. This would have been correct 40 years ago but since that time the level of sophistication in both listening to and anticipating the needs of the industry, consumers and regulators has changed significantly. Along with this there have been major improvements in the measurement, collection and analysis of relevant data in order to develop the products with the correct balance of traits which are needed by the industry. The breeding industry may have shown a reduction in the number of independent companies involved, but those who responded correctly to the challenge now offer a much greater range of products to satisfy the various sector requirements of this industry worldwide than were available 20 years ago.

Although this presentation used a health and welfare example to show the impact of Poultry Genetics we now recognize that we have entered a period of focus on the environmental impact of the livestock industry. The genetic improvement in Feed Conversion Efficiency has had and will continue to have a significant effect by both reducing the nutritional inputs required by poultry farming and also reducing the waste outputs it generates as a result of the past and future activities of poultry breeding. Finally, in support of this view the contribution of poultry breeding companies to the broader aspects of the global food market covering layers and turkeys as well as broilers has been reviewed by Flock et al. (2005). This paper outlines the further contribution through eradication of vertically transmitted diseases, selection for general liveability and not least the dissemination of management recommendations which help customers to reduce losses at the commercial level.

Summary

Poultry Genetics – anticipating the Industry Requirements

In broiler breeding, selection is often said to be focused only on rapid growth at the expense of traits important for animal welfare. In fact, economically important traits are balanced with traits which are important for animal health and welfare. At the beginning of broiler breeding, during the 1960's, in the USA selection for liveweight at market age was predominant but over the subsequent years many more characteristics were included in the selection program (fig.1)

Improvements from the selection program are passed down the pyramid of production (fig 2.) over several years through breeders, broilers, processing and finally to the consumers.

Selection to improve leg condition through removal of TD is an example of the time involved to improve complex traits, almost 30 years and also the need for specialized equipment (the Lixiscope to measure condition of live animals).As a result of this selection incidence of TD in the field could be reduced from over 50% to less than 1%.

Advances in measuring techniques, supported by developments in molecular genetics will allow further progress in welfare and economic traits which will improve the competitive ability of poultry in the world market.

Zusammenfassung

Rechtzeitige Prognose künftiger Praxiserfordernisse: eine Voraussetzung erfolgreicher Geflügelzucht

In der Mastgeflügelzucht wird nicht – wie immer wieder behauptet - einseitig auf schnelles Wachstum auf Kosten tierschutzrelevanter Kriterien selektiert. Vielmehr hat sich im Laufe der Jahre als Zielvorstellung für das „Masthuhn der Zukunft" eine Kombination von wirtschaftlich wichtigen und „sonstigen" Merkmalen entwickelt, die aus tierschützerischer Sicht zu betonen sind. Stand zu Beginn der modernen Broilerzucht in den USA - vor 1960 – die Selektion auf hohes Lebendgewicht im marktüblichen Alter im Mittelpunkt des Interesses, so wurden in den folgenden Jahren immer mehr Merkmale erfasst und züchterisch bearbeitet (Abb. 1).

Verbesserungen in der Zuchtstufe werden mit zeitlicher Verzögerung an die Praxis (Vermehrungsbetriebe, Mäster, Schlachtereien, Konsumenten) weitergegeben, wobei durch Multiplikation über mehrere Stufen der Pyramide innerhalb weniger Jahre ein erheblicher wirtschaftlicher Nutzen aus kleinen Verbesserungen in der Zuchtstufe resultiert (Abb. 2).

Am Beispiel von Beinschäden (TD) beim Broiler wird gezeigt, wie im Laufe von 30 Jahren dank neuer technischer Möglichkeiten („Lixiscop" zur Messung von Defekten am lebenden Tier) die Häufigkeit von Defekten in der Praxis von über 50% auf unter 1% gesenkt werden konnte.

Eine Weiterentwicklung der Messtechnik, unterstützt durch die Molekulargenetik, lässt weitere Fortschritte in der Richtung erwarten, die heute als erwünscht und für die Wettbewerbsfähigkeit der Geflügelwirtschaft im Weltmarkt notwendig erkannt wird.

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Management Recommendations for Rearing Pullets for Alternative Housing Systems

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Introduction

The productivity of laying hens has been improved enormously in the last 20 years as a result of selective breeding. Modern hybrids mature very early and are characterised by top performance, very good liveability with almost consistently high egg quality and excellent feed conversion efficiency.

But this genetic improvement in productivity imposes increased demands on the management of modern layer hybrids. The key to success is to achieve a 17- to 18-week pullet rearing period. While the rearing of caged pullets to egg-laying maturity is still fairly straightforward despite increased demands, preparing pullets for conventional deep litter and perchery systems, perhaps with access to a winter garden and paddock, or for free-range systems requires more technical expertise.

The following chapter therefore focuses on the rearing of young pullets and their preparation for deep litter and perchery housing systems.

Pullets destined for alternative housing systems should also be reared in deep litter and perchery systems. The more closely the growing facility resembles the future production system, the easier it will be for the pullets to settle down in their new environment after transfer to the laying house.

Deep litter system

Floor rearing systems for chicks and pullets should consist of a well littered, climate-controlled, illuminated shed which, as well as feeders and drinkers, also provides slightly raised roosting places. Chicks learn and want to fly up to rails or perches at an early age. If perching or flying is learnt too late it can result in reduced mobility of individual hens in the future laying house. Rails or perches should therefore be available to chicks before the age 6 weeks.

Mounting feeders and drinkers on or alongside the perches is a very effective preparation for the production phase. Floor rearing systems with a droppings pit on to which feeders and drinkers are mounted are particularly effective for familiarising the birds with the design of the laying house.

Perchery system

Percheries can accommodate more birds per m² of floor area than deep litter systems because the total amount of usable space is greater. Multi-tiered perchery systems of different designs are currently offered by several manufacturers, with appropriate management recommendations.

The levels are furnished with plastic or wooden slats and feature manure belt ventilation. Feeding and watering facilities are usually located only on the bottom and middle levels. The top level is used by the pullets at night as a roosting area. This natural behaviour can be reinforced by using the lighting system to simulate sunset. This involves turning off the light in a step-wise sequence, starting with the bottom and middle levels and finally the top level.

In the morning the birds should go to the two lower levels for feeding. By moving between the resting zone and the other levels the pullets get physical exercise and familiarise themselves with the perchery environment. Staggered feeding on the lower tiers promotes flexibility of movement.

Litter

The type and quality of the litter are especially important for young chicks. Straw must be clean and free of mould. Wheat straw is preferable to barley or oat straw. Barley straw contains awn residues which can cause injury to chicks, and oat straw does not absorb sufficient moisture. To reduce dust formation the straw should not be chopped but should be put down as long straw. Splicing improves moisture absorbency. Long straw has the added advantage of encouraging the chicks to forage. This stimulates the birds' natural investigative and feeding behaviours, thus reducing the risk of feather pecking. Wood shavings are good litter material provided they are dust-free and come from softwood varieties that have not been chemically treated; minimum particle sizes of $\geq$ 1 cm are recommended. Chicks must on no account ingest fine particles as these, when combined with water, swell up in the oesophagus, causing ill health and reduced feed intake.

Litter should be put down after heating the shed, when the floor has reached the correct temperature. Significant differences between floor and room temperature when litter is spread too soon change the dew point. The litter becomes wet from below and sticky.

House climate

Desired temperatures at bird level at a relative humidity of at least 40 - 45 %:

Temperature when birds are placed		34° C
Then	day 1 - 2	34 - 32° C
	day 3 - 4	31° C
	day 5 - 7	30° C
	2nd week	29 - 28° C
	3rd week	27 - 26° C
	4th week	24 - 22° C
	5th week	20 - 18° C
	6th week	18 - 20° C

Scientific studies show that the optimal body temperature is 40 to 41° C. If this is measured with suitable thermometers house temperatures can be adjusted accordingly.

Chicks from young parent flocks require a 1° C higher temperature on arrival.

The heating should be turned on as soon as the exterior temperature drops to ensure that the recommended temperatures are maintained at bird level. A uniform house climate can be maintained by proper regulation of the heating and ventilation facilities. The chicks' behaviour gives clues to proper climate management:

- The chicks are dispersed evenly and move around freely
  => temperature and ventilation are just right
- The chicks huddle together or avoid certain parts of the building
  => temperature too low or draughts
- The chicks are prostrate with wings spread out and gasping for air
  => temperature is too high

When controlling the temperature by ventilation it is important to ensure that sufficient fresh air is provided. The following minimum requirements for house air should be maintained:

O_2	over 16 %
CO_2	under 0.3 %
CO	under 40 ppm
NH_3	under 20 ppm
H_2S	under 5 ppm

Placement of chicks – deep litter system

It is advisable to place the chicks close to the watering and feeding facilities in the building. If an even temperature distribution within the house cannot be guaranteed or if radiant heaters are used, the use of chick guards or similar devices for keeping the chicks together has proved effective. These restrict the chicks to those areas of the building where the climate is optimal and where feeders and drinkers are located.

The shed can also be furnished with chick feeding bowls to ensure a better feed intake in the first few days. Both standard feeders and these additional chick bowls should be filled with a layer of about 1 cm of coarse starter feed. As soon as the chicks are able to eat from standard feeders the bowls should be gradually removed.

If radiant heaters are used chick guards or similar devices for keeping the chicks in the warm area should be installed underneath. This provides a draught-free and comfortable microclimate for the chicks during the first two to three days after hatching.

If the chicks are housed in sheds equipped with dropping pits it is advisable to place narrow strips of thin, corrugated cardboard over the slats (40 - 50 cm wide) on which drinkers, feeding lines and the chick bowls used for the first week are placed. Chick guards or similar devices are again very useful for keeping the chicks close to water, feed and heat sources during the first few days of life.

Placement of chicks – perchery

Depending on the system, the chicks are placed either on the middle or bottom level of the perchery where they remain up to about day 14/21. Feed and water are close by so that the birds become fully accustomed to their environment. From 3 to 4 weeks of age the „training tiers“ are opened. Now the birds can move freely throughout the building and learn to jump and fly. Percheries which provide feed and water on all tiers and can be operated similar to a battery system by confining the chicks during their first few weeks of life may be very convenient for the pullet producer but are less suitable for training the chicks to move around the system. In these systems, too, the tiers should be opened as early as possible and chick movement within the house stimulated by staggered feeding on the different tiers. Here, too, it is essential that take-off, landing and flying should be mastered by 6 weeks of age. During the first few days of having access to all parts of the house the chicks should be closely watched. Disorientated birds have to be moved manually and trained by the attendants.

Pullets which will later be moved to production percheries where they have to fly onto perches for feeding should preferably be familiarised with this type of perch while still in the growing facility.

The pullets should be moved to the laying house well before the proposed start of production. They are then better able to find their way around the different areas (feeding, scratching, roosting). By eliminating stress during the period of adaptation to perchery systems, existing nest boxes are more readily accepted and the daily feed intake is more likely to keep up with the birds‘ growing requirement at the onset of production.

Rough estimates of the equipment needed for deep litter/perchery systems are as follows:

Equipment needed for rearing

	Age (weeks)	
Bell-type drinkers	1	1 drinker (4 - 5 l) per 100 chicks
Circular drinking troughs	up to 20	1 drinker (Ø 46 cm) per 125 birds
Linear drinking troughs	up to 20	1 m trough length per 100 birds
Nipple drinkers (with drip cups)	up to 20	6 - 8 birds per nipple
Chick feeding bowls	1 – 2	1 bowl per 60 chicks
Cut-off chick cartons	1 – 2	1 carton per 100 chicks
Circular feed troughs	3 – 10	2 troughs (Ø 40 cm) per 100 birds
	11 – 20	3 troughs (Ø 40 cm) per 100 birds
Chain feeders	3 – 10	2.5 – 3.5 m trough length per 100 birds
	11 – 20	4.5 m trough length per 100 birds

Intermittent lighting programme for chicks

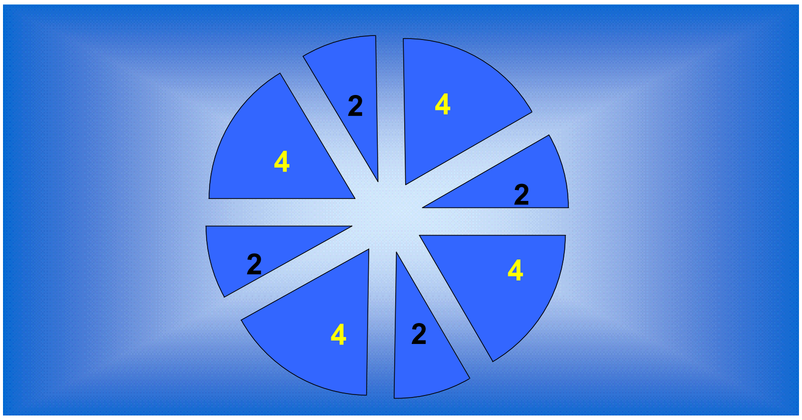
Young chicks arriving at the rearing farm have already endured a long transport after hatching. The general practice is to provide 24-hour light for the first two to three days after arrival to give the chicks time to recover and eat and drink ad libitum.

But in reality it has been observed that some chicks continue to rest after arrival while others seek out food or water. Flock activity will therefore always be uneven. During this phase of rearing attendants find it particularly difficult to accurately assess chick behaviour and condition.

An intermittent lighting programme, specially designed for this period and tested in practice, divides the day into resting and activity phases. The objective of such a programme is to synchronise chick activity in order to make it easier for the staff to assess the condition of the flock more accurately and to stimulate food and water intake through group behaviour.

It is recommended to allow the chicks a brief period of rest on arrival at the rearing farm and then start the intermittent lighting programme of 4 hours light followed by two hours dark.

Lighting programme for chicks during the first 10 days of life:



This programme can be applied up to day 7 or day 10 post arrival, followed by a switch to the regular programme with a reduction of the day length.

The benefits of using this programme are:

- Chicks rest or sleep at the same time. Chick behaviour is synchronised.
- Weak chicks are stimulated by stronger ones to be active and ingest feed and water.
- Flock behaviour is more uniform, making chick assessment easier.
- Losses in the first week are reduced.

Stocking density

The stocking density depends on the housing system. In deep litter systems stocking densities of up to 15 birds/m² of usable floor space are acceptable.

Perchery stocking rates should follow the recommendations of the manufacturer of the system concerned. Densities of up to 30 pullets / m² of usable room space are possible.

These stocking densities are only realistic, however, if the provision of feeding and watering systems complies with the regulations for technical equipment.

Grit

The provision of insoluble grit for free access feeding from circular troughs is recommended. This stimulates the development of crop and gizzard, which in turn has a positive effect on feed intake capacity.

The following are reference values for the granulation and amount of grit to be supplied:

1 - 2 weeks of age:	Once weekly 1 g/bird (1 - 2 mm granulation)
3 - 8 weeks of age:	Once weekly 2 g/bird (3 - 4 mm granulation)
From 9 weeks of age:	Once a month 3 g/bird (4 - 6 mm granulation)

Beak treatment

Birds reared on the floor and in percheries can roam freely around the barn. These housing systems do not promote the formation of stable social structures like those found in smaller flocks. Recent scientific studies have shown that when hens who do not know each other first meet in the barn they explore their flock mates by pecking. This behaviour, referred to as exploratory pecking, forms part of the natural repertoire of fowls.

Situations such as high dust levels, poor house climate, at times very high stocking densities in selected areas of the poultry house, reaction to vaccinations and other disruptive factors which, despite best efforts, cannot always be avoided in floor and perchery systems, lead to a state of frustration in hens. Aggressive feather pecking, which occurs as a consequence of such stress situations, has also been shown to be a natural reaction by hens.

Beak treatment is recommended for hens in deep litter systems and percheries in order to limit the adverse effects of both types of feather pecking and to minimize the risk of cannibalism.

The EU directive on the management of laying hens (Council Regulation 1804/1999 of 19.07.99) provides that treatment of the beak tips may be carried out up to the age of 10 days. In Germany beak treatment is subject to authorisation by a government veterinary officer.

As beak treatment is stressful for the chicks they must be conditioned for the procedure. A vitamin supplement of the A, D_3, E and K_3 groups on the day before, a 6-8-hour fast prior to the procedure and raising the room temperature by 1° C at the time of the beak treatment procedure are recommended to ensure that the birds recover quickly from this operation.

Subject to national regulations, beak treatment must be performed with utmost care! A poorly treated flock grows unevenly, resulting in lack of uniformity at the end of rearing.

Nutrition

Because of their higher activity levels, pullets kept on the floor or in percheries require more feed of the same nutrient density than caged birds. In addition to the lighting programme and adequate body weight development, nutrition is the third key factor in reaching laying maturity. When formulating diets for pullets the nutrient requirements specified by the breeder for the product concerned should be taken into consideration.

Compound feed manufacturers offer a four-phase feeding programme for this purpose (chick starter, chick grower, pullet feed, pre-lay ration):

Example of a commercially tested starter and grower feeding programme:

Nutrients		Chick starter	Chick grower	Pullet feed	Pre-lay ration
Crude protein	%	20.5	18.5	15.5	17.5
Methionine	%	0.48	0.40	0.33	0.38
Lysine	%	1.15	1.00	0.70	0.80
Calcium	%	1.05	1.00	0.90	2.00
Phosphorus	%	0.75	0.70	0.60	0.65
Sodium	%	0.16	0.16	0.16	0.16
ME MJ/kg		11.8	11.5	11.4	11.4

The indicator for switching from one diet to the next is the hens' body weight development. The correct time for changing the diet is determined not by age but by body weight. It is therefore essential to weigh chicks and pullets at regular intervals.

In-feed coccidiostats should be used only if no coccidiosis vaccination is carried out. Vaccinated hens must on no account be given coccidiostats via the feed.

Chick meal should be homogeneous and have sufficient structure. Too high a proportion of very fine constituents or a structure that is too coarse lead to selective feeding and an uneven nutrient intake. The meal should not contain whole cereal grains. Excessively fine feed reduces the birds' feed intake, leading to an undersupply of individual nutrients.

For pullets in deep litter or perchery systems who will be housed in equivalent systems after rearing the provision of a pre-lay diet is highly recommended. The pre-lay diet has approximately twice the calcium content of pullet feed and higher levels of protein and amino acids. Feeding such a diet for about 14 days prior to the proposed onset of lay is beneficial, and essential if chicks are moved to the laying house early. This diet improves flock uniformity by enabling early maturing birds to obtain sufficient calcium for eggshell production and by providing a better nutrient supply for late maturing birds.

The foundation for ensuring a sufficient intake of the feed offered, especially after moving the pullets to the production facility, should be established during the growing phase. This is achieved by feeding a ration with a lower protein density, good structure and a slightly higher crude fibre content. The pullets should learn at an early age to empty the feeders preferably once a day, but at least several times a week. A balanced intake of coarse and fine feed constituents and an improved appetite to the next feeding increase feed intake. The ability to consume large amounts of feed learnt during this phase will be crucial to the pullets after moving to the laying house, when feed intake has to increase sharply.

Uniformity

The uniformity of a flock is an important measure of the quality of rearing. It states in mathematical terms how many of the birds weighed in a sample are within a range of ± 10 % of the measured mean body weight of the sample. It is determined in 1 % of the flock by weighing individual birds.

Uniformity is an indicator of the expected production level of the flock during the laying period.

Uniformity is affected by factors such as:

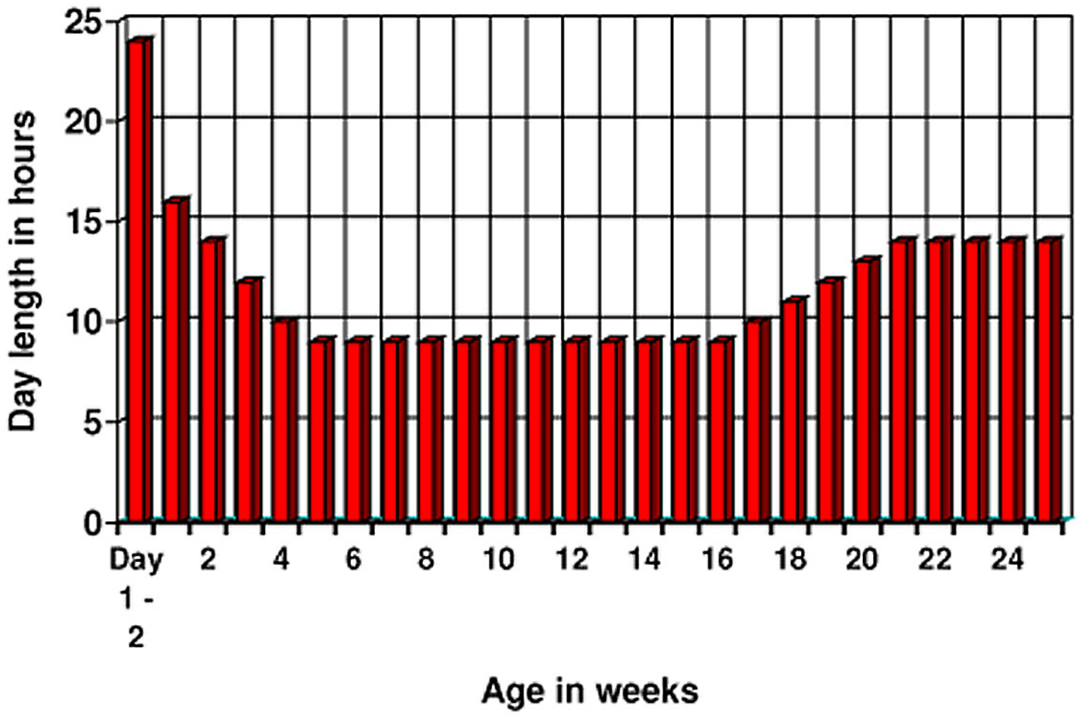
- Chick quality
- Stocking density
- Feeding
- Lighting programme
- Vaccinations
- Diseases

Healthy flocks reared in accordance with breeders' recommendations are very uniform.

Lighting programmes

Sexual maturity and laying performance are materially affected by the lighting programme to which the hens are exposed during the growing and production phase. In systems where pullets are kept in windowless housing without access to the outdoors lighting programmes can be designed in such a way that optimal rearing and preparation for the laying period are guaranteed. After placement of the chicks the day length is gradually reduced. Then, after a phase of constant day length, light hours are stepped up again in order to stimulate egg laying activity. The lighting programme shown in the graph below can be varied depending on the breeder's recommendations and the desired production level of the flock. As a general rule, the day length should not be increased during the growing phase up to point of stimulation for egg-laying and should not be decreased during the production phase.

Example of a lighting programme for windowless poultry houses:



So as not to violate this basic rule, it is recommended that houses with natural daylight entering through windows or other openings should be blacked out, especially for chicks hatched during months with increasing daylight.

Without restricting the natural day length, flocks in central European latitudes would grow into lengthening days from March to June. This would result in a premature onset of lay and subsequent underperformance. It would also be difficult to design an optimal lighting programme for flocks reared from July to September. In houses where windows or light openings cannot be blacked out a lighting programme as described in the graph for windowless houses, which proposes a temporary restriction of the day length to 8 or 9 hours, is only viable during the autumn and winter months.

Windows or openings through which natural daylight enters should therefore have a black-out facility. The times for darkening the room or opening the windows should be synchronised with the lighting programme. It is important to follow the correct sequence: in the evening close the windows first, then switch off the light; in the morning switch on the light first, then open the windows.

This procedure should be continued after transfer to the production facility until the maximum day length in accordance with the chosen lighting programme is reached. This avoids unnecessary stress for the hens caused by an abrupt lengthening of the light day after moving into accommodation with windows; 17 hours of daylight is the norm in June. It is also important to ensure that the artificial lighting programme and the natural light day do not conflict.

Vaccination programme

Vaccinations are preventative measures against infectious diseases and help to keep flocks healthy and productive. The success of vaccinations is essentially determined by the following factors:

1. Selection of suitable vaccines
2. Selection of appropriate vaccination times
3. Selection of suitable vaccination methods
4. Eligibility of birds for vaccination

Vaccines are veterinary medicinal products that are available on prescription from the veterinarian attending your flock. The manufacturer's directions for use must be observed. In Germany vaccinations of laying hens against Salmonella and Newcastle Disease are mandatory under law.

Depending on the region, hens kept in alternative systems should also be vaccinated against fowlpox and, especially in the case of free-range hens, against EDS (Egg Drop Syndrome) as wild waterfowl are a reservoir of EDS virus. A combined vaccination against IB, ND, EDS and sometimes also ART is often carried out.

Regular blood tests to monitor the success of vaccination measures are recommended.

The most common vaccinations are:

Disease	Worldwide	Regional	Vaccination methods	Comments
Marek	x		I	Single vaccination of day-old chicks in the hatchery
Coccidiosis	x		W F	
Newcastle (ND)	x		W / Sp / I	Mandatory under law
Gumboro (IBD)	x		W	
Infectious bronchitis (IB)	x		W / Sp / I	
AE	x		W	Laying hens and parent birds must be vaccinated
Mycoplasma gallisepticum (MG)		x	I	
Fowlpox		x	Injection into wing	
Pasteurellosis		x	I	
Coryza		x	I	
Salmonella	x		W / I	Mandatory under law for flocks of 250 pullets or more
ILT		x	W / ED	
EDS		x	I	
Colibacillosis	x		I	

W Drinking water I Injection ED Eye drops Sp Spray F Feed

Supplementary vaccinations

The infection pressure in deep litter systems is far greater than for caged birds. Moreover, strains of coliform bacteria and Pasteurella can occur and develop in a very narrow geographical area. In such cases it may be necessary to design highly specific vaccines for use in the rearing facility.

Vices

Watch birds closely for any signs of abnormal behaviour such as feather pecking or cannibalism. A sudden outbreak without having changed the lighting regime can have a variety of reasons. If these vices occur, check the following:

- Nutritional and health status of the flock – body weight, uniformity, signs of disease.
- Stocking density – overcrowding or insufficient feeders and drinkers cause anxiety in the flock.

- House climate – temperature, humidity, air exchange rate or pollution by dust and/or harmful gases.
- Light intensity / light source – excessive light intensity, flickering light (fluorescent tubes or energy-saving bulbs emitting light at too low a frequency) or light outside the red spectrum cause distress to the birds.
- Ecto- and endoparasites – infested birds are restless and develop diarrhoea.
- Feed consistency – do not feed very finely ground meal-type rations or pelleted feed. Both encourage abnormal behaviour.
- Amino acid content of the ration – deficiencies of sulphur-containing amino acids cause problems.
- Supply of calcium and sodium – deficiency makes the birds irritable.

Molting

Growing pullets change their plumage several times. The growing chick replaces the down of the day-old with the first full feather coat. This process is largely completed at 5 weeks of age. The birds' growth slows down during moulting.

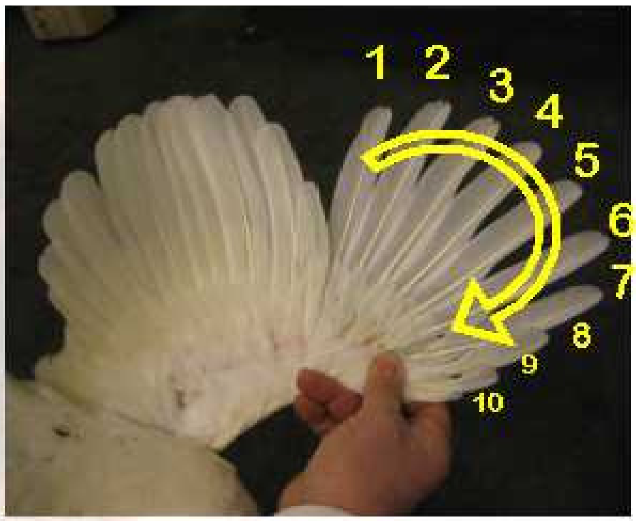
At 8 to 9 weeks old a further slight but incomplete moult takes place. At that age more feathers than usual can be found in the litter of floor-reared or perchery hens.

An intensive and complete change of plumage is observed from 13/14 weeks of age. This moult also involves successively changing the flight feathers. At 15 weeks numerous feathers are found on the floor of the poultry house of a well developed flock. The absence of molting at 13 weeks indicates poor weight development or lack of flock uniformity; bodyweight and uniformity should then be determined as a matter of urgency. If the flock is found to be underweight it is advisable to check for viral or bacterial infections (coccidiosis is a common cause of growth depressions) and to examine whether the feed quality is satisfactory.

If necessary, the ration should be changed temporarily by feeding chick grower instead of pullet feed in order to remedy the developmental deficit as quickly as possible.

Only when the final moult is almost complete (normally at 14/15 weeks of age) are light intensity and length of illumination increased in readiness for the impending start of lay. Practical experience has shown that this is the best time for moving the birds to the layer house.

Wings of a pullet aged about 18 weeks:



Moving to the laying house

The move from the growing facility to the laying house should be done gently but quickly. Catching and transporting is stressful for the birds. They also have to adapt to a strange environment. A stress-free transfer and careful acclimatisation of the flock to the new management system are crucial and ensure good production results.

It is advisable for pullets from alternative rearing systems to be moved in good time before the proposed onset of lay. This ensures that the pullets become familiar with their new surroundings before they start laying.

It is normal for pullets to lose weight after transport and rehousing. It is therefore important that the birds are quickly able to locate feed and water to ensure a sufficient food intake. Effective ways of encouraging pullets to eat include moistening the feed, running the feeding lines more frequently, the use of skim milk powder or whey fat concentrate and vitamin supplements.

Pullets must on no account lose weight after rehousing. They should continue to gain weight, or at least maintain their body weight. If the housing system permits it and provided stocking densities are not exceeded by doing so, the pullets should be confined to the grid above the dropping pit or in the perchery until they have reached approximately 75 % production.

Partially closing the scratching area (leaving the birds a minimum amount of space) and manually moving disorientated birds back into the system have also proved effective.

Summary and Conclusions

Rearing pullets in deep litter and perchery systems requires more time, effort and expertise. The flock has to be continuously monitored to ensure optimum growth. The foundation for the hens' performance in the subsequent production phase is established during the growing period. Rearing should therefore be regarded as an investment phase. It cannot be managed from an office desk. Constant monitoring and observation of the flock are the key to success.

Zusammenfassung

Managementempfehlungen zur Junghennenaufzucht für Bodenhaltungs- und Volierensysteme

Die Aufzucht legereifer Junghennen ist als eine Investitionsphase für Legehennen zu betrachten. Bei der Aufzucht für Boden- und Volierensysteme, u.U. mit Wintergarten und Freilandauslauf oder für Bio-Haltung, ist besondere Sachkenntnis erforderlich, die durch innerbetriebliche Erfahrung weiterentwickelt werden sollte. Tägliche Beobachtung im Stall ist erforderlich und nicht durch Planung im Büro zu ersetzen. Insbesondere zu beachten ist:

- Junghennen für alle nicht-Käfigsysteme sind grundsätzlich in Boden- und Volierensystemen aufzuziehen. Je ähnlicher der Aufzuchtstall dem späteren Produktionsstall gestaltet ist, umso unproblematischer wird die Umgewöhnung.
- Die Küken sollten frühzeitig – möglichst vor der 6. Lebenswoche - lernen, auf Reuter oder Sitzstangen aufzufliegen. Volieren sollten frühzeitig geöffnet werden.
- Die optimale Besatzdichte hängt vom jeweiligen Aufzuchtsystem ab; angemessene Ausstattung mit Futter- und Tränksystemen ist dabei zu beachten.
- Um Federpicken zu begrenzen und Kannibalismus möglichst zu vermeiden, ist das Behandeln der Schnäbel zu empfehlen.
- Wegen höherer Bewegungsaktivität benötigen Junghennen in Boden- oder Volierenhaltung von einem Futter vergleichbarer Nährstoffdichte größere Mengen.
- Der Futterwechsel (Küken-Starter, Küken-, Junghennen- und Vorlegefutter) richtet sich nicht nach dem Alter, sondern nach der Gewichtsentwicklung der Tiere.

- Eine ausreichende Futteraufnahme bei Legebeginn ist durch die Verfütterung eines Junghennenfutters mit geringem Protein- und hohem Rohfasergehalt zu erreichen.
- Das Lichtprogramm ist so zu gestalten, dass die Länge des Lichttages während der Aufzucht nicht zunimmt und während der Produktionsphase nicht abnimmt.
- Bei Kunstlicht aufgezogene und in Ställe mit Tageslicht umgestallte Hennen müssen sich an die veränderte Umwelt allmählich anpassen. Fenster sollten in den ersten Wochen nach der Umstallung verdunkelt werden.
- In Bodenaufzuchten ist der Infektionsdruck vielfach höher als in Käfigaufzuchten. Unter Berücksichtigung der regionalen Situation sollte ein betriebsspezifisches Impfprogramm angewendet werden.
- Die Umstallung vom Aufzucht- in den Legebetrieb muss zügig, dabei aber möglichst schonend erfolgen, um den Stress des Fangens und Transportierens zu minimieren.
- Junghennen sollten rechtzeitig vor dem geplanten Legebeginn umgestallt werden, um noch vor dem Legen mit der neuen Umgebung vertraut zu werden.
- Junghennen verlieren durch Transport und Umstallung Körpergewicht. Daher ist es wichtig, den Tieren im Legestall schnell Zugang zu Wasser und Futter zu ermöglichen.

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Trends and latest issues in broiler diet formulation[1]

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1 Changes in feed composition over the recent years

For over 30 years Degussa has provided the industry with data on the amino acid composition of raw materials. This database provided to customers - today known as AMINODat® 3.0 - has become the standard in the industry being used by compound feed producers as well as in nutrition science as the reference for amino acids. Moreover, the large data base allowed for developing robust and reliable NIR calibrations for more than 20 important raw materials used in livestock nutrition. NIR technology enables rapid amino acid analysis within few minutes.

Apart from analysing raw materials Degussa is highly experienced in amino acid analyses of compound feeds as the company offers analytical services in various respects. Thus, Degussa is providing the same analytical quality and resources in the analysis of compound feeds. Analyses of the data which accumulated during recent years revealed some interesting trends regarding specifications used in broiler diets.

Table 1: Average crude protein and total amino acid contents analysed in a total of 1632 compound broiler feeds originating from all regions in the world and collected from 2001 until 2006

Diet	CP	LYS	MET	M+C	THR
World					
Pre-Starter	23.3	1.34	0.58	0.93	0.88
Starter	22.2	1.26	0.53	0.89	0.84
Grower	20.5	1.14	0.49	0.84	0.76
Finisher	19.7	1.08	0.46	0.80	0.73

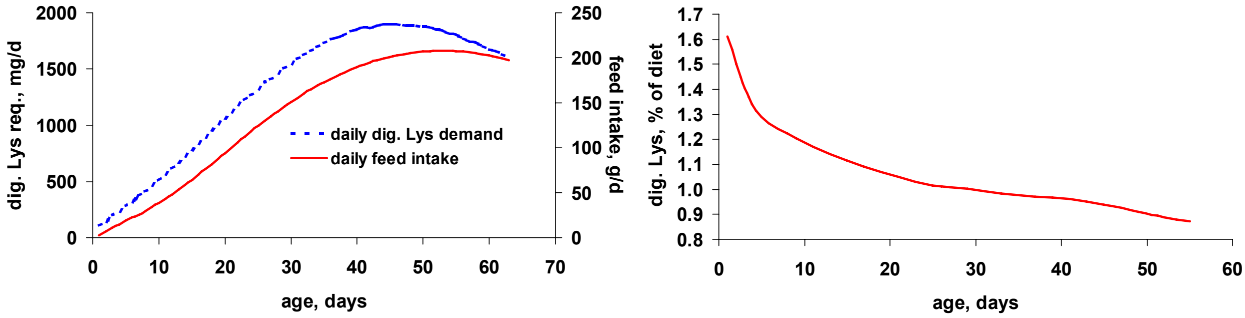
The data reported is based upon analysis of 1632 broiler feeds for amino acid content in Degussa's laboratory in Hanau, Germany. In total 105 pre-starter, 497 starter, 604 grower and 426 finisher feeds were analysed. The number of samples analysed per year were 202, 239, 274, 403, 334 and 180, respectively, for the calendar years 2001 up to and including the first six months of 2006. Only data with full information about the diets regarding the phase (pre-starter, starter, grower, and finisher diets), the country of origin, and the analytical data of total amino acids plus crude protein and supplemented amino acids were used. In this first survey only diets supplemented with DL-Methionine were used whilst those supplemented with the hydroxy analogue of methionine (liquid MHA-FA, MHA-Ca) and those containing both methionine sources were excluded. Diets from feeding experiments were also excluded. Thus, the diets used in this evaluation should represent commercial practice of the recent years.

In Table 1 the global average crude protein and amino acid levels are shown. Although the length of the phases are not specified for the single feeds, a clear dietary reduction of both protein and amino acids from pre-starter to finisher feed can be obtained. Dietary protein reduced from 23.3 % to 19.7 % and Met+Cys from 0.93 % to 0.80 %, respectively. Lys as the reference amino acid of the "Ideal Protein Concept" decreased from 1.34 % to 1.08 %. This generally fits well to the shape of the ideal curve for optimum dietary amino acid levels in compound feed which is the product from the daily feed intake and daily amino acid requirement. This is illustrated for digestible lysine in Figure 1. In

[1] Slightly shortened version of a publication in Degussa AMINONews, 2007, Special Edition, by the same authors

addition, the means given in Table 1 suggest increasing ratios to Lys particularly for Met+Cys but also for Thr which is also in line with principles of the amino acid nutrition as there is an increasing requirement for Met+Cys and also Thr with age for maintenance purposes relative to lysine. These relationships are functions of body weight which increases with age.

Figure 1: Typical curves for the daily requirement of digestible lysine (left, dotted line) an for daily feed intake (left, solid line) of meat type broilers and the resulting curve for optimum digestible lysine content in the feed (right)



However, the figures shown in Table 1 are global averages and a more detailed analysis of the data revealed that specifications varied when compared on country level. Two examples from Australia and India demonstrate this variation (Table 2). The Australian data represent specifications higher than the global average. No pre-starter diets were defined. Dietary Lys levels were higher in all type diets but especially in the grower feed. At the same time, Met+Cys to Lys ratio increased from 71 % to 81 %. In contrast, analysed crude protein and amino acid levels in compound feed from India were on average substantially lower than those of the global average.

Table 2: Average crude protein and total amino acid contents in compound broiler feeds collected from 2001 until 2006 in Australia* and India (% of diets, all figures standardized to 88 % dry matter)

Diet	CP	LYS	MET	M+C	THR
Australia*					
Starter	23.2	1.30	0.56	0.92	0.83
Grower	22.3	1.23	0.54	0.95	0.77
Finisher	21.2	1.13	0.49	0.91	0.75
India					
Pre-Starter	22.2	1.25	0.54	0.87	0.80
Starter	21.7	1.15	0.49	0.80	0.77
Grower	20.2	1.09	0.44	0.74	0.72
Finisher	19.5	1.03	0.42	0.71	0.69

* no pre-starter diets were defined

The question about the reasons for these differences will be discussed later in this review. Table 3 shows that over the course of the recent five years protein levels were rather stable at about 22.0 %, 20.5 %, and 20 % in the starter, grower, and finisher feeds, respectively. In contrast, dietary Lys levels continuously increased. The development is less pronounced for Met or Met+Cys. Particularly in the starter and finisher feeds dietary Met levels tended to increase over recent years. However, at the same time the Met+Cys to Lys ratio decreased over the years – a trend which will jeopardise optimum performance. Vieira et al. (2004) fed graded dietary Met+Cys levels to 14-35 days old male broilers of two commercial strains at adequate and high dietary protein. Regression analysis revealed that optimum ratio between digestible Met+Cys and digestible Lys is at least 77 % regardless the strain and the dietary protein level. Research by Silva et al. (2005), Mack et al. (1999), and Lippens et al. (1997) also suggested higher Met+Cys to Lys ratios. Moreover, Lemme et al. 2003a demonstrated that suboptimum Met+Cys supply not only impaired broiler performance but also increased flock variation.

Dietary Thr levels seemed to have increased only from 2004/2005 on. This might partly be due to a better availability of L-Threonine because global L-Threonine production was increased and more data on both the Thr requirement of broilers and the ideal amino acid composition got available. The use of supplemental amino acids for balancing the dietary protein has generally increased, indicating a better understanding of the amino acid nutrition of broilers. In the years 2001/2002 all diets were supplemented with a methionine source whilst 80 % of the diets contained supplemental L-Lysine and only 22 % contained added L-Threonine. About five years later (2005/2006) again DL-Methionine was supplemented to all diets but penetration of Lys supplementation increased by 13 percentage points and that of Thr even by 19 percentage points to 93 and 41 %, respectively.

Table 3: Total amino acid contents analysed in compound broiler feeds ranked according to year

Diet	CP	LYS	MET	M+C	THR
Starter diets					
2001	22.4	1.20	0.51	0.87	0.83
2002	22.3	1.23	0.53	0.90	0.83
2003	22.0	1.26	0.53	0.88	0.83
2004	22.0	1.26	0.53	0.88	0.83
2005	22.3	1.28	0.54	0.89	0.85
2006	22.2	1.29	0.55	0.90	0.86
Grower diets					
2001	20.9	1.12	0.50	0.86	0.76
2002	20.8	1.12	0.50	0.85	0.76
2003	20.2	1.12	0.48	0.84	0.75
2004	20.4	1.15	0.48	0.82	0.76
2005	20.6	1.17	0.50	0.84	0.77
2006	20.4	1.16	0.49	0.83	0.77
Finisher diets					
2001	19.8	1.02	0.42	0.77	0.73
2002	19.7	1.06	0.46	0.82	0.73
2003	19.2	1.06	0.46	0.80	0.71
2004	19.7	1.10	0.44	0.78	0.73
2005	19.8	1.10	0.48	0.81	0.73
2006	20.2	1.13	0.49	0.81	0.77

The figures shown in Tables 1 to 3 can only give trends as they are biased by a number of factors. Among them is for instance that the length of the phases (on which optimum dietary amino acids levels are dependent) were not defined, different production conditions affecting diet composition are averaged, the number of samples between countries, feed types, and years were not equally distributed. However, on the other hand there are some general trends which might explain some developments in broiler production and broiler nutrition in particular.

2 Genetic factors influencing optimum amino acid supply

Growth of the animals is basically determined by their genetic potential. Depending on the environment in which the broilers grow, the management of the operation and the composition of the feed, this potential can more or less be realised.

2.1 Genetic progress

The genetic progress in broiler breeding is spectacular. Body weight of Cobb 500 birds at day 42 has increased from 2076 to 2848 g within 10 years from 1994 until 2004 (Wilson, 2005). Mc Kay et al. (2000) reported that live weights of Ross broilers at 42 days have more than doubled from 1976 (1050 g) until 2000 (2600 g). Moreover, a male bird of 2000 g yielded 250 g of breast meat (12.5 % of body weight) in 1976 whilst in 2000 a bird with the same body weight yielded 340 g (17.0 % of body weight). Such changes in animal growth and proportion of muscle tissues must affect nutritional requirements. Havenstein et al. (2003a,b) fed diets representative for 1957 and 2001 to two broiler types. The one strain they used represented the genetic potential of 1957 (Athens-Canadian Random-bred Control, ACRC) and the other strain was Ross 308 representing current performance potential. Metabolizable Energy as well as lysine and methionine plus cystine contents of the 1957 and the 2001 diets are shown in Table 4, the results of the feeding trial are reported in Table 5. The diets were mainly based on corn and soybean meal but also animal by-products were used. However, in the 1957 diets no amino acids as well as other feed additives like choline chloride or enzymes were used as they were not available at that time.

Table 4: Metabolizable energy, total lysine, and total methionine plus cystine content of diets as common in 1957 and 2001 (Havenstein et al., 2003a,b)

	1957 diet		2001 diet	
Phase	**Starter**	**Grower**	**Starter**	**Grower**
Metab. Energy (kcal / kg)	2895	2930	3200	3150
Total Lysine (% of diet)	1.18	0.90	1.25	1.10
Total Met + Cys (% of diet)	0.75	0.65	0.91	0.87

Not only the absolute level of amino acids were raised from 1957 to 2001 but also the ratio of Met+Cys to Lys which was 73 and 79 % in the 2001 starter and grower diet and 64 and 72 % in the 1957 diets, respectively. This reflects both an improved knowledge on optimum supply of sulphur containing amino acids for broilers and simply the availability of DL-Methionine for balancing the dietary amino acid profile. In this context it should be noted that the trend of decreasing Met+Cys to Lys ratios observed in the AminoLab® data base (Table 3) can result in impaired profitability as animal performance is not optimised.

Table 5: Body weight, feed conversion, and breast meat yield of male broilers obtained from strains with genetic potential of 1957 and 2001 fed diets common in 1957 and 2001 (Havenstein et al., 2003a,b)

Strain	Diet	body weight (g)	Feed per gain (kg/kg)	Breast meat yield (%)
1957	1957	591	2.28	11.5
1957	2001	641	2.05	11.2
2001	1957	2271	1.88	17.0
2001	2001	2903	1.58	19.5

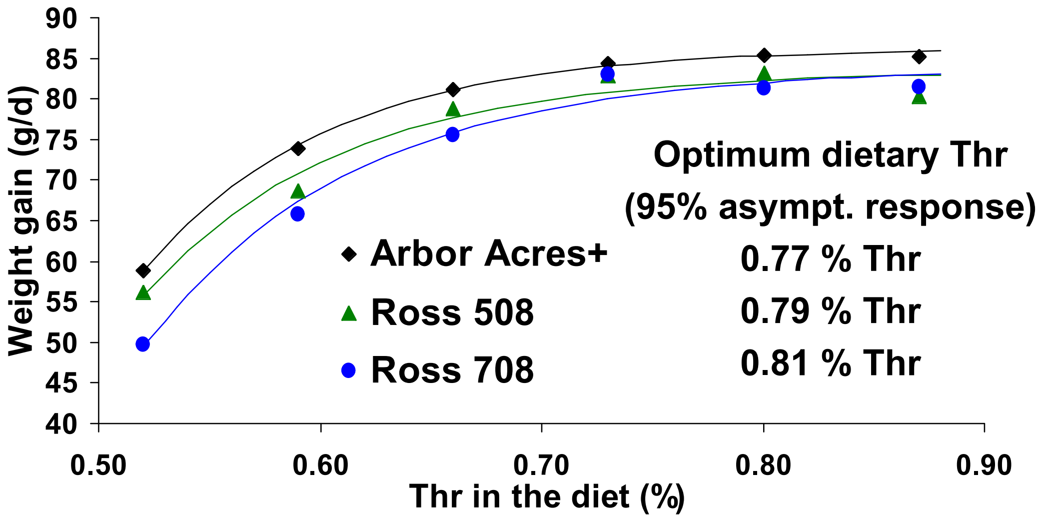
The data by Havenstein et al. (2003a,b) clearly reflect the genetic progress reported by McKay et al. (2000) and Wilson (2005). Feeding the 1957 type diet to birds of current genetic potential resulted in a significant drop in final body weight at day 42, a 30-point increase in feed conversion ratio, and a strong reduction of 2.5 %-points in breast meat yield when compared to the performance on the 2001 type diets. However, although feeding the 2001 diets to the 1957 strain improved performance compared to feeding the 1957 diet, the magnitude was much lower compared to the effects of the corresponding treatments of the 2001 strain. This clearly demonstrates both, a higher nutrient requirement and a much more efficient utilisation of dietary nutrients including amino acids of currently used broiler strains compared to former genetics. As a consequence diet specifications should be checked regularly and adjusted to the increasing performance potential of the birds.

2.2 Different genetic potentials among currently used broiler strains

Observation of the performance potential over time is meaningful. However, there are also differences in performance when currently available broiler strains are compared. As example might serve a Thr dose response trial which was performed with three Aviagen broiler strains (Kidd et al., 2004). In this trial, Thr was gradually increased from 0.52 to 0.87 % in a diet containing 1.08 % Lys. Experimental diets were fed to 21-42 days old, male Arbor Acres Plus, Ross 508, and Ross 708 broilers.

In Figure 2 the responses on body weight gain are shown. Data were analysed by exponential regression in order to derive estimates for optimum dietary Thr levels. In this trial, maximum performance was highest with Arbor Acres Plus birds achieving the asymptote at 86.3 g/d while the maximum performance of Ross 508 and 708 was similar with 83.5 and 83.8 g/d. Commonly, optimum dietary amino acid levels are estimated by determining the dose needed to achieve 95 % of the asymptotic response. Accordingly, optimum Thr levels were 0.77, 0.79, and 0.81 % for Arbor Acres Plus, Ross 508, and Ross 708 broilers indicating that optimum amino acid supply varies between strains. Related to dietary Lys these estimates revealed ratios of 71, 73, and 75 %. Lemme et al. (2004) used these data for economic considerations and figured out that for maximising the profitability (income over feed cost, considering effects on weight gain, feed conversion and changing feed costs) 0.78, 0.81, and 0.83 % Thr were needed in male Arbor Acres, Ross 508, and Ross 708 broilers (see also Figure 4). It is, thus, concluded, that amino acid specifications should be adjusted to the strain used.

Figure 2: Responses of male Arbor Acres Plus, Ross 508, and Ross 708 broilers to graded levels of dietary Thr on daily weight gain (data from Kidd et al., 2004)



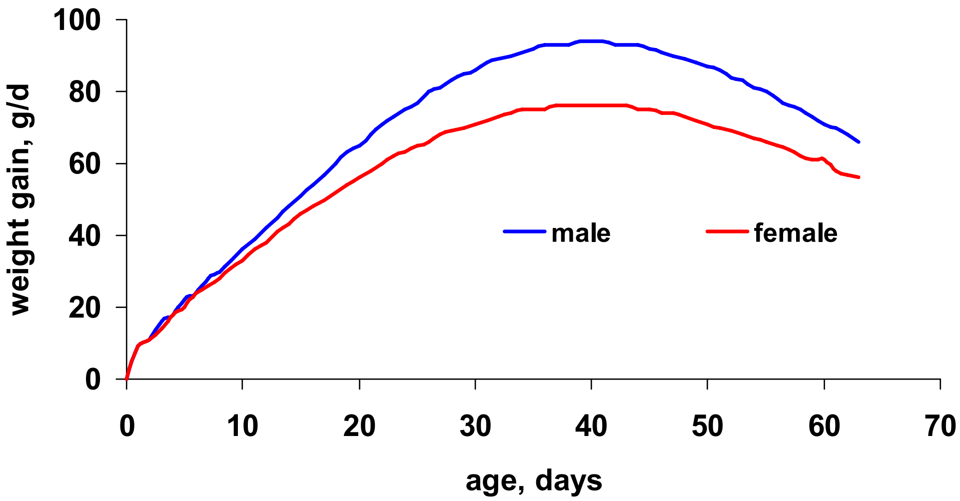
2.3 Male and female birds have different growth curves

Havenstein et al. (2003a,b) did not test only male birds (compare Table 4) but included also female broilers. In that trial female Ross 308 broilers achieved a live weight of 2441 g in 42 days when fed a modern diet, males 2903 g.

Figure 3 shows typical growth rates for current high yielding male and female broilers. Accordingly, maximum daily gain of both genders is achieved at the same age of about 40 days. However, the curve of the female birds is much flatter achieving a peak of about 75 g/d compared to males reaching a daily gain of about 95 g. From hatch to day 10 to 14, growth of both sexes is fairly similar but later on growth rates of male broilers are higher. Therefore, dietary amino acids can be lowered for female broilers in the grower and finisher diets.

Some strains available on the market are easy to sex whilst others are not. If there is no chance to separate male and female broilers the feed producers and the broiler growers are in a certain dilemma. If diets are designed for male broilers, half of the flock is overfed with nutrients which are expensive and possibly result in enhanced fat accretion in female birds. If diets are formulated to meet female's requirements, male birds are underfed and their growth will be limited. The solution will be somewhere in between - but the optimum situation would be if males and females could receive specific diets.

Figure 3: Daily weight gain of male and female broilers



3 Optimum dietary amino acid levels depend on the production goal

Changing dietary amino acid density over the years as observed in Table 1 is probably mainly due to the increasing performance potential of the birds. However, during recent years the structure of the broiler business changed as well which also influenced the feeding strategies. For example, in 1972 about 70 % of the total broiler production in the USA was sold as whole birds and only 30 % as further processed products (Ollinger et al., 2000). This picture changed completely as in 1997 about 87 % of the US broiler production was sold as further processed products. At the same time final body weight increased from 1.7 kg to 2.2 kg. In 2005, average body weight of broilers was 2.5 kg. Changing focus of the production goal impacts optimum dietary amino acid level. Pack et al. (2003) conducted meta-analyses of Met+Cys, Lys, and Thr dose-response studies conducted with growing broilers (approx. 15-40 days of age). Data of all available studies were standardised, plotted in one diagram and analysed by exponential regression. The three performance criteria body weight gain, feed conversion ratio, and breast meat yield were considered.

The outcome of the literature survey for Met+Cys (9 trials), Lys (5 trials), and Thr (4 trials) is summarised in Table 6. The lowest estimates were found for maximising body weight gain – consistently for all amino acids. In order to minimise feed conversion ratio clearly higher amino acid levels were needed whereas at least for Lys and Thr even higher dietary supply was needed to maximise breast muscle growth. These numbers demonstrate that optimum dietary amino acid levels depend on the production target.

Pack et al. (2003) made some economic considerations on optimum dietary Met+Cys and Lys levels. Increasing these amino acids by 0.10 %-points by supplementing of DL-Methionine or L-Lysine increased diet costs. However, relating the feed costs to body weight revealed that the increase of either DL-Methionine or L-Lysine reduced the feed cost per kg body weight by about 0.3 % because the growth of the birds more than compensated the additional costs. If feed costs were related to breast meat yield an increase of 0.10 % in supplemental methionine or lysine reduced the feed costs per kg breast meat even by 1.8 % (Met+Cys) or 3.9 % (Lys) reflecting that the breast muscle responds very sensitive to dietary amino acid supply.

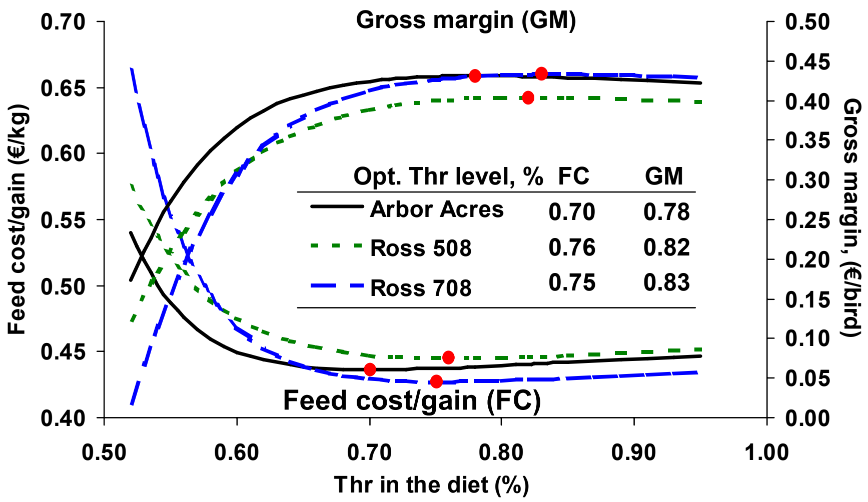
Table 6: Optimum dietary amino acid levels as estimated in literature surveys comprising 9 Met+Cys, 5 Lys and 4 Thr dose response trials conducted with 15 – 42 (Met+Cys, Lys) and 20 – 56 days old broilers (Pack et al., 2003)

Criterium	Lys, total % of diet	Met+Cys, total % of diet	Thr, total % of diet
Weight gain	1.10	0.93	0.66
Feed per gain	1.17	1.05	0.68
Breast meat yield	1.21	0.99	0.70

In the above mentioned Thr trial with three broiler strains also economic calculations were performed (Figure 4, Lemme et al., 2004). These calculations did not only focus on feed cost per kg weight gain but also on income over feed cost (gross margin). The performance response curves and the respective regression equations were combined with the feed costs which increase with increasing dietary Thr level and the revenues are shown in Figure 3. Minimizing feed cost per kg weight gain prohibits maximizing overall profitability in terms of gross margin. In this context it shall be noted that application of the ideal protein concept in broiler nutrition and increasing balanced protein levels have a tremendous effect on weight gain, breast meat yield and feed conversion which will impact gross margin.

Dietary amino acid specifications strongly depend on the production goal. If only live weight gain were optimized, lower levels are needed compared to optimizing feed conversion or maximizing breast meat yield. In the context of market developments towards further processed products the focus on

Figure 4: Impact of increasing dietary Thr on feed cost per kg gain (FC) and income over feed cost (gross margin, GM) in three broiler strains (Lemme et al., 2004)



breast meat yield continuously increases. Moreover, integrated operations in particular have the opportunity to optimize their overall profitability by optimizing their feed formulations which might be at first glance more expensive but at second glance improves overall performance and income. Coming back to the data shown in Table 2, differences between the Australian and Indian specifications might partly be driven because of differing production goals.

4 Feed intake and optimum dietary amino acid levels

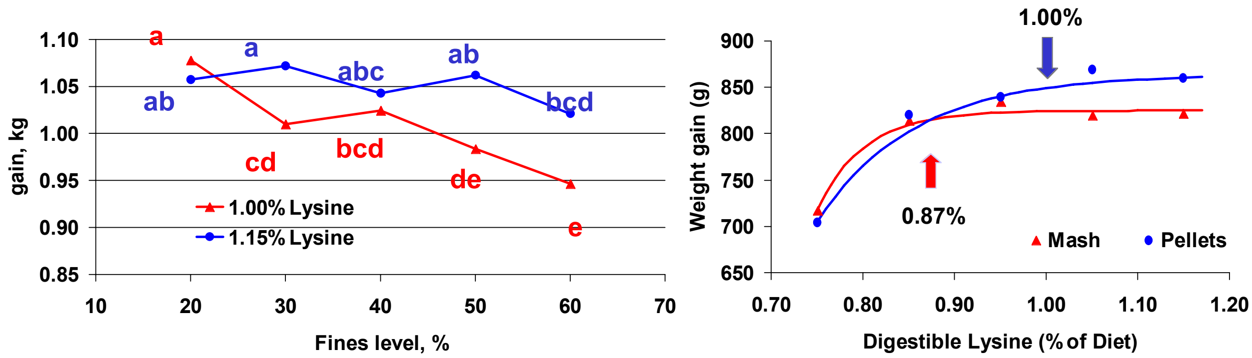
Responses to amino acids are a matter of amino acid intake rather than dietary amino acid levels. Therefore, in order to achieve a defined body weight within a given period a certain nutrient intake of the birds should be assured. Any factor decreasing feed intake will reduce nutrient intake and, therefore, impair performance. There are certainly many factors conceivable as feed intake is regulated by physiological feed back mechanisms. For instance, if a diet is deficient in Met+Cys, Lys, Thr, or any other essential amino acid feed intake is reduced. Such a situation characterises an amino acid imbalance and reduced feed intake protects the animal against harm as protein synthesis is limited by the deficient amino acid. All other amino acids exceeding the demand of this limited protein formation have to be degraded because there is no significant amino acid storage in the body. Reduced feed intake, therefore, avoids an overload of the degradation capacity. Abolishing the deficient situation by increasing the deficient amino acid improves the amino acid balance and, thus, protein synthesis and as the animal's metabolism is discharged, feed intake increases. A logic consequence of this is to find optimum balance between the amino acids – a concept which is known as "Ideal Protein Concept".

Regarding practical broiler production, there are several important factors influencing feed intake, such as stocking density, lighting program, etc. Other factors are feed form or pellet quality, dietary energy content, and ambient temperature, which will be discussed in the following.

4.1 Effects of feed form and pellet quality on feed intake

There is evidence that feed structure (particle size), feed form and pellet quality affect feed intake and, thus, nutrient intake which in turn affects the performance of the broilers. In most operations broilers are fed with pelleted feed, but due to high production rates and throughput in many feed mills, pellet quality may suffer. Pellet quality is defined by the percentage of fines resulting from breaking or damaging the pellets during transport in pipe systems or on the truck. In this context it can be assumed that many recommendations derived from dose-response trials are underestimated because the experiments were conducted using mash feed.

Figure 5: Weight gain performance of growing broilers fed two dietary Lys levels at increasing percentage of fines (left, Greenwood et al., 2004) and responses of growing broilers fed graded dietary Lys levels in mash or pelleted feed (right, Greenwood et al., 2005)

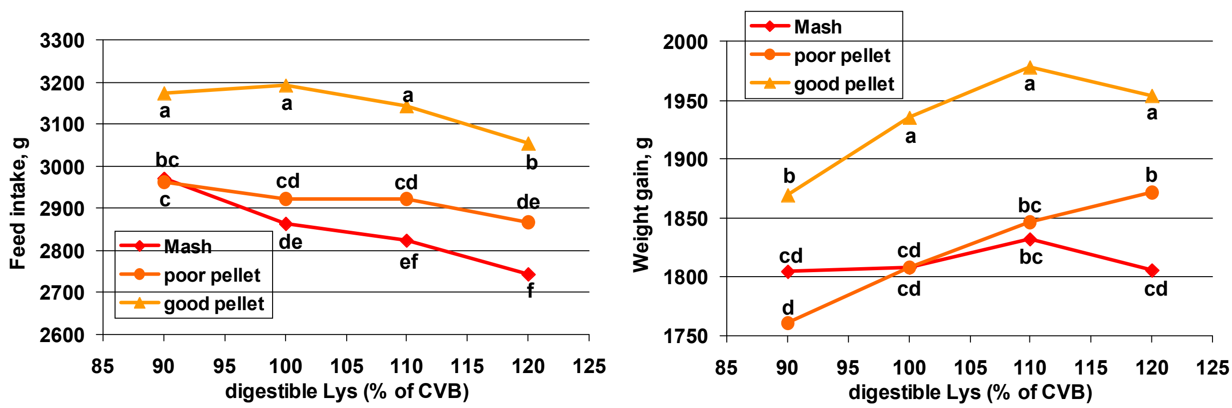


McKinney and Teeter (2004) and Quentin et al. (2004) produced experimental pelleted diets and simulated different pellet qualities with graded proportions of fines (20, 40, 60, 80, and 100 %). A mash diet served as control in the trial by McKinney and Teeter (2004). In both trials the increasing proportion of fines in the diets resulted in impaired feed intake of the finishing broilers and, thus, weight gain. This effect was obvious in slow and fast growing broiler strains (Quentin et al., 2004). With 80 % fines animal performance was almost as low as that of the mash fed birds (McKinney and Teeter, 2004). The latter authors also observed an increasing eating frequency and a decreasing resting frequency with increasing fines proportion. From this finding the authors proposed to account for the higher physical activity by adjusting the dietary energy at poor pellet quality.

Greenwood et al. (2004) conducted a similar trial, in which they produced two series of diets with varying levels of fines (20, 30, 40, 50, 60 %) for 14 to 30 days old male Cobb 500 broilers. One series of diets contained 1.00 % Lys while the other contained 1.15 %. At 20 % fines, performance at both Lys levels was almost identical, but with increasing percentage of fines the difference between treatments of both Lys levels increased (Figure 5, left). Performance at 1.00 % Lys declined stronger than at 1.15 % Lys suggesting an interaction between pellet quality and optimum amino acid level especially at decreased pellet quality.

Another trial reported by the same authors strengthens the hypothesis of an interaction (Beyer and Greenwood, 2004). Graded levels of digestible Lys were fed to 16 to 30 days old male Cobb 500 broilers in mash or pelleted feed (Figure 5, right). Exponential regression analysis of the data suggested a lower optimum digestible Lys level when mash feed is fed compared to the situation with pellets – more evidence for interactions between optimum dietary amino acid levels and feed form.

Figure 6: Feed intake (left) and weight gain (right) in growing broilers fed increasing levels of balanced protein expressed as digestible Lys as mash, poor or good quality pellets (Lemme et al., 2006)



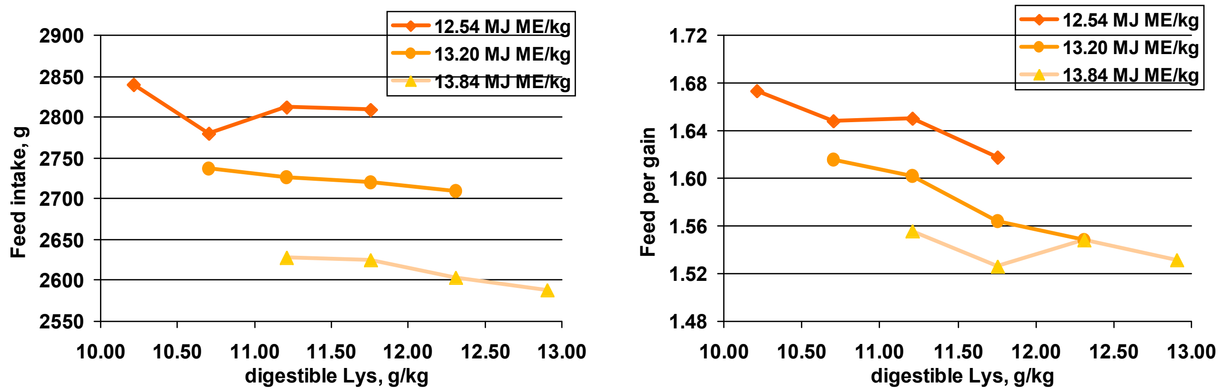
Two experiments with increasing levels of balanced protein were designed by Lemme et al. (2006). In this experiment balanced dietary protein was increased in four steps from 90 to 120 % (related to the Dutch CVB recommendations) and fed to 14 to 35 days old male Ross 308 broilers. Diets were either fed as coarse mash, as good quality pellets, or as poor quality pellets. Pellet quality was altered by varying the channel length of the pelleting die in the pellet press.

Birds fed the good pellet quality had considerably higher feed intakes resulting in higher weight gain compared to those fed poor quality pellets or coarse mash feed (Figure 6). Generally, feed intake decreased with increasing balanced protein levels, however, compared to the treatments with poor quality pellets, the decrease was more pronounced in the mash treatments. Whilst birds fed pellets had improved weight gain with increasing balanced protein, there was almost no improvement in mash fed birds. These responses indicate that optimum amino acid levels differ depending on feed form or pellet quality confirming the findings of Greenwood et al. (2004).

Generally, an impaired pellet quality leads to reduced feed intake. As a consequence, balanced dietary amino acid levels should be enhanced in poor quality pellets in order to maintain the amino acid intake. Optimum balance between feed form and amino acid levels may vary depending for example on diet cost, energy costs for pelleting, or revenues per kg live weight or per kg breast meat. Wheat based diets usually result in higher quality pellets whilst pure corn soybean meal feeds produce less stable pellets, with fines often exceeding 50 % when arriving in the feeder.

4.2 Voluntary feed intake is driven by the dietary energy level

Figure 7: Feed intake (left) and feed conversion ratio in (right) in growing broilers fed increasing levels of balanced protein expressed as digestible Lys at low, adequate and high dietary energy (Lemme et al., 2003)

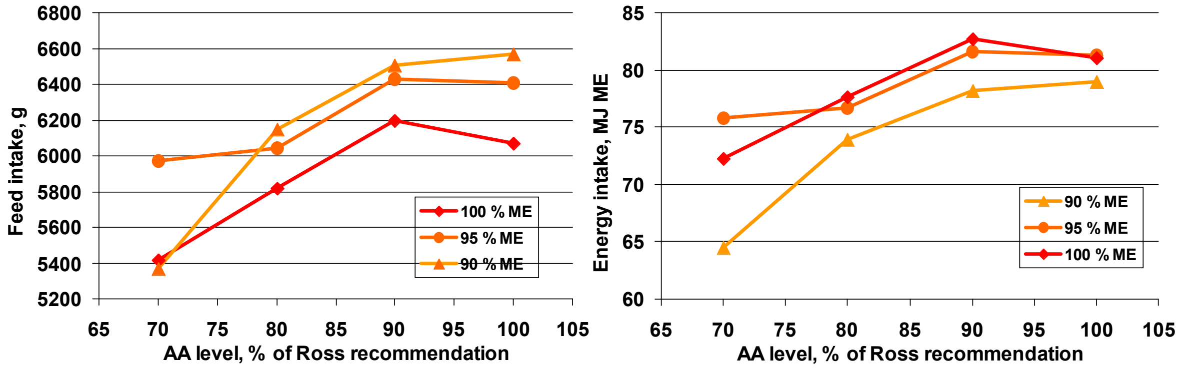


Another well known factor influencing feed intake is the dietary energy content. Lemme et al. (2003) fed increasing levels of balanced protein in diets low, adequate, or high in dietary energy to 14-35 days old male Ross 308 broilers. The trial was designed to produce identical amino acid to energy ratio at each energy level. Increasing dietary energy significantly decreased feed intake (Figure 7). By multiple regression analysis an equation was developed allowing for a prediction of feed intake only on the basis of dietary energy and dietary balance protein (r^2=0.97). This indicates that these nutritional factors are mainly responsible for regulating feed intake. Whilst increasing dietary balanced protein levels had only a small effect on feed intake, weight gain was more affected resulting in improved feed conversion with increasing amino acid supply, particularly at low (12.5 MJ or 2980 kcal ME/kg) and adequate (13.2 MJ or 3150 kcal ME/kg) energy supply. Comparing the treatments with equal amino acid to energy ratio revealed that for achieving the same performance optimum amino acid to energy ratio is not identical as sometimes suggested in the literature.

In another trial, experimental diets with increasing levels of balanced protein either at recommended (ROSS Broiler Management Manual, Aviagen, 2002), 5 % decreased, or 10 % decreased energy were fed during the starter (1-10 days), grower (11-32 days) and finisher phase (33-46 days) to male Ross 308 broilers (Lemme et al., 2005). The diets of the 90 % energy treatments did not contain any fat source simulating conditions found in regions where these ingredients are preferentially used for human nutrition. The balanced protein considering Lys, Met+Cys, Thr, Trp, Arg, Ile, and Val was increased from 70 to 100 % of ROSS recommendation.

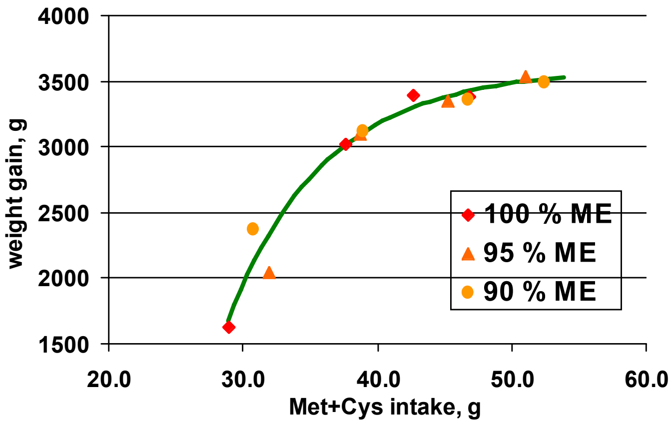
Feed intake increased non-linearly with increasing amino acid levels (Figure 8). At 70 % amino acids a severe feed wastage was observed which is attributed to the amino acid deficiency in the diets. In these treatments feed intake was lower than feed consumption which should be considered when interpreting the responses. Feed intake increased with dietary energy reduction. Data further suggested that birds were able to compensate the lower dietary energy levels by higher feed intake when energy was reduced by 5 %. A further decrease of the dietary energy to only 90 % of the recommended level apparently exceeded a certain physiological threshold as birds were not able to further increase their feed intake. This resulted in a clearly lower energy intake (Figure 8, right).

Figure 8: Feed intake (left) and energy intake (right) in 1-46 days old broilers fed increasing levels of balanced protein at very low, low, and adequate dietary energy (Lemme et al., 2005)



Weight gain generally increased non-linearly with increasing dietary amino acids (Figure 9). When related to the amino acid intake (Met+Cys taken as reference), all weight gain data points described exactly one response curve (r^2=96%). Thus, responses on weight gain and also on breast meat yield (not shown) appeared to be a function of amino acid intake rather or only indirectly of energy intake. Decreasing dietary energy actually improved amino acid intake due to increased feed intake which resulted in improved weight gain. Also this experiment does not confirm the idea of a fixed optimum amino acid to energy ratio. It is rather proposed to reduce dietary amino acids to a lower percentage as the energy in low energy diets.

Figure 9: Weight gain responses of 1-46 days old broilers fed increasing levels of balanced protein at very low, low, and adequate dietary energy plotted against amino acid intake (Met+Cys taken as reference, Lemme et al., 2005)



Two examples for affecting feed intake are given in order to demonstrate that feed intake and, thus, amino acid intake is affected by dietary energy. If there is a need to formulate low energy diets, amino acid levels should be less reduced in order to maintain performance. Coming back to the observed differences in amino acid levels in Australian and Indian feeds, it can be assumed that also the dietary energy played a role. In India, dietary energy is relatively expensive and sometimes not available resulting in low energy diets. As a consequence dietary amino acids are reduced too – and many feed producers in this region learned by experience that amino acids should be reduced to a smaller extent.

4.3 High ambient temperature affects feed intake

Broilers are increasingly being subjected to environmental temperatures that are above their thermo neutral zone. On the one hand birds grow faster than ever before and, therefore, generate more metabolic heat than previously at any given age. Gous (2004) reported that the comfort temperature of 21.5° C for a male broiler in 1970 decreased to 11.5° C in 2004. On the other hand broiler production is increasingly being introduced in environments with high ambient temperature, where the release of body heat is difficult. Methods are available for reducing the ambient temperature such as insulation, fans, evaporative coolers, reduced stocking density and others. However, in many cases it is not possible to control the temperature in the broiler house effectively. Therefore, reducing the heat load of the broilers through nutritional strategies would be valuable.

The reduction in performance of chicks observed at high temperatures is partly due to a reduced feed intake imposed by the bird's restricted ability to dissipate heat. To remain in thermal balance, heat production by the broiler must equal its heat loss. The problem at high temperatures is to reduce unnecessary heat production of the bird, otherwise fat deposition increases and feed intake declines. The amount of heat produced by a boiler is related to its body size, growth rate, degree of feather cover and other effects.

One strategy for maintaining nutrient intake could be an increased density of diets. However, increasing the energy content while maintaining the amino acid to energy ratio is not effective in combating heat stress in broilers (Gous, 2004). This is in contrast to laying hens. A 1.8 kg broiler consumes twice the amount of energy consumed by a laying hen of the same body weight. The amount of energy that a boiler needs to lose as heat to the environment is more than a laying hen consumes each day. That explains, why broilers suffer more than layers at high temperature and why boilers cannot benefit to the same extent as the hen from a high-density diet under high temperature.

Since feed intake is driven by dietary energy, a variation of the amino acid to energy ratio might be a strategy. Trials by Wijtten et al. (2004a,b) and Lemme et al. (2006) conducted under optimum temperature regimes revealed that increasing levels of a balanced protein to high levels at unchanged dietary energy consistently improved weight gain. In most cases feed intake decreased with balanced protein levels particularly at higher than recommended levels which resulted always in significant linear improvements in feed conversion. However, research reviewed by Gous (2004) suggested that also this approach is not successful to avoid performance depression under heat stress. The explanation is that under heat conditions birds are not able to get rid of additional heat which is mainly accompanied with protein synthesis (McLoud, 1997).

Nutritional strategies involving adjustments on the amino acid side are not successful to compensate for a reduced feed intake and, thus, performance under heat stress conditions. All approaches like increasing the amino acid (balanced protein) to energy ratio or improving the amino acid balance in general might be of benefit to a certain extent – but such strategies should also be applied under thermo neutral conditions.

5 Summary

- Checking diet specifications on a regular basis is a key issue in profitable broiler production.
- Statistical evaluation of 2001-2006 AMINOLab® data reveals changes in feed formulation over recent years and potential imbalances which may increase production costs.
- Continuous improvement in broiler genetics requires regular evaluation of nutrient specifications in raw materials as well as in compound feeds to exploit the genetic potential.
- Careful adaptation of diet specifications regarding climate (high temperature), production management (split sex or as hatched) and production goal (target body weight, cut ups vs. whole carcass) is essential.
- Pellet quality (% fines) and dietary energy level are main drivers of feed intake, thereby indirectly driving performance. However, amino acid concentrations have a direct and dominant effect on performance, provided they are supplied in a balanced ratio.

- The new QuickChick software tool from Degussa supports dynamic decision making concerning the above topics.

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[2] Additional references are given in the Degussa publication "Check your Specs" by the same authors.

Crossbreeding in dairy cattle: International trends and results from crossbreeding data in Germany

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Introduction

Crossbreeding has been the breeding method of choice for several species in plants and livestock. In plants, the main reason for crossbreeding is to exploit heterosis effects which can be maximized via the use of highly inbred parental strains. In livestock, notably in poultry and swine, positional effects of pure-bred parents of crosses are well known and hence crossbreeding systems are set up accordingly. Compared to plant breeding, heterosis effects are not expected to be as high but are still significant and thus give an additional benefit. Breeding systems for swine and poultry thus almost exclusively use crossbreeding systems.

In dairy cattle, however, pure breeding has been the dominant breeding method for many years with only few exceptions. The reasons for this, comparing dairy cattle to swine or poultry, are mainly due to biological facts: Dairy cows have a much lower reproduction rate (≤ 1 offspring per year), a long generation interval and the individual animal has a relatively high value. These facts have contributed to a situation in which little difference is observed between commercial milk producers and pedigree breeders. In most European countries, large fractions of the populations are also registered as breeding stock, whereas in the United States commercial herds without any registered cattle exist besides herds with varying fractions of registered cattle.

Throughout the world, the main activities of breeding organizations still rely heavily on selecting animals from the entire population of a country or region. Some exceptions from this rule also exist. These pertain to organizations maintaining their own nuclei. However, these organizations have not yet captured a significant share of the world markets for bull semen, frozen embryos or live cattle.

During the Eighties, dairy cattle breeders worldwide explored possibilities arising from the use of new biotechnologies to overcome the ineffectiveness of conventional breeding systems. One of these biotechnologies was embryo transfer including deep-freezing of embryos. However, initial progress levelled off with still unsatisfactory success rates. Around seven transferable embryos per flush after super-ovulation for cows reacting properly to a super-ovulation (equal to four pregnancies) is a level which has given embryo transfer only limited significance for increasing the reproductive rate of highly selected females. For the broad population, however, the significance of embryo transfer is close to nil.

Sexing of bull semen with sufficient accuracy has finally become available for dairy cattle breeders and for commercial milk producers worldwide. However, due to the high cost of semen sexing and low pregnancy rates this method so far is being used only in niche parts of the entire bull semen market.

Conventional and improved systems of purebreeding

Most conventional systems rely on selecting potential dams of bulls in the field, i.e. from herds owned by individual breeders. These bull dams are then mated to highly selected proven bulls. Their male offspring is reared for about one year until reaching sexual maturity, semen is collected from these young bulls and subsequently used in appropriate volume (400 to 1000 doses) for a progeny test under field conditions. The female offspring from these matings is reared to obtain cows with first calving and first lactation milk yield. Based on the results obtained from the milk recording systems in the field, finally, around four to five years after birth of the young bull, breeding values for dairy production can be estimated for these bulls. Based on the results of the genetic evaluation, selection can take place. Most bulls are slaughtered (around 90 %), and the remaining ones can be marketed by the breeding organization as proven bulls. Within the marketable proven bulls, the few very best are again selected for the elite matings with potential bull dams.

Modifications of this basic scheme have included the use of embryo transfer for bull dams in order to increase the probability that male calves are born. Some attempts for closed nuclei have also been made. The advantages of nucleus breeding schemes in dairy cattle obviously are the direct control over all breeding activities by the breeding organization, the facilitation of accurate recording of traits other than production traits and logistic advantages when implementing biotechnologies. However, systems trying to keep nucleus lines fully closed without progeny testing young bulls in the field have failed. Keeping nucleus lines closed under a dairy cattle situation has the distinct disadvantage that the size of such operations is too small and hence possibilities to find genetically superior animals in the broad population still exist and should be exploited. Relying only on sib-testing within a small nucleus population will lead to breeding values of low reliability and consequently less variation compared to bulls progeny-tested in the field. Therefore, nucleus schemes still exist but are usually kept open and also use a progeny test in the broad population. In the future, these conditions may change if and when genomic selection based on large Single Nucleotide Polymorphisms chips (SNP) becomes the method of choice.

Growing interest in crossbreeding

In dairy cattle, the Holstein breed, formally called Holstein Friesian, has become the dominant breed throughout the world. Today, Holstein cows have the genetic potential to produce >10,000 kg milk per cow and lactation with a protein content of around 3.3 to 3.5 %. Given adequate nutrition, housing and health care, this level of production is combined with acceptable performance in functional traits such as fertility, health, functional conformation, and longevity. Genetic antagonisms between dairy production traits and functional traits exist but are usually low, within a range between zero and -0.3. Given this, genetic trends of most functional trends are slightly negative and nowadays breeding organizations focus on this problem by giving more and more weight to functional traits within the aggregate genotype. Most total merit indices used by the major breeding organizations today use weights of around 50 % for production traits and 50 % for functional traits.

On the phenotypic level, however, many dairy operations fail to manage their high producing Holstein cows adequately and thus phenotypic trends for functional traits in general appear more negative than genetic ones. Examples are stillbirths and mastitis resistance. Well managed farms achieve results with < 3 to 4 % stillbirths and < 20 % mastitis cases per cow and lactation. For less well managed farms, stillbirth rates of > 10 % and mastitis cases > 50 % are common. In view of this situation, dairy farmers are increasingly looking for new ways to overcome these difficulties which directly affect their family income. Since health and longevity are traits with known low heritability, heterosis effects can be expected from specific crosses, supporting the growing interest in crossbreeding dairy cattle.

Crossbreeding in practice

For production conditions with high costs for labour and building, optimal economic returns are achieved when maximizing production per cow. This is the case for most parts of Europe as well as for North America. In New Zealand, on the other hand, barns to house the cows are not needed or can be very simple, because the climate permits year-round grazing. The optimal production system in this case includes strict seasonal calving and a dry period during the southern winter. Under such conditions, economic returns are maximized with increased stocking rate per area of grassland and therefore the focus in New Zealand is on maximizing milk solids per hectare. Herd production records averaged 3,736 kg milk, 186 kg fat and 139 kg protein per cow in 2005/06 (LIC, 2006) and thus are very low compared to North American or European statistics. On the other hand, New Zealand achieves a stocking rate of 2.8 cows per hectare and hence a production of 520 kg fat per effective hectare. Although statistics based on this parameter are not available for other countries, it can be assumed that the latter figure presents a world record. The high stocking rate and strict seasonal calving emphasize that a focus on survival and fertility is needed for New Zealand's dairy producers and explains why crossbreeding and the exploitation of heterosis effects are common practice. Among the New Zealand cows under milk recording, 47 % belong to the Friesian (Holstein) breed, 17 % are Jersey, 1 % are Ayrshires and 35 % are crosses between Holstein and Jersey (LIC, 2006).

Although the Holstein breed under North American and European conditions nowadays is capable of herd averages > 10,000 kg milk per cow, under New Zealand conditions the advantage in dairy production over other breeds or crosses on a per cow basis is only slight if not zero. However, for the lowly heritable traits survival and fertility, crosses show marked heterotic effects and hence are a natural choice under such conditions. On a per hectare basis, crosses are superior over pure breeds.

To a large extent, crossbreeding has also been done in beef cattle. The explanation for this is similar to the case of New Zealand for dairy cattle: A beef cow is expected to produce one weaned calf annually, and this is almost all a commercial producer expects from her. Fertility and survival is the focus for the commercial beef cattle ranger while pedigree breeders also try to improve fattening abilities and carcase traits. For many commercial producers, it is therefore quite logical to work with a crossbred cow. In many European countries, commercial beef cattle holders often start their business with crossbreds between dairy breeds and beef breeds. This system ensures that the crossbred dam not only exhibits heterosis effects with respect to fertility and survival, but also produces more milk for her calf than any beef breed.

Results from the literature

Reviewing the literature, Touchberry (1992) points out that a number of crossbreeding experiments in dairy cattle actually were carried out in the first half of the 20th century. A long term experiment involving the Holstein and Guernsey breeds was carried out in the 50's in Illinois. Heterosis amounted to between 5 and 8 % for production traits and 12.8 % and 9.4 % for number of inseminations per pregnancy and days open, respectively. This underlines the potential for exploiting heterosis effects for fertility. In another publication, McAllister et al. (1994) presented results from a crossbreeding experiment involving Holstein and Ayrshire. For 'annualized discounted net return', the 'bottom line' trait from an economic perspective, 20 % heterosis was achieved. Some of the crossbred combinations were superior over purebreds in production, but the advantage of crossbreds was mainly due to superior fertility and survival.

Given the above as outlined in the previous section, Lopez-Villalobos et al. (2000abc) found positive heterotic effects for virtually all traits of importance to New Zealand's dairy producers and estimated a 25 % advantage for a rotational cross between Jersey and Holstein over the purebreds for the trait net income per hectare.

Van Raden and Sanders (2001) used the large US data base for the genetic evaluation of all dairy breeds and identified the various crosses present in the data. It should be noted that the vast majority of their data represented purebreds. Applying statistical models they estimated heterosis effects of 3 to 4 % for milk production traits, but were unable to detect any heterosis for somatic cell count, an important trait to dairy producers. Furthermore, heterosis effects for length of productive life were only at a level of 1.2 %.

Recently, Heins et al. (2006abc) reported on the analysis of crossbreeding data from seven large dairies in California. Apart from the Holstein breed which was used by all dairies, the breeds Normande, Montbeliarde, and Scandinavian Red (SR) were used for crossbreeding. The latter breed actually consisted of two breeds, the Norwegian Red and the Swedish Red Breed (SRB). Production of the crossbreds was lower than for Holsteins, but not statistically different for total fat plus protein yield of SR crosses. Significant advantages for crossbreds and especially for SR crosses were observed for calving ease, stillbirths, fertility and survival. The results from these California data have led to a very significant demand for semen of SRB bulls in the USA and in Europe to be used for crossbreeding (Svensk Avel, pers. comm., 2007).

Results from own data in Germany

Brown Swiss x Holstein in a high yielding herd

The results on crossbreeding reported in the literature are typically based on field data without underlying experimental design. Obviously, a planned experiment on crossbreeding in dairy cattle is costly, of limited size, or both. We attempted to carry out a designed experiment involving Holstein purebreds (HOL) in comparison with Brown Swiss x Holstein crosses (BS x HOL) to make up for limitations in size with accurate planning and repeated measurement of a large number of traits per animal. The experiment, carried out in cooperation between the State Research Agency for Agriculture of the state of Saxony Anhalt and the University of Halle, is still in progress and involves the high yielding herd of the State Research Agency in Iden. In 2003, when the first cows of the experiment calved, this herd (376 cows) had an average production of 11,186 kg milk, 422 kg fat, and 380 kg protein per cow.

From the Iden experiment: A Holstein cow flanked by three Brown Swiss x Holstein crosses

Two groups were formed, a Holstein purebred group and a crossbred group. For both groups, 10 sires each were selected involving sires of high genetic merit for both breeds and available in Germany in 2002. A total of 355 inseminations were carried out with 10 to 15 inseminations per sire. Sires were mated to cows well distributed over parities and genetic merit as estimated by cows' breeding values. 134 calves were born in both groups from 124 (BS x HOL) and 131 (HOL) pregnancies, respectively. Deducting losses during birth and during rearing, and deducting male calves which were sold after birth, 55 BS x HOL and 51 HOL heifers calved and started lactating. Early losses during the first lactation left 50 BS x HOL and 45 HOL first calf cows with complete lactation records that could be evaluated using a 'test day model', in our case weekly records. Losses from birth till calving were not statistically different between the two groups.

While all cows have completed their first lactation, most of them are in their second lactation and a few have begun their third lactation, we can summarize the first preliminary findings as follows:

- BS x HOL calves had higher birth weights compared to HOL. Also, the sexual dimorphism was more pronounced. No increases in calving problems were observed since calves with extreme birth weights, mostly BS x HOL in the range of 50 to 55 kg, were almost exclusively born from older dams.
- Weights and backfat thickness during time of rearing throughout the rearing period were equal for both groups.
- Additive effects due to the crossbreeding partner BS as sire breed were observed for measurements taken from the claw (more 'compact' and upright for BS x HOL) and taken from the udder (longer and thicker teats for BS x HOL).
- No differences were observed for calving ease and stillbirth for births of the cows of both groups in the first parity.
- Milking speed for BS x HOL cows was significantly slower than for HOL.
- Metabolic parameters measured from milk and urine were within a 'healthy' range for both groups although significant differences existed, e.g. for urea content of milk and urine (increased in BS x HOL).
- BS x HOL cows tended to show an improved fertility, but the difference was non-significant in the first lactation.

- Daily feed intake from day 7 to day 56 after calving was higher for BS x HOL (17.00 kg) than for HOL, which consumed 16.14 kg drymatter per day.

The results for dairy production traits are summarized in Table 1. Statistical analysis was performed applying a test day model for the weekly measurements (exception: somatic cell score, monthly measurements) of production per day. The model comprised the effects of the breed group along with management group, age of calving, year-season of calving and regression factors to account for the curve of lactation production according to days in milk. Significant differences are only found for protein percentage and content of urea while all other traits including the main trait in focus, protein yield (kg) were not statistically different.

Table 1: Results (LSMEANS) for production traits (production per cow and day) from the Iden experiment for Holstein purebreds (HOL) and Brown Swiss x Holstein (BS x HOL) crosses (asterisks denote significant differences)

Trait	BS x HOL	s.e.	HOL	s.e.
Milk yield (kg)	29.06	1.19	29.25	1.22
Fat (%)	4.31	0.12	4.20	0.12
Protein (%)	3.72*	0.06	3.63*	0.06
Fat yield (kg)	1.23	0.04	1.20	0.04
Protein yield (kg)	1.07	0.03	1.04	0.03
Somatic Cell Score	1.91	0.26	2.28	0.27
milk urea (mmol/l)	5.49*	0.04	5.28*	0.04

Summarizing the results, at present, no clear advantage of crossbreds can be seen from this experiment. Quite contrary, the inferiority of BS x HOL for the important traits milking speed and especially feed consumption would lead to the preliminary conclusion to rather stick with purebreds than BS crossbreds. However, the experiment is still in progress and differences in survival after several lactations as well as fertility parameters from several lactations have to be analyzed before drawing final conclusions. Furthermore, the preliminary conclusion may only hold for a high yielding dairy herd with close to perfect management as given at Iden.

Swedish Red Breed x Holstein and Brown Swiss x Holstein on an organic farm

Since 2002, the owner of a large organic farm in the state of Brandenburg has been crossbreeding with bulls of the Swedish Red Breed and also with Brown Swiss bulls on the basis of his original Holstein herd. The herd average under the organic conditions is around 7500 kg of milk per cow and lactation.

Top Holstein cow

Top Swedish cow

As for other reports in the literature, the data obtained from the farm are not from a planned experiment and represent the specific situation and genetic strategy on the farm. So far, comparisons can be made for Holstein purebreds, SRB x HOL crosses and BS x HOL crosses. No purebreds of the BS and SRB breeds are available on the farm and thus heterosis effects can not be estimated. Data from calving years 2003 to July 2007 were used for the analysis. During this time, substantial data were available for Holstein purebreds and the two crosses SRB x HOL and BS x HOL. Other crosses, e.g. HOL x (SRB x HOL) and BS x (SRB x HOL) were also present in the data but still of a limited number so that the results will not be presented here. The breeding strategy of the farm now is a true three-way rotational cross between the three breeds mentioned. Therefore, future data, once the lactations have been completed, will be available and subject to further analysis.

For the two crossbred groups, four sires of the breeds SRB and BS were used, respectively. This fact underlines that the results should be interpreted with great care since four sires per breed hardly can be viewed as a representative sample of the breed.

The number of cows by breed group and the number of test day records available for analysis under a test day model including regression factors for the curve of the lactation, age at calving, breed group, and cow within breed group is given in Table 2. The results for production traits are presented in Table 3.

SRB x HOL crosses show distinct and significant advantages over the two other breeds for all traits except protein percentage and somatic cell score. For protein percentage, the additive genetic effect of the Brown Swiss breed was expected to yield superior results in the crosses. The somatic cell scores are within a ‘healthy’ range for all three groups and thus observed differences may not be relevant in practice, even if statistically significant.

Table 2: Number of animals and test day records by breed group (Brandenburg data)

Breed group	No. of cows	No. of test day records
HOL	380	3760
SRB x HOL	110	1189
BS x HOL	96	880

Table 3: Production characteristics (LSMEANS, production per cow and day) for the three breed groups in the Brandenburg data

Trait	HOL	s.e.	SRB x HOL	s.e.	BS x HOL	s.e.
Milk yield (kg)	21.02	0.27	22.27	0.46	20.62	0.53
Fat %	3.76	0.02	3.83	0.04	3.84	0.04
Protein %	3.18	0.01	3.26	0.02	3.31	0.02
Fat yield (kg)	0.78	0.01	0.83	0.02	0.79	0.02
Protein yield (kg)	0.66	0.01	0.71	0.01	0.67	0.02
Somatic Cell Score	2.75	0.06	3.18	0.10	2.99	0.12

Since the number of sires for the crossbred groups was limited, a further test day model was fitted including sires as fixed effects. From this analysis, sires were ranked and the rankings were compared to their estimated breeding values in the respective breed of origin. Not too surprisingly, ranks of sires differed between performance in purebreds and crossbred animals. For BS sires, one striking example was a highly significant difference of 5 kg milk per day in the progeny of two bulls that had equal breeding values for milk production in their respective purebred population. This finding gives a hint that a specific combining ability not only may exist for a specific cross but also for individual bulls. The three breed groups were also compared with respect to survival and fertility. For survival, losses within the first 365 days after the first calving were compared. HOL had losses of 16.8 %, SRB x HOL showed only 8.2 % and BS x HOL equalled 18.1 %. For fertility, the traits days to first service (DFS) and number of inseminations per pregnancy (NIPP) were considered. No significant differences were found for DFS. For NIPP, HOL had 2.28 inseminations while SRB x HOL and BS x HOL were on a level of 1.76 and 1.77 inseminations, respectively. The results for SRB x HOL crosses in general agree well with the results by Heins et al. (2006abc).

Crossbreeding under European conditions

Concluding from the above, it appears that crossbreeding indeed has distinct advantages for functional traits such as survival and fertility. However, all results mentioned with the exception of the special case of New Zealand, were obtained from comparisons of F_1-animals with purebreds. However, for dairy breeders and producers who normally intend to breed their own replacements, an important question is how to go on from F_1-animals. Backcrossing to Holstein will reduce heterosis effects and thus may not be advisable. Rotational crosses would require sophisticated breeding strategies within each herd, and up to now no results exist from experiments under European or North American conditions.

The distinct advantages of F_1-animals can only be fully exploited in a hierarchical system with specialized breeding and production tiers. Commercial milk producers would then buy F1-animals and replace them regularly, concentrating on producing milk. Under present conditions, there is no way for breeding herds to produce their own replacements and F_1-animals for sale. This could only be envisaged if semen sexing would become common practice. Up to now, only a limited amount of sexed semen is available at high price and low expected pregnancy rates, but it may find increasing acceptance, especially for inseminating virgin heifers in well managed herds, until further refinements of the procedure of sexing semen are achieved. In view of the current demand and attractive price for purebred Holstein breeding stock, breeders are more likely to stick to the Holstein breed as first choice for well managed herds.

The indication of specific combining ability of individual bulls will not surprise plant or animal breeders. But it should be taken as a note of caution against recommending crossbreeding as an easy solution to current problems. Systematic crossbreeding would require a long-term breeding plan to progeny-test young bulls for purebred and crossbred performance. In contrast to chickens or pigs, the information from sisters will be limited due to low reproductive rates. Small breeds like SRB would need to organize crossline testing of all their young bulls on a sufficient scale - in addition to their current pureline testing – with subsequent selection for combining ability.

Conclusions

Crossbreeding in dairy cattle under the conditions as found in Europe and North America is a tempting alternative. F_1-animals show distinct advantages with respect to fertility and survival while their production characteristics reach those of the Holstein breed. However, it is not clear how individual cattle holders should continue from the F_1-animals since producers like to breed their own replacements. The use of F_1-animals and a separation of the breeding and the commercial tier would be facilitated if sexed semen could routinely be used for cows at all ages which is not the case at present. Data from long-term experiments of rotational crosses are not available except for the specific case of New Zealand.

Summary

Crossbreeding in dairy cattle is of growing interest to dairy cattle breeders and milk producers since in the dominant dairy breed, i.e. Holstein, negative phenotypic trends have been observed for functional traits like health, fertility and longevity. Although Holsteins are the most profitable dairy cows on well managed farms, this may not apply to other farms. Crossbreeding to exploit heterosis effects for lowly

heritable functional traits is a tempting alternative. Under specific production systems, e.g. in New Zealand, where high stocking rate and production of solids per hectare is the primary goal, fertility and survival are even more in the focus and hence a significant share of the New Zealand dairy cows population are indeed crossbreds.

A review of literature indicates that heterosis effects of 4 to 5 % for production traits and substantially more heterosis for fertility and survival can be expected. Recent experimental data from Germany indicate that the advantage of crosses is negligible at a very high management level. For some traits, e.g. feed efficiency, even adverse effects can be observed. At a lower level of management, crosses exhibit their superiority with respect to production, fertility, and survival. Unresolved questions remain:

a) the optimal design for a long-term crossbreeding system, assuming that farmers prefer present practices to produce their own replacements and

b) the apparent need to progeny-test individual bulls of 'sire' breeds for combining ability with Holstein cows.

Zusammenfassung

Das Interesse an der Kreuzungszucht für Milchrinder hat bei Züchtern und Milchviehhaltern zugenommen, da für die dominierende Milchrinderrasse, das Holsteinrind, negative phänotypische Trends für die Merkmale Gesundheit, Fruchtbarkeit und Langlebigkeit beobachtet werden. Auch wenn gut geführte Betriebe zeigen, dass für sie die Holsteinrasse die profitabelste Rasse ist, so gilt dies u.U. nicht für viele andere Betriebe. In dieser Situation ist die Kreuzungszucht mit der Ausnutzung von Heterosiseffekten gerade für die niedrig erblichen Merkmale eine verlockende Alternative.

Für spezielle Produktionssysteme, z.B. in Neuseeland, wo die Besatzdichte und die Produktion je Hektar maximiert werden soll, stehen die Merkmale Fruchtbarkeit und Langlebigkeit noch mehr im Fokus und ganz folgerichtig sind ein beträchtlicher Anteil der neuseeländischen Kühe Kreuzungstiere. Aus der Literatur kann gezeigt werden, dass Heterosiseffekte in der Größenordnung von 4 – 5 % für Produktionsmerkmale und noch deutlich höhere Heterosiseffekte für Fruchtbarkeit und Langlebigkeit erwartet werden können.

Anhand der Analyse eigener Daten unter deutschen Bedingungen kann gezeigt werden, dass die Vorteile der Kreuzungstiere bei einem sehr hohen Managementstandard vernachlässigbar sind. Es sind sogar gegenteilige Effekte zu beobachten (Futtereffizienz). Unter einem niedrigeren Managementniveau können die Kreuzungstiere ihre Stärken hinsichtlich der Produktionsmerkmale, der Fruchtbarkeit und der Langlebigkeit ausspielen. Es bleiben jedoch unbeantwortete Fragen. Diese sind a) die Wahl des Kreuzungssystems für dauerhafte Zuchtstrategien, wobei beachtet werden muss, dass die meisten Milchviehhalter ihre Remonte selbst erzeugen möchten und b) das offenbar nötige Testen von Bullen auf Kreuzungseignung im Sinne einer bullenindividuellen spezifischen Kombinationseignung in Anpaarung an Holsteinkühe.

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Iodine in animal nutrition and Iodine transfer from feed into food of animal origin

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Introduction

Iodine is an essential trace element for humans and animals. More than 95 % of total iodine is accumulated in the thyroid gland. The only known roles of iodine in metabolism are its incorporation into the thyroid hormones, thyroxine (T_4) and triiodothyronine (T_3), and into the precursor iodotyrosines. Both hormones have multiple functions in the energy metabolism of cells, in the growth, as a transmitter of nervous stimuli, and as an important factor in brain development (Mc Dowell, 2003; Underwood and Suttle, 2001). Iodine deficiency reduces the production of thyroid hormones in humans and animals, leading to morphological and functional changes of the thyroid gland and reduction of the formation of thyroxin (ICCIDD, 2001). A high proportion of the population in Western and Central Europe is still at risk of iodine deficiency (Delange, 2002; Vitti et al., 2003; Delange and Dunn, 2004). Globally about 800 Mio people still suffer from iodine deficiency. Therefore improvement of iodine supply is still a great challenge for nutritionists (Lauerberg, 2004).

Numerous measures have, therefore, been undertaken to improve the iodine supply to human diets, e.g., using iodized salts (e.g., Lind et al., 2002; Zimmermann, 2004), other vehicles for iodine (e.g., Dunn, 2003) supplementation of foods of plant or animal origin (e.g. Schöne et al., 2003; Zimmermann et al., 2005), or supplementing iodine to animal feed in order to increase the iodine content of food of animal origin (e.g., Kaufmann and Rambeck, 1998; Flachowsky et al., 2006; Schöne et al., 2006).

During the last few years, the status of iodine nutrition in some European countries has improved (Lind et al., 2002, Thamm et al. 2007) thanks to the use of various possibilities of adding iodine to human diets. But there are still problems with the contributions of various iodine sources.

Iodine requirements of food producing animals

The iodine requirements of food producing animals vary between 0.15 and 0.6 mg/kg dry matter (DM) of feed according to various scientific committees (Table 1).

Table 1: Iodine requirements of food producing animals by the German Society of Nutrition Physiology (GfE) and the National Research Council in the USA (NRC in mg/kg DM)

Species/ Categories	GfE (German Society of Nutrion Physiology) (1999, 2001, 2004, 2006)	NRC (National Research Council) (1994, 1998, 2001)
Cattle		
Dairy cows	0.5	0.5
Beef cattle	0.3	0.4
Pigs		
Fattening pigs	0.15	0.16
Breeding sows	0.5 - 0.6	0.16
Poultry		
Poulets	0.4	0.33 - 0.35
Laying hens	0.5	0.32 - 0.48
Broiler	0.5	0.35
Turkey	0.5	0.40

Human needs and upper levels

The iodine requirements of humans depend on age, physiological stage and scientific committee (Table 2).

Table 2: Iodine requirements of humans depending on age, physiological stage and scientific committee (in µg per day)

Age/ physiological stage	Scientific committee		
	WHO (2001)	USA DRI (2001)	D - A - CH (2000)
0 - 1 year		110 - 130	40 - 80
0 - 6 years	90		
1 - 8 years		90	
1 - 15 years			100 - 200
6 - 12 years	120		
9 - 13 years		120	
14 - 18 years/adults	150	150	180 - 200
Pregnancy		220	
Pregnancy/lactation	200		
Lactation		290	260

It increases from 50-100 to 200 µg and more per day. Pregnancy and lactation require more iodine. The iodine concentration in human food (≈ 0.4 – 0.5 mg/kg DM) is adequate to animal requirements under consideration of DM-intake of humans (compare Tables 1 and 2).

There is a considerable variation in the tolerable upper levels of iodine intake of healthy humans (Table 3).

Table 3: Tolerable upper levels (UL) of iodine intake of healthy humans depending on age, physiological stage and scientific committee (in µg per day)

Age/ physiological stage	Scientific committee			
	USA- FNB (2001)	SCF (2002)	WHO (1994)	D - A - CH (2000)
1 - 3 years	200	200	< 1 mg (1000 µg) per day are considered as safe	< 500 µg per day are considered as safe
4 - 6 years	-	250		
4 - 8 years	300	-		
7 - 10 years	-	300		
9 - 13 years	600	-		
11 - 14 years	-	450		
14 - 18 years	900	-		
15 - 17 years	-	500		
> 19 / adults	1100	600		
Pregnancy	900	600		
Lactation	1100	600		

Iodine is characterized by a high risk of deficiency in human nutrition (Delange 2002, Delange and Dunn, 2004), but there is a low difference between requirements (Table 2, ≈ 200 µg/day for adults) and the UL (Table 3, ≈ 600 µg/day, SCF 2002).

That means the range between requirements and UL is only about 1 : 3. Therefore iodine belongs to the trace elements of the Supply Category I (high risk of deficiency from the global view) and of the High Risk Category (high risk of excess; BfR, 2004; EFSA, 2006; Gassmann 2006). Therefore, more information is necessary to avoid deficiencies and to prevent iodine excess in human nutrition.

Objectives of the report

Recently the EFSA (2005) dealt with this problem, esp. with the use of iodine in animal nutrition and with the transfer from feed into food of animal origin. The following conclusions were given:

- More dose-response studies with food producing animals are necessary,
- Iodine requirements of modern breeds of animals should be revised,
- Assessment of further iodine inputs in food of animal origin is recommended.

During the last few years, some studies were done to overcome those weaknesses. The present paper informed about some recent dose-response studies with animals and contributions of food of animal origin to overcome iodine deficiency and to avoid iodine excess.

Dose-Response-Studies

Some dose-response-studies with food producing animals were carried out at the Institute of Animal Nutrition of the FAL during the last few years, further studies are still underway. Iodine in feed, body samples, milk and eggs were analysed by ICP-MS.

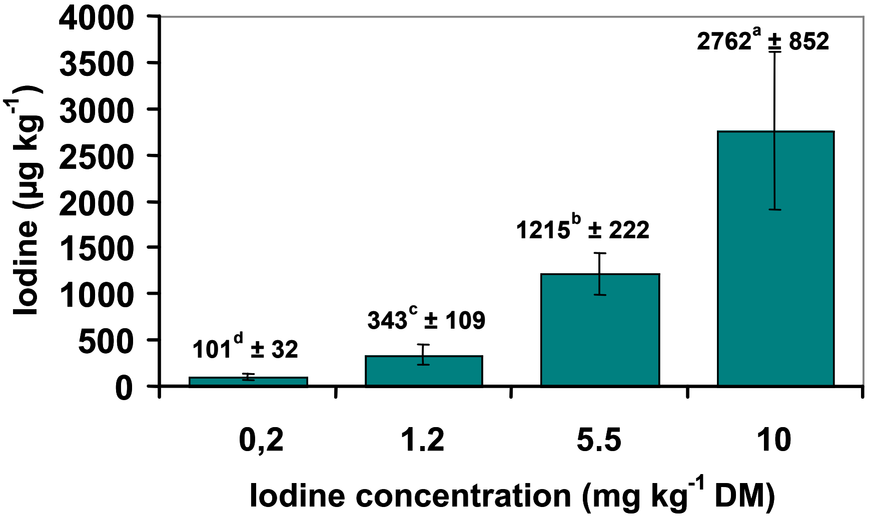
The paper informs about results from studies with dairy cows, growing bulls and growing pigs.

Dairy cows

In a preliminary test a grass - maize silage concentrate ration (0.2 mg I/kg DM) was supplemented with 0, 1, 4 or 10 mg I/kg DM and fed to five late lactating cows over 14 days (average milk yield: 22.1 ± 2.0 kg/day).

Figure 1 shows the dramatic increase of iodine concentration in milk.

Figure 1: Iodine concentration of milk (µg/kg) depending on the iodine concentration of feed (5 cows, 14 days of treatment; Flachowsky et al., 2006)



Beef cattle

A dose-response-study was carried out with 34 growing bulls of the German-Friesian breed (223-550 kg BW). The bulls consumed 3 kg concentrate per day and maize silage ad libitum. The bulls were divided into three groups and the diets were supplemented with 0.5, 4 and 10 mg/kg DM (11/11/12 bulls per treatment). At the end of the study, all bulls were slaughtered and the iodine concentration in some body samples was analysed.

Iodine did not significantly influence the weight gain of bulls, but the daily weight gain of the most highly supplemented animal was 110 g lower than those of the control group (Table 4). Apart from the thyroid, the weights of body samples were not significantly influenced by iodine supplementation.

Table 4: Influence of iodine supplementation on selected live and carcass traits of bulls (fattened from 223 to 550 kg) and the iodine content in various body samples (n = 11/11/12; Meyer et al., 2007)

Iodine supplementation analysed iodine concentration in feed (mg/kg DM)	0.5/0.79	4.0/3.52	10.0/8.31
Feed intake (kg DM/day)	7.79 ± 0.64	7.66 ± 0.45	7.70 ± 0.60
Weight gain (g/day)	1453 ± 179	1419 ± 172	1343 ± 208
Feed efficiency (kg DM/kg body weight)	5.32 ± 0.61	5.35 ± 0.65	5.70 ± 0.63
Carcass yield (% of live weight)	52.0 ± 0.8	52.3 ± 1.0	52.4 ± 1.3
Thyroid weight (g)	32^a ± 11	26^a ± 6	42^b ± 10
Iodine concentration (µg/kg fresh weight; thyroid: µg/g fresh weight)			
Liver	73^a ± 10	138^b ± 15	245^c ± 6
Kidney	93^a ± 16	231^b ± 43	450^c ± 67
Thyroid	378^a ± 91	495^a ± 125	844^b ± 558
Musc.long.dorsi	16^a ± 3	45^b ± 11	80c ± 20
Musc. gluteaus medius	32^c ± 25	83^b ± 27	147^c ± 34

[a, b, c] Various letters in one line show significant differences (p<0.05)

Iodine concentration in organs and tissue samples increased significantly with iodine supplementation (Table 4), but much less than in milk (see Figure 1).

Fattening pigs

70 growing pigs were divided into 5 groups and supplemented with 0, 0.5, 1, 2 and 5 mg iodine per kg dry feed. All pigs were slaughtered with a final weight of 120 kg. The native iodine content of feed amounted to 0.17 mg/kg, which is in accordance with the present iodine requirements of growing pigs (Table 1).

Iodine supplementations did not influence (p >0.05) feed intake and weight gain of pigs (Table 5).

Table 5: Influence of iodine supplementation on pigs fattened from 27 to 120 kg (n = 14; Berk et al., 2004)

Iodine supplementation/Iodine content of feed (mg/kg)	0 / 0.17	0.5 / 0.41	1.0 / 0.99	2.0 / 2.20	5.0 / 4.38
Feed intake (kg/day)	2.60 ± 0.10	2.24 ± 0.13	2.21 ± 0.10	2.24 ± 0.13	2.26 ± 0.10
Daily weight gain (g/day)	837 ± 70	819 ± 99	811 ± 93	851 ± 84	867 ± 63
Energy efficiency (MJ ME/kg weight gain)	37.4 ± 2.9	38.3 ± 3.7	37.8 ± 3.8	36.4 ± 2.5	36.0 ± 2.1

The iodine concentration in all body samples increased significantly after iodine supplementation (Table 6), but the concentration was much lower than in milk (see Figure 1).

Table 6: Influence of iodine supplementation on iodine content in various body samples (n = 4; Franke et al., 2006)

Iodine supplementation/Iodine content of feed (mg/kg)	0 / 0.17	0.5 / 0.41	1.0 / 0.99	2.0 / 2.20	5.0 / 4.38
Muscle/fat (µg/kg fresh weight)	3.9[a] ± 0.6	6.0[a] ± 1.9	8.5[b] ± 1.9	10.8[b] ± 1.2	17.1[c] ± 1.5
Thyroid (µg/g fresh weight)	620[a] ± 71	1054[b] ± 280	1154[b] ± 191	1699[c] ± 184	1645[c] ± 159
Body samples (liver, kidney, heart, spleen; µg/kg fresh weight)	94[a] ± 61	63[a] ± 40	138[a,b] ± 73	230[b] ± 145	226[b] ± 38

[a, b, c] Various letters in one line show significant differences (p<0.05)

Iodine transfer

These results demonstrate that there are large differences in transfer of iodine from feed into pork (≈ 0.3 %) and beef (< 1 %) compared to milk from dairy cows (30-40 %) on the other hand.
Iodine transfer from feed into eggs is also much higher (10 – 20 %) than from feed into meat as shown by dose-response-studies by Richter (1995) and Yalcin et al. (2004).

Based on the differences in transfer, large differences also exist in the iodine concentration of various food of animal origin (Table 7).

Especially the iodine concentration in milk and eggs of low supplemented animals is much higher (Table 7) than values given in the present food tables (Table 8). Also results from field studies (Table 10 to 14) show higher iodine concentrations than the food tables (Table 8).

Table 7: Iodine content in food of animal origin (µg/kg fresh matter) depending on iodine supplementation in feed

Food and animal origin	Iodine in feed (mg/kg DM)					
	Native 0.1 - 0.25	0.5	1 - 2.2	2	4 - 5	10
Milk[1)]	101	-	393	-	1215	2692
Beef[1)]	-	16	-	-	45	80
Pork[1)]	3.9	6.0	8.5	11	17	-
Poultry meat[2)]	6	-	(20)	-	-	(100)
Eggs[2)]	-	140	330	-	1460	-

[1)] Data from Institute of Animal Nutrition [2)] Data from literature

Table 8: Iodine content in food of animal origin according to food value tables (Souci et al., 2000)

Food and animal origin	Iodine content (µg/kg fresh matter) $\bar{x}$	(Range)
Ruminants		
Milk, cow	27	(20 - 60)
Milk, goats	41	(21 - 110)
Veal	26	(25 - 28)
Beef	54	(17 - 68)
Mutton	18	(-)
Pigs		
Muscle	45	(26 - 52)
Heart	30	(-)
Liver	140	(-)
Poultry		
Geese, meat	40	(-)
Eggs	95	(10 - 400)
Egg yolk	120	(80 - 160)

Iodine entry in milk via teat dipping of cows

Five late-lactating cows of the German Friesian breed were used for the study. The iodine content of the diet amounted to 0.2 mg/kg DM. After milking in the morning and evening, the teats were dipped in a teat disinfection solution containing Nonoxinol (9)-Iodine with 3 g available iodine per kg.

Teat dipping with the disinfectant significantly increased the iodine concentration of milk (Figure 2), which is in agreement with other authors (Table 9).

Figure 2: Iodine concentration of milk without and with teat dipping (iodine content of dipping substances: 3 g l^{-1}, dipping after milking; Flachowsky et al., 2007)

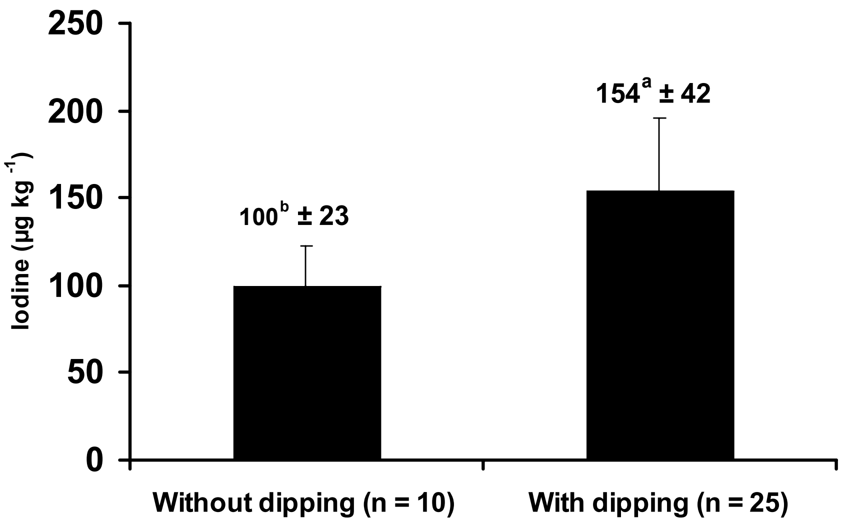


Table 9: Influence of teat dipping on iodine concentration in milk

Iodine in dipping solution (g/l)	Dipping before (B) or after (A) milking	Increase of iodine concentration in milk (µg/kg)	References
1	A	35	Galton et al. (1986)
2	A	11 - 60	van Ryssen et al. (1985)
2.7	B	30	Falkenberg (2002)
3	A	54	Flachowsky et al. (2007)
5	A	27 - 32	Galton (2004)
5	A	36	Galton et al. (1984)
5	A	120	Hamann and Heeschen (1982)
10	A	46	Swanson et al. (1990)
10	A	76	Galton et al. (1986)
10	A	90	Galton et al. (1984)
10	B/A	110	Galton et al. (1986)
10	B/A	150	Galton et al. (1984)

Three to five grams available iodine per litre disinfectant, and dipping after milking, increase the iodine content in milk by 50-60 µg per litre and contribute to the iodine supply of humans.

Field measurements

Apart from the dose-response-studies there some field measurements also exist on the iodine concentration in milk (Tables 10 and 11), poultry meat (Table 12) and eggs (Tables 13 and 14).

Milk

The iodine concentration in milk increased in many European countries during the last few years (Table 10).

Milk contains more than 100 µg/l in many countries (Table 11), exceeding 300 µg/l in England and the Czech Republic.

Such high concentrations could be a real problem under consideration of human needs (Table 2) and upper levels (Table 3), esp. for children.

Table 10: Iodine content in milk from various field samples

Authors	Iodine content (µg/kg)
Binnerts (1986, NL)	35 - 53
Dahl et al. (2003, Norway) 1971:	Summer: 65 Winter: 120
2000:	Summer: 88 Winter: 232
Kursa et al. (2004, CZ)	324 (70 - 2542)
Launer and Richter (2005; Samples 1996-2004)	74 - 210
Leiterer et al. (2001)	160
MAFF (2000) 1991/1992:	Summer: 90 Winter: 210
2000:	Summer: 200 Winter: 430
Philipps et al. (1998, UK)	130 - 200
Preis et al. (1997)	84 - 180 (During the year)
Zimmerman et al. (2005)	
Cow milk	175
Goat milk	384

Table 11: Iodine concentration in milk in various European countries (Ryšava et al., 2007)

Country	Iodine concentration (µg/kg)	(Range)
Austria	74	(45 - 92)
Poland	90	(86 - 93)
Switzerland	90	(79 - 106)
Germany	130	(93 - 159)
Belgium	158	(158)
France	207	(192 - 221)
Slovakia	240	(180 - 310)
England	325	(305 - 345)
Czech Rep.	472	(387 - 601)

Poultry meat

The iodine concentration of poultry meat is relatively low (Table 12) and comparable with pork. Previous data by Groppel et al. (1991) show higher values, but on the basis of DM.

Table 12: Iodine content of poultry meat by various authors

Iodine supplementation		Body tissue				Author
		Beast-muscle	Heart	Liver (µg/kg DM)	Kidney	Groppel et al. (1991)
Feeding studies with various Iodine sources/ amounts	(0.03 mg I/kg DM)	32	354	30	88	
	+ 0.1 mg I/kg DM (KIO_3)	57	459	45	97	
	+ 1 mg I/kg DM (KIO_3)	73	518	71	126	
	+ 10 mg I/kg DM (KIO_3)	385	1295	525	558	
	+ 10 mg I/kg DM (KI)	302	1148	901	646	
		(µg/kg fresh matter)				
Laying hens from field						Stibilj and Holcman (2002)
- Free range	0.18 mg I/kg feed	6.8 (5.6-8.5)	-	23 (16-35)	27 (22-32)	
- Indoor	0.66 mg I/kg feed	5.8		32	35	Vadujal (1996)
Samples from Supermarket	no date	Broiler 23.2 - 29.1				Hassanein et al. (2000)

Eggs

Table 13: Iodine content in egg albumen and egg yolk from field samples

	Iodine content (mg/kg feed)	Egg albumen	Egg yolk	Authors
Free range	0.18	6.7 ± 2.2	114 ± 21	Stibilj and Holcman (2002)
Indoor	0.18	7.5 ± 2.0	268 ± 42	Savski (1999)
	0.66	37.5 ± 3.9	740 ± 22	Vadujal (1996)

The iodine concentration in egg yolk is much higher than in albumen (e.g. 856 and 16.2 µg/kg; Travnicek et al., 2006, Table 13).

Assuming that the egg yolk weight is 18 g and the albumen weight is 34 g, one egg produced in large flocks in the Czech Republic (see Table 14) contained 31.2 µg (≈ 15 %) and in small flocks about 10 µg iodine (≈ 5 % of iodine requirements of adults, see Table 2).

Feed supplementation

Based on previous results and the preventive consumer protection, the iodine upper level in feeding-stuffs for dairy cows and laying hens was reduced from 10 to 5 mg per kg in 2005 (EU 2005).

Table 14: Iodine content in the yolk of eggs from large and small flocks in the Czech Rep. (Travnicek et al., 2006)

Flock	Year (Number of flocks)	Eggs (n)	Iodine content in the yolk (µg/kg fresh matter)
Large[1)]	2004 (9)	54	1014 ± 357
	2005 (10)	135	1664 ± 1080
Small	2004 (16)	96	307 ± 256
	2005 (15)	114	502 ± 508

1) Mostly higher I-supplementation of feed (≈ 1 mg/kg DM) in comparison to small flocks (0.3-0.5 mg/kg DM)

Table 15: Iodine concentration in feeding stuffs for cattle, pigs and laying hens (field samples, Grünewald et al., 2006)

	Dairy cows	Beef cattle	Fattening pigs	Laying hens
Samples (n)	51	8	46	24
Average (mg/kg DM)	1.27	1.48	2.27	1.27
Min. (mg/kg DM)	0.49	0.25	0.32	0.54
Max. (mg/kg DM)	5.70	4.58	8.48	2.64

10 mg iodine per kg feedingstuffs are still permitted for other food producing animals (fish: 20 mg). The upper limits are much higher than the present iodine supplementation of various feedingstuffs under farm conditions (Table 15). But nevertheless, there is an iodine supplementation on the average between 1 and 2 mg kg^{-1} dry matter. This iodine concentration in field samples (e.g., Tables 10, 11 and 14) responses to the iodine supplementation in comparison to previous values (Table 8) and is in agreement with data from dose-response studies (see Table 7).

Summary

Many people still suffer from iodine deficiency all over the world, but there is only a small range between human requirements and upper levels (≈ 1 : 3). Therefore iodine belongs to the trace elements of the Supply Category I (high risk of deficiency) and of the High Risk Category (high risk of excess). Food of animal origin should contribute to improve the iodine supply to humans, but excesses have to be avoided.

Some dose-response studies were carried out to assess the iodine transfer from feed into food of animal origin. Mainly the transfer from feed into meat is below 1 % of supplemented iodine, but it can be increased up to 30 % in the case of milk and eggs. In consequence of the high transfer, the EU-commission decreased the iodine-maximum level for dairy cows and laying hens from 10 to 5 mg kg^{-1} feed

More dose-response studies seem to be necessary with dairy cows and laying hens under consideration of the iodine supply of humans and the preventive consumer protection.

Zusammenfassung

Jod in der Tierernährung und Jodtransfer von Futter in Lebensmittel tierischer Herkunft

Weltweit leiden immer noch viele Menschen an Jodmangel. Andererseits besteht jedoch eine geringe Spanne zwischen Jodbedarf des Menschen und möglichem Überschuss (≈ 1 : 3). Jod gehört deshalb zu den Spurenelementen der Versorgungskategorie I (hohes Risiko eines Defizits) und zur Risikokategorie Hoch (hohes Risiko eines Überschusses). Lebensmittel tierischer Herkunft sollen zur Verbesserung der Jodversorgung der Menschen beitragen; Überversorgungen sind jedoch zu vermeiden. Verschiedene Dosis-Wirkungs-Studien zur Beurteilung des Jodtransfers vom Futter in Lebensmittel tierischer Herkunft wurden durchgeführt. Dabei zeigte sich, dass der Transfer vom Futter in Fleisch bei unter 1 % liegt, während in Eier und vor allem in Milch bis zu 30 % des zugesetzten Jods übergehen können.

Unter Berücksichtigung dieses hohen Transfers hat die EU-Kommission die Jod-Höchstgehalte im Futter von Legehennen und Milchkühen von 10 auf 5 mg/kg Futter gesenkt. Weitere Dosis-Wirkungsstudien mit Legehennen und Milchkühen sind vor allem unter dem Aspekt des vorbeugenden Verbraucherschutzes notwendig.

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