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Cuxhaven, October 2009

Editorial

Prof. Dietmar Flock,
Editor

Most of us are directly or indirectly affected by global issues like the recent financial crisis, rising energy prices or attempts to reduce CO_2 emissions. Obviously, the burden to carry is not equally distributed and differs greatly between countries and individuals within a country, depending on the level of education and opportunities for productive employment. Each of us can contribute at least symbolically, e.g. by reducing energy waste and giving a good example for others. Major contributions have to come from innovations in industry and agriculture. Equally important is that more of the money "saved" by efficient food production is spent on education and consumer goods which require less energy to produce and maintain.
Agriculture is challenged to provide adequate food for a world population of 6.8 billion in 2010, continuing to grow by 80 million per year. The FAO recently estimated that 1 billion people suffer from hunger. Major problems exist in developing countries due to massive migration from rural areas with low-input family farming to big cities. For these low-income people it is essential to make use of existing knowledge in modern farming and animal production. We should keep this in mind while trying to make ends meet at home.
This issue of Lohmann Information includes seven papers as „food for thought":

1. **Dr. Günther Eberz, Bayer CropScience AG**, sets the stage with his review **"Agriculture needs innovation and a sense of responsibility - challenges facing sustainable agriculture"**. His key message is: we need a new initiative to drive agricultural innovation, a "second green revolution", to extend the potential of our crops to meet the needs in our time while protecting and preserving the environment for future generations.

2. The editor, **Prof. Dietmar K. Flock**, reviews genetic improvements in the efficiency of egg production since the introduction of "reciprocal recurrent selection" 60 years ago: **"A history of layer breeding in Cuxhaven since 1959: from serendipity to sustainability"**. The remarkable improvement in feed efficiency is also an important contribution in terms of sustainability.

3. Consumers demand safe food from healthy animals, while producers are trying to minimize mortality and loss of productivity due to common field infections. Consumer protection laws have eliminated the possibility to control diseases with antibiotic feed additives, and licensed vaccines are not available for all diseases. **Attila von Hankó, EW Group**, in his paper **"Autogenous Vaccines"** presents an extended concept for farm-specific solutions applicable within the European Union.

4. New information on optimal nutrition remains of primary interest to many of our readers, and nutrition experts of Lohmann Tierzucht keep screening the international literature to update management recommendations. The article by **Dr. Andreas Lemme, Evonik-Degussa, "Amino Acid recommendations for laying hens"** is reproduced from a publication in AMINONews (July 2009). Optimizing the dietary amino acid profile helps to minimize feed cost per egg and N emissions.

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Editor: Prof. Dr. Dietmar Flock · Akazienweg 5, 27478 Cuxhaven, Germany
Dietmar.Flock@lohmann-information.com

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5. Some of our readers are not only interested in poultry nutrition, but also in other species where producers are confronted with similar problems. **Prof. Matusevicius** and **Prof. Jeroch, Lithuanian Veterinary Academy, Kaunas**, report on the results of feeding trials with probiotic and phytobiotic preparations in their paper **"Efficacy of probiotic "ToyoCerin" and phytobiotic "Cuxarom Spicemaster" on growing rabbits"**.

6. Egg production used to be seasonal in many parts of the world until the response of birds to changing day length was understood and artificial lighting programs were introduced. Especially those who are new in this business and work with natural light will benefit from the article **"Light stimulation of commercial layers"** by **Dr. Hans-Heinrich Thiele, Lohmann Tierzucht GmbH.** To optimize the lighting program for any specific farm, the principles explained in this paper should be understood.

7. Parent flocks of meat type chickens and turkeys require much more sophisticated management than layers to optimize weight gain and onset of lay, as explained in the article **"Lighting for broiler and turkey breeders"** by **Dr. Peter Lewis, University of Kwazulu-Natal, South Africa**. Even if you are only concerned with egg-type chickens and never heard the word "refractoriness", this article should contribute to a better understanding how poultry responds to specific management tools. Correct lighting is an essential part of managing parent flocks, and more chicks per breeder hen adds to the sustainability of the business.

Please feel free to pass Lohmann Information to colleagues or send their name and address to the editor for future direct mailing.

With kind regards,

Prof. Dietmar Flock,
Editor

Agriculture needs innovation and a sense of responsibility Challenges facing sustainable agriculture

Günther Eberz, Bayer CropScience AG

Introduction

The sustained growth of the world's population and the economic development of emerging countries are combining to create a growing demand for agricultural products. The demand for renewable raw materials to provide energy and fuel is also increasing. However, the amount of arable land available is limited and subject to rising urban sprawl and soil degradation. Moreover, water shortage is endangering agriculture more and more, particularly in the southern hemisphere. Together these complex factors are creating some major challenges for a multifunctional and sustainable agriculture.

There are more and more of us

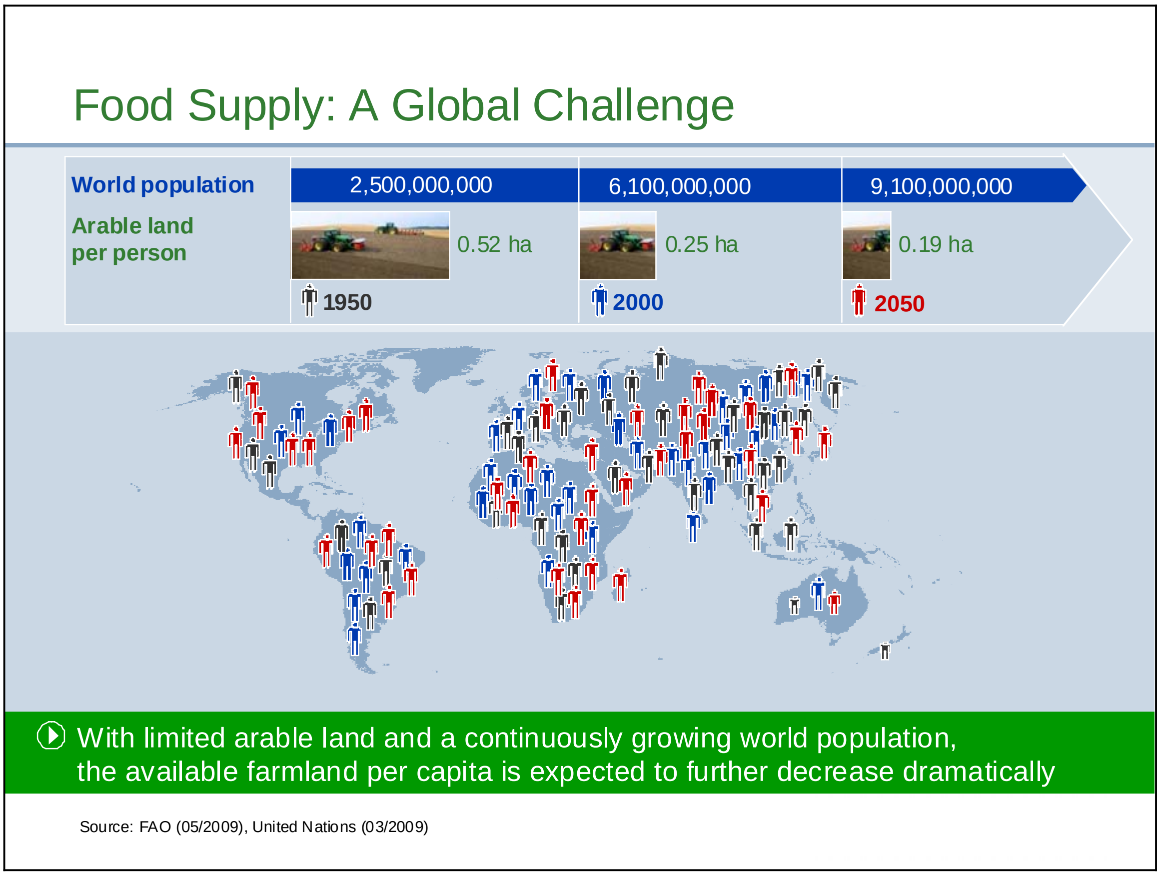
Although population growth is slowing, there will probably, according to the United Nations World Population Prospects, still be more than nine billion people living on our planet in 2050. Most of this growth will take place in what are currently developing countries. This is where more than 80 percent of all the people on Earth live and it is where an inadequate food supply is a common occurrence. Around a billion people currently do not have enough to eat. The population in sub-Saharan Africa and Asia is especially affected by hunger, with a particular focus within Asia on India and China. An additional trend is emerging. The proportion of people who live in an urban setting is increasing worldwide. The figure is expected to grow to around 60 percent by 2030. In Latin America, the urban population already outnumbers the rural population. However, some 80 percent of the undernourished people live outside the cities. Half of the hungry people live in households dependent on small-scale farming.

Agriculture needs to respond in many ways

Of the approximately 13 billion hectares of land on our planet, some 1.6 billion are used for agriculture and a further 3.5 billion as meadowland and pasture. There is hardly any potential left for expanding the growing areas for wheat, rice or millet. In many parts of Asia, every last hill which can possibly be used has already been covered with rice terraces and fields. In addition, some areas of the world that are suitable for crops are being threatened by soil degradation or loss, e.g. as a result of salination or erosion. Every year, around 10 million hectares of arable land are lost to erosion worldwide and further agricultural land is endangered by salination, desertification and urban development. Increasing urbanization is additionally boosting the amount of land required for settlement and infrastructure. Additionally, political objectives designed to reduce greenhouse gas emissions are driving the use of renewable agricultural raw materials for energy generation, e.g. in order to provide fuel for the transport sector. These factors combine to create far-reaching challenges for agriculture, which consequently needs to satisfy economic, ecological and social criteria. Overall, there is no doubt that the provision of adequate food for a growing number of people is one of the most urgent imperatives of our time.

Securing the food supply is a global task

Even today, if we didn't use modern crop protection measures and fertilizers, we would need more arable land to feed the world. A continually growing population and changing consumption habits mean that agricultural production needs to be boosted substantially. For example, per capita calorie consumption in developing countries and emerging economies continues to rise in response to increasing incomes, if nothing else, and is approaching the level in industrialized countries. China illustrates this development very clearly. Meat consumption in this country has roughly doubled in the past 15 years. This increase is associated with a growing demand for animal protein and in turn with the need to use a growing proportion of the world's cereal harvest as animal feed. In simplified terms we can say that it takes 7 kg of cereal to produce 1 kg of beef. This differential also increases the pressure on the demand side.



According to prognoses, agricultural production must more or less double by 2050 if it is to meet the future demands for food and feed. However, there will be almost no scope for increasing the amount of land available for agricultural purposes overall in the world. This confers particular importance on agricultural production in the industrialized countries too. Although agricultural production here has already reached a high level, the industrialized countries still have a special responsibility to help in securing the world's food supply. The World Bank, for example, expects Africa and Asia to be importing over 250 million tons of cereals in 2030. Going on present trends, most of this requirement will have to be met by exports from the industrialized countries.

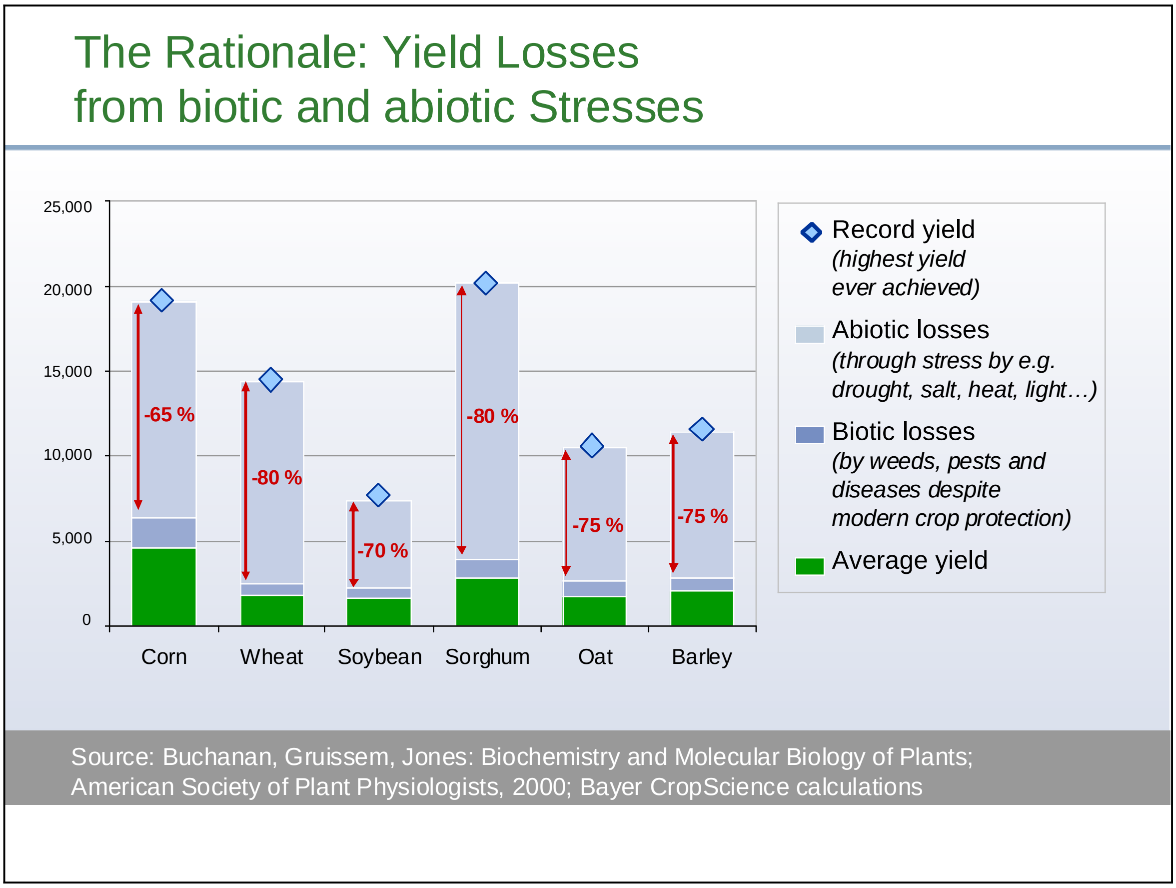
Extreme weather phenomena threaten harvests

Meteorologists all over the world are recording more and more frequent extreme weather events such as absence or displacement of tropical rainfall as well as abnormal ocean current phenomena. One well-known example is El Niño. Every three to six years, torrential rains devastate whole tracts of land in South America, while at the same time extreme weather leads to droughts in South-East Africa, Indonesia and Australia and frost in Florida – and consequently to enormous harvest losses for framers. But it is not only natural disasters that cause billions of dollars worth of agricultural damage every year. Persistently unfavorable farming conditions such as water shortages, increasing salination of arable land and extreme heat and cold are prime causes of huge harvest losses. Corn, rice and wheat, for example, can no longer cope with these extreme environmental factors. The impact of extreme weather conditions can be severe: even with the best of care for their fields, farmers regularly lose between 30 and 80 percent of their harvest around the world.

Although the impact of global warming as a result of climate change varies on a regional basis, it is assumed that it will have a globally negative effect on agricultural productivity. Experts expect the yield potential of crops to decrease even if local mean temperatures increase by only 1 to 2°C, particularly in seasonally dry regions and the tropics. According the World Bank, it is very likely that effects of climate change will increase the number of people at risk of hunger. Water plays a key role here, and it has been designated as one of the most limited natural resources of this century.

Efficiency is a basis for sustainable agricultural production

The need to provide a growing number of people with sufficient, high-quality, affordable food is one of the biggest challenges facing the agriculture of the future. The prices of agricultural products declined substantially during the 20th century, only to rebound strongly, particularly in 2008. This was the result of many factors, among them increased demand, higher production and transport costs, diminished inventories, climate-related harvest failures, trade restrictions as well as the fact that agricultural markets became the focus of the financial markets. In spite of the recent price decreases in 2009, the Organization for Economic Development and Cooperation (OECD), for example, expect prices for agricultural raw materials to remain at a considerably higher level in the longer term than they were a few years ago. The complex interplay of factors and the many and varied requirements that agricultural production needs to satisfy, make efficient use of natural resources, e.g. water, soil and nutrients such as nitrogen, absolutely vital. At the same time, the high quality of harvests needs to be ensured. It is, therefore, important to ensure that high-quality crops can be grown on the limited land available and to increase yields wherever possible. The higher the yield per hectare of cultivated land, the greater the opportunities for achieving a balance between agricultural and natural land.



Not using crop protection, limits efficient use of resources

Crop protection products help to secure yields by protecting crops against harmful organisms. The effect of harmful factors on yields has been investigated in several studies. Studies at the Institute for Plant Diseases at University of Bonn, Germany, for example, indicate that weeds, fungal diseases and insects together account for the loss of 42 percent of harvests of the world's eight most important crops: rice, wheat, barley, corn, potatoes, soybeans, cotton and coffee. If no crop protection products at all were used, up to 70 percent of these crops would be lost. Scientists did observe some major fluctuations. Rice, for example, has the genetic capacity to produce up to 20 tons of grains per hectare. Real yields, however, vary between just one and 11 tons. These lower yields are the result of environmental stress factors mentioned previously.

A fungicide which helps wheat to grow

Some particular active ingredients used in crop protection products are opening up new horizons. One of them is trifloxystrobin from Bayer CropScience, an antifungal agent belonging to the strobilurin class of active ingredients which protects cereals, vegetables and fruit against harmful fungal diseases. It also increases the resistance of plants to stress. Field trials have shown that crops treated with strobilurins produce better harvests than those protected with other types of antifungal agent. Crops protected with trifloxystrobin also do much better than untreated plants under conditions of drought. The active ingredient evidently triggers a number of different beneficial effects in the plant, which result in an above-average increase in yield. Recent research has also shown that certain active ingredients – such as the one used in the insecticide Gaucho® from Bayer CropScience – can even make rice plants more resistant to fluctuations in the salt content of water.

Bayer CropScience has one of the largest research budgets in the industry (some EUR 650 million annually), and will be maintaining its innovative emphasis on novel crop protection products with new modes of action which will enable farmers to achieve high yields. These not only include chemical crop protection products but also products for biological pest control such as *Bacillus firmus*, which can be used to protect seeds against nematodes (soil-dwelling threadworms).

Innovation is indispensable

New technologies will play a major role in making efficient use of scarce agricultural resources. In the past, scientific progress and modern crop protection enabled yields to be increased substantially and safeguarded. However, analysis of the International Food Policy Research Institute, Washington, USA makes clear, that spending on agricultural research has slowed considerably all over the world since the 1970s. The consequences are dramatic. In the 1980s, cereal yields were increasing at a rate of more than three percent annually; today, yields of wheat and rice in particular, are growing at between one and two percent. The forecast trends in demand show clearly that this is nowhere near enough. This is why agricultural research is more important today than ever before. A global agricultural initiative to drive innovation is needed, to sustainably exploit the potential of agricultural crops.

Stress-tolerant plants cope considerably better with extreme climates

One of the foremost objectives of crop protection research is to increase the yields of corn, rice and wheat and to make plants more tolerant to severe heat, cold, drought or intense sunlight. These factors expose plants to enormous stress. They trigger a process that can lead to self-destruction. Energy-intensive repair processes substantially increase the plant's energy consumption. This has dramatic consequences for the plant: It can no longer properly supply leaves, fruit or stems with energy. Individual cells gradually die, ultimately leading to the death of the plant.

Researchers at Bayer CropScience are using biotechnology to equip canola plants, for example, to cope with several stress factors. They are designing a kind of fitness program for plants. Firstly, they incorporate genes into plants which should help them deal with excessive stress caused by dry and wet conditions. Secondly, they quite specifically deactivate individual genes which trigger excessive stress reactions in normal plants which result in lower yields. This should enable the plants to produce consistently high, stable yields over the longer term, despite fluctuating environmental conditions.

Bayer CropScience is using classic plant breeding techniques, plant genetic engineering methods and other approaches based on modern molecular biology, such as marker-assisted breeding, in its efforts to develop high-quality seed with improved traits. In the latter, plants are selected for crossing not on the basis of their external characteristics but because of their genetic traits, which new methods allow scientists to establish beforehand. In this way, suitable partners can be selected specifically, thus accelerating the breeding process.

Plant biotechnology complements innovative crop protection

The use of biotechnology in combination with crop protection solutions in a targeted manner, can achieve significant advances in productivity. The Consultative Group on International Agricultural Research estimates that plant biotechnology alone has the potential to increase yields by around 25 percent. As a result, modern breeding methods can help to fight global hunger. The United Nations Task Force on Hunger advocates the use of plant genetic engineering in the fight against hunger. Greater resistance to environmental stress factors such as drought, salty soil, unfavorable temperatures, plant pests and diseases and an improved nutrient content are also thought to be advantageous for small-scale farmers in developing countries. Studies recently published by scientists at the Department of Agricultural Economics and Rural Development, University of Göttingen, Germany, show examples where the cultivation of plants bred using genetic engineering effects poverty reduction in some developing countries.

The BioScience business unit at Bayer CropScience uses modern plant-breeding techniques to develop, among other things, high-yielding hybrid crop varieties with improved tolerance towards environmental stress factors. Our modern hybrid rice, for example, has a yield potential that is 20 to 30 % higher than that of conventional rice varieties. Its yield advantage is even greater under conditions of infection by bacterial leaf blight. When this disease hits, farmers who use our modern hybrid rice can produce up to 80 % more yield than using classical varieties.

Plant genetic engineering concerns us all

The technical application of biological processes has been used for thousands of years. For example, biotechnology has been used to modify the plant world through selection and breeding ever since mankind began to grow food. Genetic engineering methods were first applied in the early 1970s and since then the importance of biotechnology has increased continually and has become a stronger focus of public attention. Contemporaneously, plant genetic engineering has also increasingly been the subject of intense debate about risk and in some cases of emotive public discussion. From the point of view of agricultural policy, past experience with surplus agricultural production in some industrialized countries, encouraged the view that a further increase in production volumes would be undesirable.

However, in view of the future challenges facing the world, industrialized countries also have a responsibility to help secure the food supply. Against this background, they have a moral obligation to enable an open and objective dialog to take place in society about the contribution that plant genetic engineering can make. Since acting ethically, also means acquiring the knowledge and awareness that will permit solutions to be found through respectful and tolerant discourse.

Agricultural policy: A fundamental element of responsible social policy

The global challenges associated with a growing world population demand an awareness of the need for solidarity and the ability and willpower to accept responsibility. Our cultural experience has taught us that efficient and sustainable agricultural production is a major fundament of our prosperity and that it is progress, not stagnation, which will help mankind to secure the future. The consideration to use modern crop protection and biotechnological products responsibly goes hand in hand with an obligation to search for ways of safeguarding the food supply and agricultural resources in the long term. Innovative agricultural policy is thus a fundamental element of a forward-looking social policy.

Abstract

Limited arable land, climate change and a continually growing world population are posing major challenges for agriculture. It is vital to safeguard, and even boost, yields of agricultural raw materials. Bayer CropScience has one of the largest research budgets in the industry, at around EUR 650 million annually, and will be maintaining its innovative emphasis on novel crop protection products with new modes of action which can help to safeguard yields, produce high-quality crops and manage resources efficiently, in the interests of the environment. We are convinced that we need to increase our focus on modern plant breeding in the development of new and high-yielding hybrid varieties and make greater use of the opportunities offered by plant biotechnology.

Scientific progress has made a crucial contribution to enabling agricultural yields to be increased substantially. The challenges facing the world require us, once again, to reinforce our commitment to agricultural science, research and application-oriented innovations. Society has a responsibility to show its solidarity by searching for ways of safeguarding the world's food supply. What we need, therefore, is a new initiative to drive agricultural innovation – in other words a "second green revolution" – that will extend the precious potential of our crops to meet needs while preserving the environment.

Zusammenfassung

Herausforderungen für nachhaltige Landwirtschaft

Begrenzte Anbauflächen, klimatische Veränderungen und eine weiter steigende Weltbevölkerung stellen die Landwirtschaft vor große Herausforderungen. Dabei müssen die Ernteerträge der Agrarrohstoffe sicher gestellt und sogar weiter ausgebaut werden. Bayer CropScience wird mit einem der größten Forschungsetats in seiner Branche in Höhe von rund 650 Millionen Euro auch in Zukunft seine Innovationsschwerpunkte auf neuartige Pflanzenschutzprodukte mit neuen Wirkmechanismen legen, die Erträge sichern und hochwertige Ernten sowie ein effizientes und damit umweltschonendes Ressourcenmanagement ermöglichen. Wir sind davon überzeugt, dass wir dabei die Möglichkeiten der modernen Pflanzenzüchtung mit der Entwicklung neuer Hochertrags-Hybridsorten sowie die Chancen der Pflanzenbiotechnologie verstärkt nutzen müssen.

Der wissenschaftliche Fortschritt hat maßgeblich dazu beigetragen, dass die Agrarerträge bisher beträchtlich gesteigert werden konnten. Die weltweiten Herausforderungen machen erneut ein verstärktes Engagement in Agrarwissenschaften, Forschung und anwendungsorientierte Innovationen erforderlich. Dabei steht die Gesellschaft in der solidarischen Verantwortung, nach Lösungen für eine weltweite Sicherung der Ernährung zu suchen. Wir brauchen insofern eine neue landwirtschaftliche Innovationsinitiative, d.h. eine „zweite grüne Revolution", um das kostbare Potenzial unserer Kulturpflanzen bedarfsgerecht und umweltschonend auszubauen.

Author's Address

Dr. Günther Eberz
Bayer CropScience AG
Corporate Communications
Corporate Policy & Media Relations
Alfred-Nobel-Str. 50
40789 Monheim, Germany

A history of layer breeding in Cuxhaven since 1959: from serendipity to sustainability

D.K. Flock, Cuxhaven, Germany

serendipity: a gift for discovery by accident and sagacity while in pursuit of something else[1]

1949-1959: Serendipitous introduction of RRS by Art Heisdorf

During the recovery period after World War II, European poultry breeders were busy rebuilding pre-war structures and resumed conventional herdbook breeding with egg-type and dual purpose breeds. Meanwhile, poultry breeders in North America had discovered the benefits of crossing different breeds or lines of the same breed. The scientific foundation of the poultry breeding program in Cuxhaven can be traced back to the **"Heterosis Conference"** at Iowa State College, where plant and animal geneticists met in 1949 to discuss different theories and potential utilization of "heterosis" for plant and animal improvement. Among the participants was Art Heisdorf, a young poultry geneticist who had recently started his own breeding company Heisdorf & Nelson Farms. Mr. Heisdorf was keen to get a better general understanding of "heterosis" and was especially attracted by alternatives to the concept of inbred-hybrids, introduced by Hy-Line in the 1940s.

At the heterosis conference, Comstock *et al.* (1949) presented **"reciprocal recurrent selection"** (RRS) as an alternative to crossing inbred lines. The basic idea of this theory is that superior crosses can be further improved by "recurrent" (i.e. repeated in each generation) selection based on the performance of cross-line relatives (daughters or half-sisters), while pure-line information should be completely ignored. This theory assumes that overdominance can be an important part of heterosis, i.e. within-line selection would always favor heterozygotes and keep gene frequencies intermediate. RRS, on the other hand, should drive the frequencies of relevant alleles in opposite direction, thus increasing the frequency of heterozygotes in the commercial cross. Heisdorf returned home convinced that the theory behind RRS was sound and decided to test it on two of his White Leghorn lines, which happened to "nick" well from the start and continue to respond to RRS even 60 years later.

As shown later in a review by Bell (1972), other selection experiments failed to demonstrate the superiority of RRS, either because the lines used did not differ sufficiently in allele frequencies when the selection started or the experiment was terminated prematurely. Art Heisdorf's decision to apply RRS on a suitable set of lines and the subsequent success of the breeding program in Cuxhaven is an illustration of "serendipity": we may not be celebrating 50 years layer breeding in Cuxhaven this year, had it not been for the lucky combination of four factors: (1) the decision to test and verify RRS theory in a long-term breeding program; (2) availability of a set of non-inbred White Leghorn lines with superior combining ability and genetic variation responding to RRS; (3) providing a stimulating research environment to attract and inspire a team of qualified geneticists who believed in RRS; and (4) cooperating with business partners who share similar values and are dedicated to serve the egg industry and egg consumers with highly efficient layers.

Not only did the original two White Leghorn lines used by H&N "nick" well, Lohmann and Heisdorf were also a perfect match. Art Heisdorf's German ancestry probably helped him to trust Heinz Lohmann as a business partner when Lohmann asked for access to pure-lines and complete know-how in modern breeding and management as a basis for the license agreement which was signed in 1958. The H&N "Nick Chick" had won more random sample tests in the USA than any other strain, but when the **"HNL Nick Chick"** was first tested in Germany, it was soon recognized that a higher egg weight was desirable to satisfy European preferences – an additional argument to justify a stand-alone breeding program in Germany.

[1] One of several explanations of serendipity found on the website http://livingheritage.org/three_princes-2.htm

1959-1969: Dr. von Krosigk and Dr. Pirchner as geneticists in Cuxhaven

Max von Krosigk played an important part in setting up the HNL breeding program in Cuxhaven as a replicate of the RRS breeding scheme at Hollywood Hills in Washington, which by then already consisted of two replicates – the "A" and "B" populations, to supply the growing demand year-round. Franz Pirchner, whom I first met in 1962 during the World Fair in Seattle, was hired by H&N to replace Max von Krosigk, but decided to pursue a University career after two years in Cuxhaven (1963/64). Before I was hired to succeed Max von Krosigk as geneticist in charge of the HNL breeding program in Cuxhaven, I had met both on various occasions and found out more about our common background as PhD students of Prof. Lush at Iowa State University.

Not only the first three geneticists hired by H&N to supervise the HNL breeding program in Cuxhaven, but also my successors Rudolf Preisinger and Matthias Schmutz started with a dairy cattle breeding project for their PhD thesis before changing to layer breeding. The extensive experience analyzing large data sets was very helpful, and as Max von Krosigk would say: all you need for a start is a solid theoretical background in genetic statistics, design of experiments and mathematical probability; all else can be learned from available data and in open discussions with colleagues and business partners.

The RRS program involved three main steps every year:

(1) summarize performance records of pedigreed paternal and maternal half-sisters, calculate genetic parameters and rank their pure-line brothers and sisters on a "selection index"; select the best males and females on the productivity of their cross-line sisters (ignoring pure-line data);

(2) assign reciprocal matings of 100 males x 10 females each to produce the next generation of 2000 pedigreed cross-lines families, avoiding close relation among females mated to the same male;

(3) switch males between lines after cross-line reproduction, avoiding mating of related males and females, to produce non-inbred pure-line progeny for sib selection in the next generation.

In addition to the RRS routine, Pirchner initiated several experimental programs. He compared different lighting programs, estimated genetic parameters of feed efficiency and started to develop inbred sublines by full-sib matings. His interest in poultry breeding continued after he left Cuxhaven to accept positions as University professor in animal breeding in Vienna, Austria and Weihenstephan, Germany. The inbred lines he started were abandoned after I became responsible for the HNL breeding program.

The idea to **select directly for improved feed efficiency** was contrary to the widely accepted opinion of Nordskog *et al.* (1973) that selection for higher egg mass and lower body weight would achieve the same goal without the extra cost of measuring individual feed consumption. Von Krosigk and Pirchner (1964) presented first estimates of genetic relationships between feed consumption and productive traits in laying hens at the British Poultry Breeders' Roundtable, but it took another 10 years and high feed prices in the mid 1970s before we introduced testing for feed efficiency on a larger scale in our breeding program. Several of Pirchner's graduate students (Damme, Heil, Wang) worked with feed efficiency data from a long-term selection program at Weihenstephan, involving two brown-egg lines (Rhode Island Red and Sussex) of H&N origin.

I first met Art Heisdorf in 1966 after the World Poultry Congress in Kiev/USSR, when I was interviewed as potential successor of Max von Krosigk. Art's personality and the image of Heisdorf & Nelson and Lohmann as research oriented, progressive breeding companies convinced me to accept a challenging job in the industry, a decision I never regretted.

Genetic progress and **limits to selection** were popular topics during the 1960s, and we tried to separate genetic and environmental trends with appropriate statistical methods. In a joint publication with Henderson, Kempthorne and Searle (1959), von Krosigk compared statistical approaches developed at Ames and Cornell, using field data from milk recording in Iowa herds. At H&N and Lohmann, a **"repeat mating design"** was introduced to compare progeny from two generations in the same environment. Although not completely unbiased, the estimates published by von Krosigk *et al.* (1972) confirmed that our selection produced predictable results. In subsequent years, I discontinued the repeat mating controls and focused on the results of random sample tests to monitor the rates of change in different strain crosses (Flock and Heil, 2002).

1969-1979: Analysis of part records; selection for Marek's resistance

When I presented my first paper at a franchize hatchery meeting in Cuxhaven (1969) and asked the audience whether they agreed with the performance profile defined in our breeding goals, our distributors appeared to be completely happy with the HNL Nick Chick and only worried the new geneticist may try something stupid like reducing age at sexual maturity or lowering body weight to improve feed efficiency.

To get a better understanding of variation in egg production and potential for genetic improvement, we collected and analyzed egg production data from pedigreed test crosses in 4-week periods to determine the optimum length of testing period (Willeke, 1972; Flock, 1977). As a result, we started to put **more emphasis on persistency** and tried to hold age at sexual maturity constant instead of selecting on cumulative part records. Following the same reasoning, we later extended the testing period and the generation interval from 12 to 14 months.

Marek's disease (MD) was known from other areas and selection for MD resistance discussed as a possibility. But our veterinary colleagues predicted that vaccines would solve the problem before we could develop genetically resistant layers, and we geneticists did not understand the important difference between MD and Leukosis (LL) at that time. In retrospect, it was a prudent decision to **select a set of sub-lines for MD resistance** (mortality on problem farms in Spain), while genetic improvement of the main lines continued in the MD-free environment of our pedigree farms in Germany.

When MD vaccines became available in the early 1970s, interest in the more MD-resistant lines soon vanished. The cumulative changes during the 5-year period demonstrated that MD resistance can be substantially improved – if we sacrifice other traits: the main lines were 20 eggs and 2 kg egg mass per HH ahead of the 'resistant' lines, which had about 20% lower mortality under challenge conditions (Flock, 1974; Flock *et al.*, 1975). Had we included MD resistance in the selection index for the main lines, we may have been out of business after MD-vaccines became available.

Once we understood the basic difference between MD and LL, we focused on **eradicating Leukosis viruses** from all our pure-lines. Although HNL had the image of low mortality due to LL, we started to test 100% at the pedigree level and gradually eliminated LL from all parent flocks. This eradication contributed significantly to reaching 300+ eggs in 500-day random sample tests (Flock, 1984; Flock and Kühne, 1985) and became essential for the introduction of a feather-sexing White Leghorn cross in subsequent years.

After Pfizer acquired H&N in the early 1970s, it was agreed not to renew the license agreement beyond 1978. Lohmann continued to use the original H&N lines, but changed the trade name from "HNL Nick Chick" to **"Lohmann Selected Leghorn"** (LSL), while H&N became a competitor in the global market.

In 1978, Lohmann AG acquired Hy-Line from Pioneer - mainly to gain access to the US market - and expanded the breeding activities in Cuxhaven to develop competitive white-egg and brown-egg crosses for world-wide distribution. For many years, both sides benefitted from a productive exchange of ideas between geneticists with independent backgrounds. The Hy-Line and LTZ gene pools remained completely separate, which adds to the security for the EW Group.

1979-1989: Change from RRS to mRRS; LSL-F and LB as new products

RRS theory assumes that overdominance is important. This potentially valuable part of variation could not be utilized with traditional pure-breeding and would be lost if we paid any attention to pure-line production. The pure-line candidates for selection were therefore kept in large floor pens while their cross-line sisters were tested in single cages. With this system, we were unable to monitor changes in heterosis.

To learn more about genetic variation and heterosis in our White Leghorn lines, we produced simultaneously pure-line and cross-line progeny from all selected sires to be tested under identical conditions in cages. Results from generation 1973/74 including all F2 and backcross combinations were presented at the European Poultry Conference in Hamburg (Flock, 1980). The experimental design to produce all possible combinations required artificial insemination (Stöve, 1980). Having performance-tested pure-lines in cages opened the possibility to select on a combination of cross-line and pure-line information (mRRS) and to monitor how this would affect progress in pure-line and cross-line performance.

With high selection intensity it is not possible to avoid inbreeding completely, but in our RRS breeding program we **minimized inbreeding by keeping large populations.** In connection with the analysis of inbreeding during 25 years from pedigree data of our lines (Ameli, 1989; Flock *et al.*, 1991), we generated new data to estimate heterosis and inbreeding effects in generation 1986/87. As documented in a later paper (Flock, 2000), some heterosis for egg production was indeed "lost" after we introduced mRRS (as predicted from theory if overdominance is important), but the "loss" can be explained by the ceiling of 1 egg per day: more potential for improvement in the pure-lines (peaking initially around 80%) than in the F1 crosses (already peaking around 95%).

As shown in table 1, we estimated 43 eggs and 3.15 kg egg mass heterosis after 22 generations of RRS, of which only 30 eggs and 2.42 kg egg mass were left after 13 additional years of mRRS. Perhaps we could have made a little more progress in the commercial layer and even increased heterosis by ignoring pure-line information, but our general breeding goal was to produce saleable chickens, not to maximize heterosis. If deleterious genes in the pure-lines are the cause of dominance and overdominance, we should not hesitate to eliminate them by family selection. Improved pure-line performance actually helped us to increase selection intensity, and correlated improvement of parent performance reduced chick production cost for our distributors.

In a non-commercial long-term selection experiment we should have continued to apply RRS in its pure form to see how much more heterosis can be added, but commercial breeders have to focus on competitive parents and commercial layers, "heterosis" is not saleable.

Table 1: Estimates of heterosis in generations 1973/74 vs. 1986/87 (Flock, 2000)

	Livability %		Egg number/HH		Egg mass kg/HH	
	1973/74	1986/87	1973/74	1986/87	1973/74	1986/87
F1 crosses	91.8	97.8	292	318	17.67	19.37
Purelines	88.6	93.6	249	288	14.52	16.95
Diff. F1-PL	+3.2	+4.2	+43	+30	+3.15	+2.42
% Heterosis	4.5	4.5	17.1	10.2	23.1	14.3

During the 1970s, brown-egg and feather-sexing White Leghorn strains were gaining market shares. To benefit from the expanding world market, Lohmann Tierzucht expanded the R&D program, focusing on the development of a competitive brown-egg layer and feather-sexing White Leghorns to replace the vent-sexing HNL. In order to develop a feather-sexing variety of LSL, we started with introgression of the slow feathering gene K from an experimental White Leghorn line into our LSL female line, followed by 10 generations of backcrossing and balanced selection. Before field-testing the new LSL-F variety, Leukosis virus was eradicated from all lines.

Convinced that our white-egg layer LSL was superior to any brown-egg layer in terms of egg production, feed efficiency and egg quality, Lohmann started later than other breeders to invest into sufficient additional facilities for a strong brown-egg breeding program. We briefly tried to introduce a RIR x Sussex cross under the name "Lohmann Super Brown". After replacing the Sussex line with a more productive White Rock female line, "Lohmann Brown" started to catch up in terms of all major traits of interest: optimal egg size, attractive shell color, high number of saleable eggs, efficient feed conversion, low mortality, competitive parent performance.

Breeding goals were adapted to the increasing competition between white-egg and brown-egg layers: we focused on shell strength in white-egg layers and feed conversion in brown-egg layers in response to the common belief that white-egg layers are more efficient, while brown eggs have stronger shells. Within a few generations, LSL entries in German random sample tests exceeded 40 Newton in shell breaking strength, and Lohmann Brown entries approached 2.00 feed conversion ratio.

In 1989, when we celebrated "30 years egg-type breeding in Cuxhaven" **Art Heisdorf** was a prominent guest speaker on our program and told us "how it was in the olden days" (Heisdorf, 1969, 1990). He was obviously happy to see LTZ continuing a strong layer breeding program and H&N International part of the Lohmann group, and I am sure he would be even happier to see the continuing development to this day.

<u>1989-1999:</u> Increasing emphasis on sustainability

Sustainable breeding of laying hens is focused on long-term contributions to the quality of life for egg consumers and producers worldwide, with appropriate attention to bird welfare and natural resources.

With increasing international sales of brown-egg and white-egg layers, Lohmann Tierzucht was confronted with different regional priorities and sometimes opposite ideas of customers, especially when it came to optimum egg weight and how to assess feed efficiency. Intensive communication with customers during periods of changing egg and feed prices or new disease problems helped us to understand the global egg industry better and to adjust priorities of our selection programs. It soon became obvious that we needed more than one white-egg and one brown-egg cross to satisfy different regional demand.

During my first decade in Cuxhaven (1969-79) we focused on one product for the European white-egg market: the HNL Nick Chick. During the second decade (1979-89) we introduced the feather-sexing LSL, entered the global brown-egg market, focused on feed efficiency and adapted egg weight to market needs. During my third decade in Cuxhaven (1989-99) Rudolf Preisinger joined our genetics team and helped to refine our routines, introduced new techniques and fresh ideas. I could then afford to spend more time reading and listening to people outside our mainstream business.

Sustainability became a public issue, and we as primary breeders were confronted with the question whether our breeding methods were compatible with society demands such as: (1) transparency of food production from farm to fork and from primary breeder to the commercial product; (2) husbandry conditions compatible with ethical standards of society; (3) minimal pollution of the environment; (4) preservation of genetic diversity; (4) long-term perspectives for adequate nutrition of a growing world population and increasing competition for land to be used for food, feed or fuel production. Selection for improved feed efficiency has made a substantial contribution to optimize the use of resources and minimize pollution of the environment. Selection against cannibalism has made egg production in non-cage systems easier. Our work on the genetics of osteoporosis in laying hens also suggests a reduction of bone breakage (Fleming *et al.*, 1997).

Active participation in public research is a "give and take" and more can be gained by transparency than by secrecy. Details of our breeding programs in Cuxhaven have been published extensively over the years (e.g. recently by Flock *et al.*, 2008). Sustainable farm animal breeding as defined in the European FABRE TP project (2008) for different species of farm animals includes principles we have been following for decades in our breeding programs (Flock, 1994; Flock and Preisinger, 2002).

Developments during the most recent ten year period from 1999 - 2009 will be reviewed in a follow-up paper by R. Preisinger in a future issue of Lohmann Information.

Zusammenfassung

Ein Rückblick auf die Legehennenzucht in Cuxhaven von 1959-2009: glückliche Startbedingungen und gute Aussichten für die Zukunft

Beim Beginn der Zucht 1959 konnte Lohmann auf 10-jährige Erfahrungen im amerikanischen Zuchtbetrieb H&N aufbauen. Im Rahmen eines Lizenzvertrages wurde das komplette Know-how einschließlich reiner Linien importiert. Bis Mitte der 1970er Jahre war das HNL-Zuchtprogramm in Cuxhaven eine Kopie der Basis in den USA, lediglich das Leistungsprofil sollte sich am deutschen Eiermarkt orientieren. Nach Ablauf des Lizenzvertrages wurden die züchterischen Aktivitäten erweitert und neue Wege in der Züchtung beschritten. Wesentliche Entwicklungen waren (1) wettbewerbsfähige braune Legehybriden; (2) federsexbare weiße Legehybriden; (3) nach Eigewicht differenzierte weiße und braune Linienkombinationen; (4) verbesserte Elterntierleistungen; (5) Freiheit von übertragbaren Krankheitserregern (Leukose-Viren, Mykoplasmen, Salmonellen); und (6) erweitertes Kommunikationsnetz mit Kunden.

In dieser Übersicht werden Schwerpunkte der Züchtung aus den vergangenen fünf Dekaden dargestellt. Wer sich ausführlicher in deutscher Sprache über die Entwicklung der modernen Legehennenzucht informieren möchte, sei auf das Kapitel „Praktische Legehennenzüchtung“ (Flock, Schmutz und Preisinger, 2008) in Brade, Flachowsky und Schrader (Ed.) verwiesen.

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Author's Address

Prof. Dr. Dietmar K. Flock
Akazienweg 5
27478 Cuxhaven, Germany

Autogenous Vaccines[1]

Attila von Hankó
EW-Group GmbH, Cuxhaven, Germany

Introduction

Autogenous vaccines play a critical role in the treatment and prevention of diseases in Germany and other EU countries. A similar integrated approach of autogenous vaccines and registered vaccines as complementary concepts is practiced in North America. Despite the generally increasing need for flexible & fast solutions many countries of the global animal health market still rely on registered vaccines only, with at times serious negative consequences for veterinarians and farmers. Based on the existing dual approach plus a third vehicle (MUMS vaccines) in the coming, EU countries are without doubt in an advantageous situation.

Lohmann Tierzucht (LTZ) has a longstanding history in the field of autogenous vaccines and during the recent past consequently pursued the pro-active and strategic development of these activities. This article intends to build a bridge between 50 years of "Veterinary Laboratory" history, present activities and an aspiring future.

Success factors of the early Lohmann Veterinary Laboratory

During the 1950s and 1960s, through application of advanced poultry farming concepts acquired in the USA, the historic Lohmann & Co, KG was a key player in transforming the „back-yard farming" stage of Germany's poultry production into modern, industrialized farming. Given its pioneer status, Lohmann had no choice but to engage in all relevant aspects of integrated animal husbandry, covering genetics, farm management (including equipment), nutrition, diagnostics and, last but not least, prevention and treatment of diseases.

Many of the critical diseases affecting commercial flocks did not exist or were unknown in these early times. The Veterinary Laboratory of Lohmann consequently became a frontrunner in diagnostics & vaccine development and naturally evolved into a pro-active interface between veterinarians, opinion leaders, institutes and universities. The holistic approach of Lohmann with all critical competencies under one roof produced revolutionary solutions to keep birds healthy. As always, successful pioneer work was triggered by creativity, courage to go new ways, intensive knowledge and close connection to the market and customers.

Lohmann Tierzucht "Veterinary Laboratory" mirrored against history

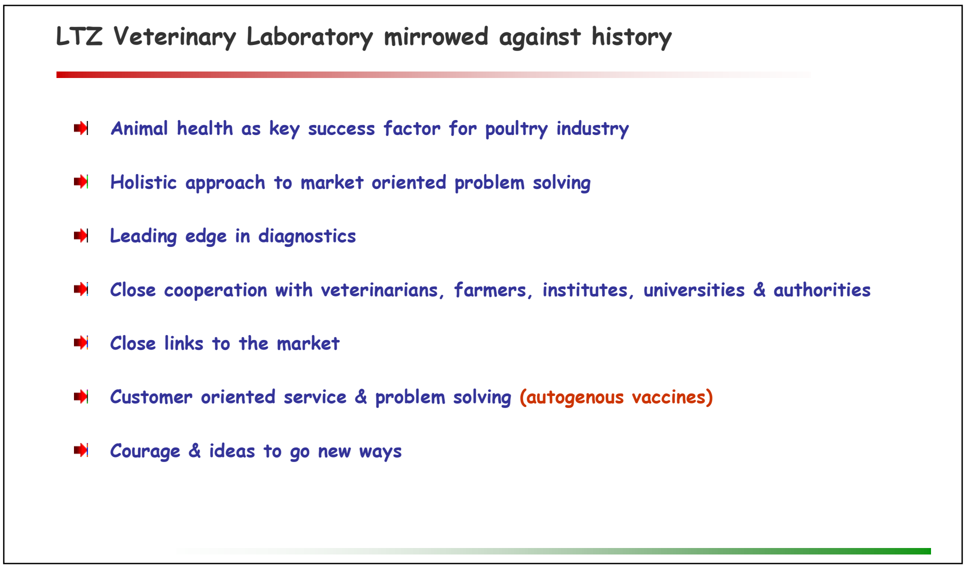
Comparing the activities of today's "VetLabor" against the background of the past 50 years reveals that all key success factors applied under the historic setup are still in place and practiced today. The only relevant difference is the focus on autogenous instead of registered vaccines.

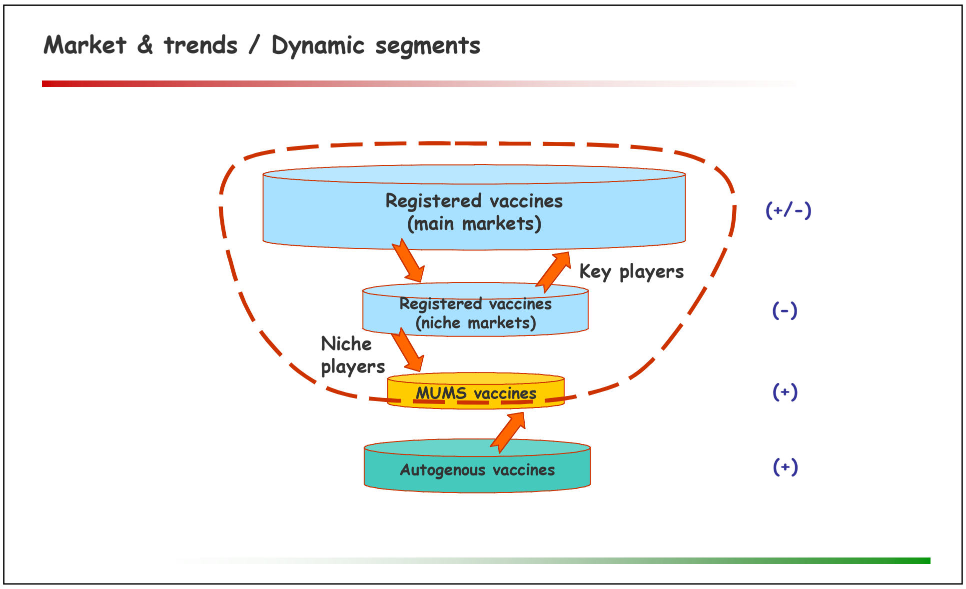
The market of registered vaccines

The landscape of registered vaccines is undergoing significant changes due to several factors:

- Declining number of new diseases with „blockbuster potential" resulting in similar vaccines offered by multiple suppliers, hence increasing competition for standard vaccines
- Market growth in developed major livestock markets limited at best
- Major vaccine players with well-established market shares in livestock focusing on companion animal segment
- Resources & time required for development and registration of vaccines continuing to increase, resulting in rising risks at falling margins
- Producers of registered vaccines under pressure to realize economies of scale, resulting in withdrawals from niche markets and ongoing consolidation

1 Adapted from a presentation on the occasion of the 50th anniversary of the Veterinary Laboratory of Lohmann Tierzucht GmbH.





The market of autogenous vaccines

One significant trend in this segment is the growing need for flexible solutions, for a number of reasons: Upcoming new as well as recurring 'old' diseases; mutations and resistance among existing strains; changes to practices & priorities in farm management (e.g. increasing integration, free range farming, intensive coverage through veterinarians, cost pressure); improved diagnostics; difficulties of key players to enter or continue serving niche markets.

Regulatory perspectives within the European Union

Autogenous vaccines in Germany and the EU are an integral part of modern animal health and hence closely monitored by their respective authorities. An international conference organised in 2003 by the German ‚Paul Ehrlich Institute" presented the following comments & conclusions in respect to autogenous vaccines:

- "Important instrument for prevention of diseases in case of non-availability of registered vaccines"
- "Increasing use in veterinary practice due to changing pathogens, changing farm management and changed priorities of registered vaccine manufacturers"
- "Efficiency is rational for use"
- "Significant changes in structure of poultry industry"

At the same time weaknesses in the regulatory framework have been defined:

- „Unregulated, non-harmonized use of autogenous vaccines not acceptable“;
- „Health of humans & animals has to be considered“
- „Autogenous vaccines cross national borders, thus national regulatory frameworks not adequate any longer“
- „Regulatory framework not in line with present & future needs of animal health“
- „GMP-like production and quality standards desirable“

The conference addressed the topic of „minor use minor species“ (MUMS) vaccines with following conclusions:

- „Commercial pressure forces producers of registered vaccines to focus on major products“
- „Globalisation reduces relative position of niche products“
- „Producers of registered vaccines avoid risk of developing niche products “
- „Lack of suitable registered vaccines leads to Off-Label-Use and illegal use of autogenous vaccines“
- „Development of niche products has to become more attractive“

The evolving picture concerning autogenous & MUMS vaccines was presented as follows:

- “Two complementary & essential vaccine categories required for effective prevention & treatment of diseases”
- “Necessity to adjust regulatory framework to realities of markets”
- “Regulatory focus concerning autogenous vaccines on improved control and harmonisation within the EU”
- “Regulatory focus concerning MUMS vaccines on increased attractiveness for development, production & marketing”
- “Definition of MUMS vaccines through list of products issued by EMEA”
- “Registration of MUMS vaccines similar to registered vaccines, but with less stringent requirements and shortened development times”

LTZ investment in state-of-the-art production facility

The changes described above facilitated a pro-active re-orientation of the autogenous vaccine activities of Lohmann Tierzucht, as shown in the following chronological overview of developments:

2003-2007	Increasing pressure from authorities to improve production and quality control conditions at the Veterinary Laboratory
2005-2007	Evaluation of several scenarios ensuring a future oriented continuation of existing activities
2007	Decision to invest in new GMP standard production facility, hence creation of first-class conditions for consequent further development of autogenous vaccines
2008	Completion & start-up of new facility
2009	GMP certification and further organisational developments

Vision

Lohmann Tierzucht has a clear vision concerning the future of its activities with autogenous vaccines. Cornerstones of this vision are:

- Preferred partner of German poultry veterinarians & farms concerning autogenous vaccines
- Europe-wide accepted partner for poultry diagnostics & autogenous vaccines
- Holistic problem-solving through team competence in critical aspects of poultry health (genetics, management, nutrition, diagnostics, vaccination)
- Dynamic & flexible portfolio with high degree of special products
- Future oriented production facility & quality standards
- Pro-active interface between science & practice

Product portfolio

A portfolio of autogenous vaccines by its very nature is flexible and continuously adapted to market requirements. The portfolio overview outlined below consequently has to be seen as an inventory at this point of time:

Bacterial vaccines

E. coli
Coli/Past/Ery/Gali
Coli
E. coli/S. infantis
Coli/Past
Coli/Past/Ery
Coli/Riemerella/Galli
Coli/faecium
Coli/ Ery
E.coli
Coli/Staph
Coli/Past/OR
Coli/ORT
Coli/Galli
Coli/ E.faecalis

Avibacterium spp

Pasteurella spp
Pasteurella
Past/Ery/ORT
Past/Ery
Coli/Gallibacterium
Coli/Bord/Past/Clost

Gallibacterium

Enterococcus spp
E. faecalis

Erysipelothrix rusiopathiae
Ery

Mycoplasma spp

Ornithobacterium rhinotracheale
ORT/Riemerella
ORT/Past
ORT

Salmonella spp
S. infantis
S. Hadar

Riemerella spp
Rimerella/Past/Coli
Rimerella/Past

Clostridium spp

Viral vaccines

Avian Reo-Viruses
Reo
Reo/Adeno
Reo/Coli/Staph
Reo/Coli

Avian Adeno-Viruses

Infectious Bronchitis
IB China QX

Duck Hepatitis
Duck Hepatitis

Low pathogen Avian Influenza-Viruses

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Profile of strength

In a nutshell, autogenous vaccines developed, produced and marketed by Lohmann Tierzucht are the result of 50 years history consequently shaped into a unique profile of strength in the field of autogenous vaccines:

- GMP certified production & quality control standards
- Flexibility of small production scale
- Wide range of bacterial & viral vaccines
- Leading competence in determination of field strains
- Worldwide monitoring of disease trends in the field
- Comprehensive competencies in genetics, management, nutrition, diagnostics, vaccines

Zusammenfassung

Bestandspezifische Impfstoffe

Stallspezifische Impfstoffe spielen in Deutschland und der EU eine wichtige Rolle in der Behandlung und Prävention von Krankheiten. Während die Notwendigkeit nach flexiblen & schnellen Lösungen in der täglichen Praxis der Tiergesundheit zunimmt, unterliegen registrierte Impfstoffe globalen Trends, die das Bereitstellen von Impfstoffen für Nischenmärkte immer schwieriger machen. Die nationalen Tiergesundheitsbehörden haben diese Entwicklung seit Jahren erkannt und arbeiten gezielt daran, praxisorientierte Rahmenbedingungen zu schaffen. Im Vordergrund stehen hier die verbesserte Kontrolle und EU Harmonisierung von stallspezifischen Impfstoffen sowie die Einführung der neuen Impfstoffkategorie “Minor-Use-Minor-Species (MUMS)”. Dem Markt stehen somit drei sich ergänzende Impfstoffkategorien zur Verfügung. Das Veterinärlabor der Lohmann Tierzucht GmbH blickt auf eine 50jährige Geschichte und bedeutende Pionierleistungen in der Diagnostik und Entwicklung/Herstellung von Impfstoffen zurück. Die enge Einbindung in alle relevanten Aspekte der Tierzucht und die über Jahrzehnte gewachsenen Kompetenzen in der Tiergesundheit geben dem heutigen Veterinärlabor ein ausgeprägtes Stärkeprofil als Partner für Problemlösungen mit stallspezifischen Impfstoffen. Die im September 2008 fertiggestellte Investition in eine neue Produktionsstätte für bestandspezifische Impfstoffe auf GMP Niveau stellt einen konsequenten und wichtigen Meilenstein für die strategische Weiterentwicklung dieses Geschäftsbereichs dar.

Author’s Address:

Attila von Hankó
EW-Group GmbH
Am Seedeich 9
D-27472 Cuxhaven
E-mail: attila.vonhanko@ew-group.de

Amino Acid Recommendations for laying hens

Andreas Lemme
Evonik - Deguss GmbH, Germany

Introduction

During recent decades productivity of laying hens increased substantially (Elliot, 2008). Not only egg number, egg mass, and feed conversion has increased but also persistency of lay has improved. As such, this must have implications on the optimal amino acid nutrition of current laying hen strains. Simply stated, increasing egg mass output per hen means an increased amino acid output which has to be provided by the feed. Moreover, while performance criteria of laying hens have improved, body weight has decreased (Elliot, 2008). Consequently, the amino acid requirement for maintenance purposes is influenced. In addition to the quantitative demands for amino acids by the modern laying hen changing, there also is the potential that the qualitative demands for dietary protein might have changed as optimum amino acid composition for egg production differs from that for maintenance.

Therefore, the current amino acid recommendations for layers provided by Evonik Degussa Feed Additives have been revised. Since methionine is considered the first limiting amino acid in most common diet compositions, literature was screened for methionine response studies in order to derive a value for optimum dietary methionine level. Subsequently, the optimum amino acid profile was defined by means of recent ideal protein research which ultimately allowed for calculating optimal dietary amino acid levels for modern laying hen strains.

Several methionine dose response studies with laying hens are available

International literature was searched for methionine dose-response studies with laying hens in order to perform a meta-analysis. Thirteen papers were published since 1990 reporting 19 experiments which were suitable for this survey (Table 1). Age of laying hens ranged between 18 and 64 weeks but on average trials were performed from 24 to 39 weeks of age. Moreover, various genetics were used in these trials including Hy-Line W-36, Lohmann LSL, Lohmann brown, Single Comb White Leghorn, Hisex brown, Dekalb delta, and ISA Babcock hens. However, because of the limited number of trials, it was not possible to derive specific amino acid recommendations for individual strains.

There were considerable differences in diet compositions between these trials as the ingredients used, protein and amino acid levels, and metabolisable energy contents varied. At least it can be stated that all basal diets were deficient in methionine (Met) and methionine+cysteine (Met+Cys), otherwise the hens would not have responded to increasing levels of supplemental DL-Met. In order to avoid or at least to reduce interactions between performance data and digestibility of the dietary Met, all performance data were regressed against digestible Met or Met+Cys. However, some publications only reported total amino acid contents of the diets, and in those cases, the digestible amino acid levels of the diets were recalculated using AminoDat 3.0® software (Degussa 2006). Digestibility figures origin from broiler research as digestibility research on laying hens is scarce.

The basic idea of meta-analyses is to put data of many experiments together in order to analyse them in one process. In this context the challenge of the present survey was dealing with high variation of response data within a trial but particularly between trials. In order to reduce this variability, egg mass per hen per day was considered as key performance parameter. However, when egg mass/hen/day was plotted against dietary digestible Met content, data were still relatively variable and regression analysis revealed a relative poor fit ($r^2 = 0.24$, Figure 1). One goal of the nutritionist is to ensure a least intake of nutrients which is the result of dietary concentration and feed intake. As feed intake is influenced by a number of factors such as body weight (an effect of strain) nutrient intake is considered to be a better basis for standardisation. Therefore, the data were standardised to digestible methionine intake.

Physiological feed back mechanisms allow laying hens to eat according to the first limiting nutritional factor, which is usually dietary energy. So, differences in dietary energy levels must have implications

Table 1: Methionine and Methionine+Cysteine dose response studies which were considered in the meta-analysis

Authors	Year	Experiment	strain	period		CP	ME	dig. Met*	tot Met	dig M+C	tot M+C	dig. Lys	tot. Lys
Bateman et al, 2005	2001		Hy-Line W-36	24	35	15.0	12.00	0.25	0.27	0.45	0.51	0.65	0.75
Bertram et al., 1995a	1995	high energy	Lohmann LSL	24	36	14.8	11.72	0.22	0.25	0.42	0.51	0.71	0.79
Bertram et al., 1995a	1995	low energy	Lohmann LSL	24	36	15.1	10.88	0.22	0.25	0.42	0.50	0.71	0.79
Bertram et al., 1995b	1995		Lohmann Brown	23	35	15.6	11.70	0.19	0.23	0.39	0.50	0.68	0.77
Calderon and Jensen, 1990	1990	Expt. 1	Comb White Leghorn	32	36	13.0	12.18	0.20	0.24	0.40	0.45	0.61	0.68
Calderon and Jensen, 1990	1990	Expt. 2	Comb White Leghorn	59	64	13.0	12.18	0.20	0.24	0.40	0.45	0.61	0.68
Dänner and Bessei, 2002	2002		Lohmann LSL	22	45	15.1	11.39	0.19	0.22	0.43	0.49	0.75	0.84
Filho et al., 2006	2006		Hisex brown	20	44	17.2	11.72	0.29	0.31	0.54	0.61	0.84	0.97
Fuente Martinez et al., 2005	2005		ISA Babcock B-300	24	34	15.2	12.13	0.21	0.24	0.41	0.49	0.69	0.79
Lemme et al., 2004	2003		Hy-Line W-36	24	40	14.5	11.84	0.21	0.23	0.40	0.48	0.72	0.80
Lemme et al., 2004	2003		Lohmann Brown	22	46	15.4	11.80	0.20	0.23	0.42	0.50	0.80	0.88
Mack et al., 1999	1999	Dekalb delta	Dekalb delta	18	30	14.6	11.92	0.21	0.22	0.43	0.46	0.65	0.73
Mack et al., 1999	1999	Hy-Line W-36	Hy-Line W-36	18	30	14.6	11.92	0.21	0.22	0.43	0.46	0.65	0.73
Mack et al., 1999	1999	Lohmann LSL	Lohmann LSL	18	30	14.6	11.92	0.21	0.22	0.43	0.46	0.65	0.73
Narváez, 1996	1996	brown layers	not mentioned	22	38	14.4	11.51	0.21	0.23	0.44	0.48	0.62	0.71
Narváez et al., 2005	1996	white layers	Lohmann LSL	22	38	14.4	11.51	0.21	0.23	0.44	0.48	0.62	0.71
Novak et al., 2004	2004	high Lys	Dekalb delta	20	43	17.7	12.09	0.31	0.36	0.55	0.66	0.90	0.98
Novak et al.., 2004	2004	low Lys	Dekalb delta	20	43	17.7	12.09	0.32	0.36	0.56	0.65	0.81	0.87
Schutte et al., 1994	1994	Expt. 1	Lohmann LSL	25	37	14.5	12.13	0.20	0.23	0.41	0.48	0.68	0.77

on feed intake and consequently on Met intake. Regressing daily egg mass data against daily digestible Met intake per MJ ME improved the fit of the regression curve to a reasonable r-square of 0.78 (Figure 2).

Finally, data were analysed by exponential regression as suggested by Morris (2004), who demonstrated that performance response curves to amino acid levels of a population of animals are of non-linear nature. The 19 experiments delivered 97 data points, and the resulting regression equation suggested that 35.15 mg Met intake/MJ ME/hen/d is optimal (95 % of asymptotic response). This number cor-

Figure 1: Daily egg mass data out of 19 experiments plotted against the digestible methionine content of the diet

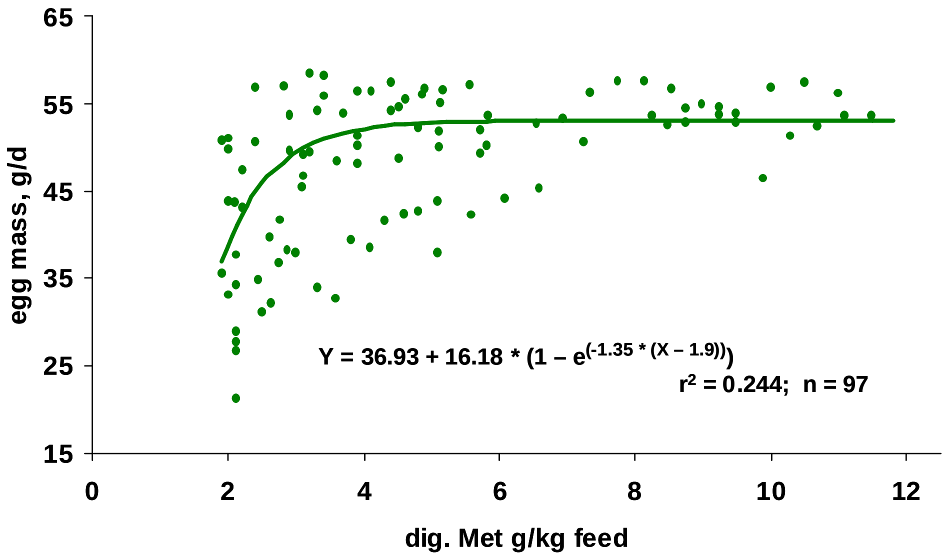
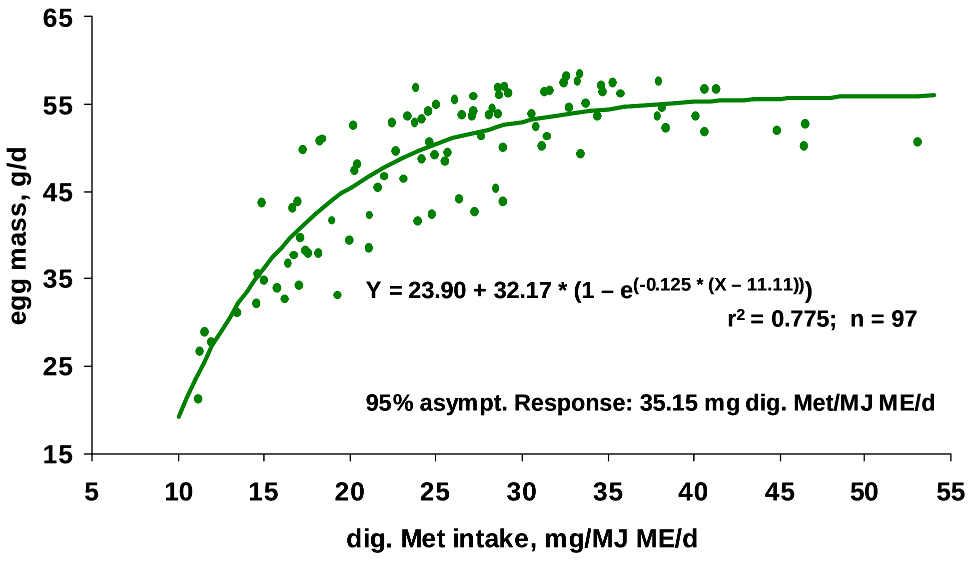


Figure 2: Daily egg mass data out of 19 experiments plotted against the daily digestible methionine intake which was standardised to the dietary energy content

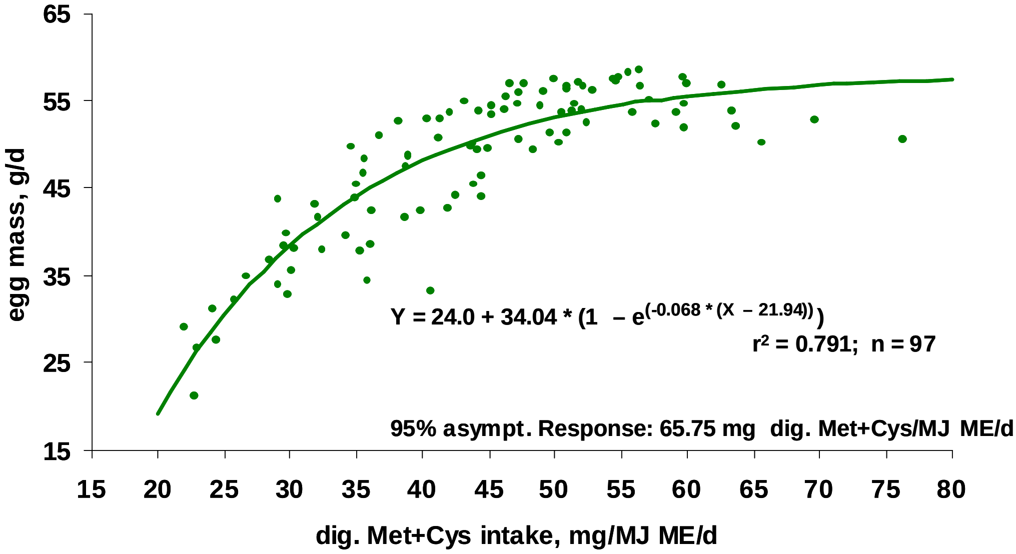


responds to a daily intake of 415 mg of Met using a dietary energy level of 11.82 MJ ME, which was the average across all considered studies. This number of 415 mg dig. Met/hen/d is about 6 % higher than our current recommendation (390 mg/hen/d) but in line with that suggested by Joly (2007), who estimated 420 mg dig. Met/hen/d.

The procedure applied for digestible methionine was also applied for digestible methionine + cysteine levels (Figure 3). Accordingly, the resulting optimum is 65.76 mg digestible Met+Cys intake/MJ ME/hen/d corresponding to 777 mg dig. Met+Cys/hen/d. This value is about 13 % higher than the current Evonik recommendation of 690 mg/hen/d.

While the determined optimum supply of 415 mg dig. Met/hen/d and 777 mg dig. Met+Cys/hen/d may initially seem high, these levels suggest an optimum dig. Met to dig. Met+Cys ratio of 54 %. This ratio is similar to that suggested by Bregendahl et al. (2008), who determined an optimum dig. Met to

Figure 3: Daily egg mass data out of 19 experiments plotted against the daily digestible methionine+cysteine intake which was standardised to the dietary energy content



Met+Cys ratio of 52 and 55 % based on daily egg mass and feed conversion ratio data out of two consecutive experiments, respectively. It also agrees with Rostagno (2005), who recommended a dig. Met to Met+Cys ratio of 55 %. However, this estimate is lower than Joly (2007), who suggested 650 mg dig. Met+Cys/hen/d to be optimal which would corresponds to a dig. Met to Met+Cys ratio of 65 %. The ratio of Joly (2007) suggests a considerably lower Cys requirement of the birds as the dig. Met level by Joly (2007) is quite in line with our findings. Finally, suggestions by Leeson and Summers (2005) and Coon and Zhang (1999) were 58 % and 60 %, which are slightly higher than our findings, but lower than those of Joly (2007).

Ideal Protein Profiles

Although Met and Met+Cys, respectively, play a key role in laying hen nutrition because they are first limiting in most common commercial diets, lysine is typically used as the reference amino acid in the Ideal Protein concept. The advantage of this concept is that all essential amino acids are considered because optimising performance requires that the whole range of essential amino acids are provided to the animal in adequate amounts. Recently, Bregendahl *et al*. (2008) published an extended study on the Ideal Protein profile of modern laying hens, but there are several other references for this topic including Jais *et al*.(1995), Coon and Zhang (1999), Rostagno (2005) and Leeson and Summers (2005). Respective ideal protein profiles are listed in Table 2.

There is a good consistency between the suggested profiles although methodologies applied to derive the values differed with a couple of exceptions. For example, compared with all other studies indicating an average value of 50 % for the dig. Met to Lys ratio, Jais et al. (1995) reported 44 %, which seemed to be too low. Suggested Met+Cys to Lys ratios ranged from 81 % (Coon and Zhang, 1999) to 96 % (Bregendahl *et al*., 2008) and showed thus higher variability. With respect to Thr, Leeson and Summers (2005) suggested a relatively high ratio to Lys (80 %) whereas Rostagno (2005) recommends a rather low figure (66 %). Regarding Trp:Lys the ratio provided by Jais *et al*.(1995) was substantially lower compared to the other references. Likewise, the suggested Arg to Lys ratio of 130 % by Coon and Zhang (1999) is considerably higher than those by Rostagno (2005) and Leeson and Summers (2005) and especially by Jais *et al.* (1995). Similar findings apply for Val to Lys ratios. Ile to Lys ratios varied between 76 % and 86 %.

Table 2: Ideal amino acid profiles proposed by different authors

Source	Jais *et al.*, 1995	Leeson and Summers, 2005	Rostagno, 2005	Bregendahl *et al.*, 2008		Coon and Zhang, 1999
	digestible	total	digestible	digestible	digestible	digestible
Lys	100	100	100	100	100	100
Met	44	51	50	47	52	49
Met+Cys	--	88	91	94	96	81
Thr	74	80	66	77	--	73
Trp	16	21	23	22	--	20
Arg	82	103	100	--	--	130
Ile	76	79	83	79	--	86
Val	64	89	90	93	--	102

Recommended amino acid levels for layers have been increased

Based on our meta-analysis and the above mentioned ideal protein sources we revised our current amino acid recommendations for laying hens, which are reported in Table 3. The basis of our revised recommendations is the optimum daily intake of 415 mg dig. Met/hen which was the outcome of our meta-analysis. In a second step, optimal intake of the other amino acids was calculated by using the ideal ratios which are presented in Table 3. Those ratios were more or less the average of the numbers given in Table 2. The Met to Lys as well as the Trp to Lys ratio reported by Jais *et al.* (1995) were excluded. For the optimal Met+Cys to Lys ratio also the Met to Met+Cys ratio derived from our meta analysis was considered. Although numbers in Table 2 suggest a Thr to Lys ratio of 74 % we rather suggest to use a ratio of 70 %. Variation of literature data is large. Ratios referring to Bregendahl *et al.* (2008) refer to daily egg mass data. However, feed conversion responses suggested a ratio of 67 %. In addition, information from layer feed producers also suggests that optimal ratio might be lower than 74 %.

An intake of 415 mg dig. Met/hen/d and an optimum dig. Met to Lys ratio of 50 % revealed a daily dig. Lys intake of 830 mg/hen/d (Table 3). Then, dietary levels were calculated using optimum daily intakes and assuming varying daily feed intakes from 80 to 120 g (Table 3). Accordingly, the concentration of amino acids (and ideally other nutrients and energy) increases with decreasing feed intake.

A recommended daily intake of 830 mg dig. Lys/hen might appear high, especially when compared with our previous recommendation of 770 mg/hen/d. However, in an experiment by Bonekamp *et al.* (2007), dig. Lys intake was increased from 550 to 800 mg/hen/d in two layer strains (Lohmann brown classic, Lohmann LSL classic). Note that in this trial, the whole amino acid profile was increased in conjunction with Lys, whereas energy and minerals were maintained. Responses on daily egg mass and feed conversion ratio were of non-linear nature (Figure 4). Exponential regression analysis indicated that the maximum daily egg mass and minimum feed conversion ratio were not achieved. Respective regression equations suggested that the optimal dig. Lys intakes were higher than the highest tested level but also clearly higher than 830 mg/hen/d, which imply that modern layers require high levels of dietary amino acids to realize their full genetic performance potential. Moreover, optimum amino acid levels for maximising performance seemed to be similar between strains.

Most of the studies used for the meta-analysis on sulphur amino acids and ideal protein were done with laying hens from start of lay to around peak production. Having typical egg production and egg weight curves in mind, it appears logic that optimum amino acid levels differ with age. Our recommendations as given in Table 3 are meant for layers up to peak production. In later phases when performance decreases, their amino acid requirements will also decrease, thus the dietary amino acid levels might be reduced.

Table 3: Recommendations for both digestible amino acid intake of laying hens and in % of diet for laying hens with differing daily feed intake (Dietary energy: 11.82 MJ ME/kg)

	dig. Lys	dig. Met	dig. Met+Cys	dig. Thr	dig. Trp	dig. Arg	dig. Ile	dig. Val
optimal ratios to Lys	**100**	**50**	**91**	**70**	**21**	**104**	**80**	**88**
intake, mg/d	**831**	**415**	**756**	**582**	**174**	**864**	**665**	**731**
Feed intake, g/d	**Digestible Amino acids in g/kg diet**							
80	10.39	5.19	9.45	7.27	2.18	10.80	8.31	9.14
85	9.78	4.89	8.90	6.84	2.05	10.17	7.82	8.60
90	9.23	4.62	8.40	6.46	1.94	9.60	7.39	8.12
95	8.75	4.37	7.96	6.12	1.84	9.10	7.00	7.70
100	8.31	4.15	7.56	5.82	1.74	8.64	6.65	7.31
105	7.91	3.96	7.20	5.54	1.66	8.23	6.33	6.96
110	7.55	3.78	6.87	5.29	1.59	7.86	6.04	6.65
115	7.23	3.61	6.58	5.06	1.52	7.51	5.78	6.36
120	6.92	3.46	6.30	4.85	1.45	7.20	5.54	6.09

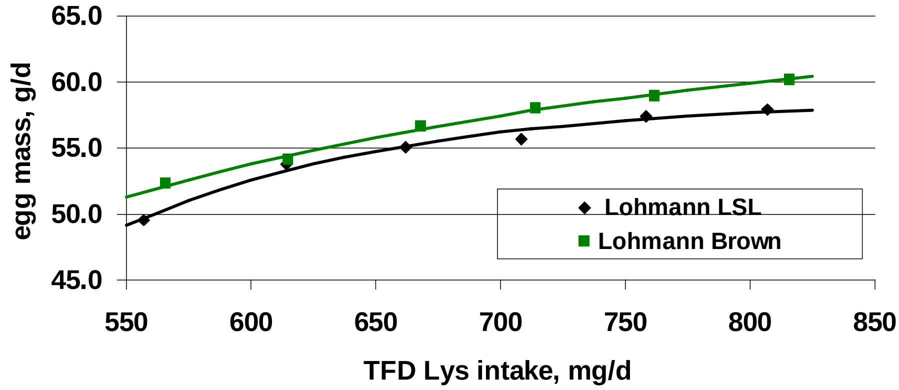
The potential for differences in the maintenance and production requirements and their subsequent differences in their ideal amino acid profiles also should be considered. The ratios suggested by Rostagno (2005) are applied for various body weights, weight gain, and daily egg mass of the hens but there is no consideration given to differences in maintenance and production resulting in changes of the ratios. However, the recommendations by GfE (1999) do consider those differences, but the recommended amino acid profile changes only marginally. Therefore, our recommended amino acid ratios (Lys=100) remain the same for all production phases for practical reasons.

Feed intake is influenced by dietary energy

Feed intake of laying hens is dependent on the dietary energy level. Morris (2004) referring to an earlier work of his lab from 1968 showed that laying hens reduce their feed intake as soon as dietary metabolisable energy (ME) content has been increased. However, Morris (2004) further reported that if dietary ME is increased and also the limiting amino acids are increased proportionally, hens gained fat. He concluded that a reduction in feed intake was not enough to maintain energy intake. As a solution, Morris (2004) suggested to use the effective energy concept which is more similar to net energy instead of metabolisable energy. The change in dietary metabolisable energy is often accompanied with a change in fibre and fat content, fractions which per definition have different energetic effectiveness. However, the effective energy concept has not been established in poultry nutrition.

An experiment was conducted in which ISA brown layers were fed increasing levels of a well balanced protein at two metabolisable energy intakes (Wijtten *et al.*, 2006). Energy intake of 294 kcal ME/hen/d and 314 kcal ME/hen/d were achieved by restricted feeding. Digestible Lys intake was increased from about 600 to 750 mg/hen/d at both energy intakes. At the same time the whole amino acid profile was raised maintaining ratios between the amino acids. Responses on daily egg mass are shown in Figure 5. Performance increased in a linear fashion with increasing levels of balanced protein at both energy intakes suggesting that higher levels would have been needed to achieve the asymptote. This effect again suggests that the optimal dietary dig. Lys level (and those of all other essential amino acids) is much higher than our former recommendation of 770 mg dig. Lys/hen/d.

Figure 4: Daily egg mass and feed conversion ratio of two layer strains fed graded levels of balanced protein (Bonekamp *et al.*, 2007)



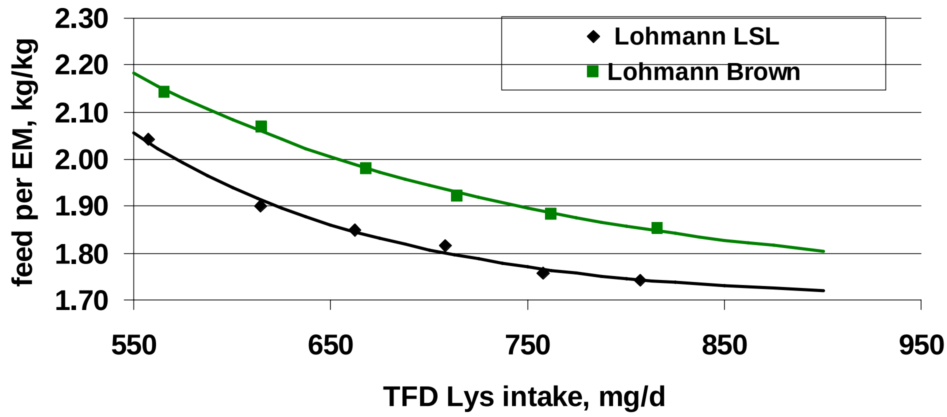
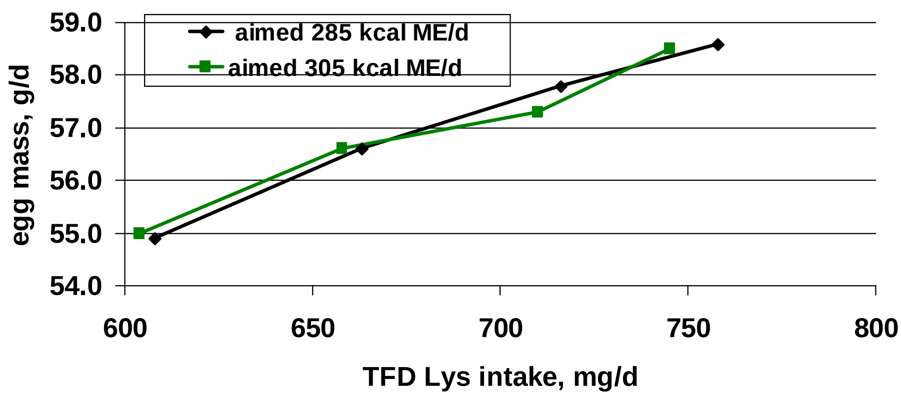
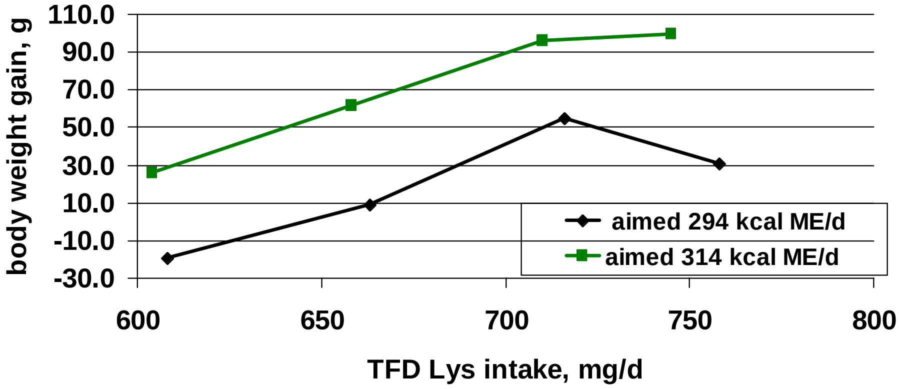


Figure 5: Daily egg mass of ISA brown layers with graded levels of balanced protein intake (True fecal digestible Lys given as reference) at two energy intakes (Wijtten *et al.*, 2006)



There was no difference between the two energy treatments indicating that if energy intake is reduced, amino acid intake should be maintained in order to keep performance at the same level (Figure 5). Differences in energy intake were achieved by controlling feed intake. Consequently feed conversion ratio was better at lower energy intake but the response to increasing dietary balanced protein (BP)

Figure 6: Body weight gains of ISA brown layers with graded levels of balanced protein intake (True fecal digestible Lys given as reference) at two energy intakes (Wijtten *et al.*, 2006)



was again very similar at both energy intakes. Interestingly, both increasing dietary BP and energy intake levels affected body weight development of the hens over the 16-week experiment. Body weight increased with increasing BP (Figure 6). It is assumed that effects on body weight are mainly due to fat accretion, however, this has not been confirmed. Body weight gain was consistently higher at higher energy intake. Therefore, it was concluded that the higher energy intake could not be utilised for higher egg mass production, so the extra energy was stored as fat. These responses imply that an energy intake of 314 kcal ME/hen/d can be reduced as energy is partly used for weight gain which is not necessarily desired in layers.

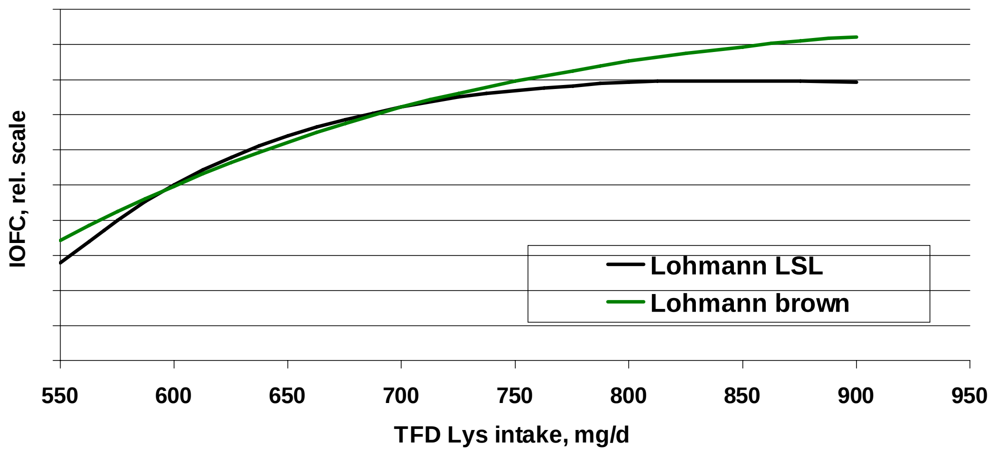
Differences in energy intake can only be achieved by feed restriction. In case of changing ME levels in the diet, hens would respond with changes in feed intake in order to maintain energy intake. However, the current experiment suggests that controlling energy intake of hens might be a tool to control body weight (fat) gain of layers.

Raw material prices and availability force nutritionists to find alternative sources and concepts particularly when it comes to energy. In this context, the question arises how to adjust dietary amino acids if dietary energy is reduced. As mentioned above, Morris (2004) reported that proportional adjustment of amino acids with changes in dietary metabolisable energy is not satisfying. A recent literature survey suggests that amino acids levels in broiler diets should not be adjusted proportionally to changes in dietary energy in order to maintain performance and profitability (Lemme, 2007). Changes in dietary composition (fat, fibre, carbohydrates, protein) and their respective net energy or effective energy contents might partly explain this finding. This concept has been implemented in our QuickChick software, which gives amino acid recommendations for broilers. It suggests that relative changes in amino acid levels are only half of the dietary ME changes. When applying the same concept to layer amino acid recommendation, levels would change as presented in Table 4 where ME was reduced by 5 % to 11.23 MJ ME/kg.

Optimal dietary amino acid levels are influenced by economic conditions

Dietary amino acid specifications should allow for high performance. However, maximum performance does not necessarily mean maximum profitability. Therefore, nutrient specifications in general but amino acid specification in particular should be adjusted to the economic conditions including feed cost and egg price. In Figure 7, income over feed cost is used as a profitability indicator. The considerations for this calculation were: a general diet price of 180 EURO; a price increase of 1 EURO per 100 mg increase of daily dig. Lys intake (at 100g daily feed intake this corresponds to an increase of 0.1 % dig. Lys of the balanced protein); and 15 EURO per kg egg mass. These considerations were combined with predicted daily egg mass and feed conversion ratio using the respective exponential regression equations. Although the curve of Lohmann LSL hens was flatter than that of Lohmann brown hens, both curves did not achieve a maximum even at 830 mg dig. Lys intake/hen/d which

Figure 7: Income over feed cost calculations (IOFC) using experimental data (regression equations) from Bonekamp *et al.* (2007) and assuming a basal feed price of 1.80 EURO/kg feed, 15.00 EURO/kg egg output, and a feed price increase of 1.00 EURO/100 mg higher dig. Lys (balanced protein) intake.



was outside the tested range in the experiment. Interestingly, general diet price did not impact optimal dietary amino acid levels. Stronger feed price changes per unit balanced dietary protein would reduce the economically optimal amino acid intake. Also price per kg egg mass influences optimal specifications.

Our revised recommendation as given in Tables 3 and 4 will allow for maximum egg mass production and minimum feed conversion ratio, but not necessarily optimise profitability. Therefore, nutritionists need to fine tune specifications in relation to the economic conditions. However, while the absolute level of amino acids may change with the economic situation, ideal ratios between the amino acids remain the same.

Table 4: Recommendations for both digestible amino acid intake of laying hens and in % of diet for laying hens with differing daily feed intake (Dietary energy reduced: From 11.82 to 11.23 MJ ME/kg)

		dig. Lys	dig. Met	dig. Met+Cys	dig. Thr	dig. Trp	dig. Arg	dig. Ile	dig. Val
optimal ratios to Lys		100	50	91	70	21	104	80	88
Feed intake, g/d		**Digestible Amino acids in g/kg diet**							
Before energy reduction	**After energy reduction**								
80	**84**	10.13	5.06	9.22	7.09	2.13	10.53	8.10	8.91
85	**89**	9.53	4.77	8.67	6.67	2.00	9.91	7.63	8.39
90	**95**	9.00	4.50	8.19	6.30	1.89	9.36	7.20	7.92
95	**100**	8.53	4.26	7.76	5.97	1.79	8.87	6.82	7.51
100	**105**	8.10	4.05	7.37	5.67	1.70	8.43	6.48	7.13
105	**110**	7.72	3.86	7.02	5.40	1.62	8.02	6.17	6.79
110	**116**	7.37	3.68	6.70	5.16	1.55	7.66	5.89	6.48
115	**121**	7.05	3.52	6.41	4.93	1.48	7.33	5.64	6.20
120	**126**	6.75	3.38	6.14	4.73	1.42	7.02	5.40	5.94

Table 5: Diet formulations for laying hens using revised amino acid specifications and using DL-Met, DL-Met and L-Lys HCl, DL-Met and L-Lys HCl and L-Thr or DL-Met, L-Lys HCl, L-Thr and L-Trp (Protein limiting amino acids are marked with grey cells)

INGREDIENTS		Met	Met, Lys	Met, Lys, Thr	Met, Lys, Thr, Trp
Corn		59.863	61.418	61.822	62.538
SBM (46 %)		26.410	25.076	24.727	24.104
Feather meal		2.000	2.000	2.000	2.000
Soy oil		1.297	1.018	0.945	0.813
L-Lys HCl		-	0.039	0.049	0.067
DL-Met		0.230	0.240	0.243	0.247
L-Thr		-	-	0.004	0.012
L-Trp		-	-	-	0.003
Limestone		8.352	8.355	8.356	8.358
Ca_2P		1.247	1.254	1.255	1.258
Salt		0.400	0.400	0.400	0.400
Premix		0.200	0.200	0.200	0.200
TOTAL		100.00	100.00	100.00	100.00
Cost (RMB/kg)		2.7759	2.7305	2.7193	2.7102
NUTRIENTS AND ENERGY					
Energy, kcal ME/kg		2,800	2,800	2,800	2,800
CP, %		18.99	18.55	18.44	18.24
Dig. Lys, %	0.83	0.83	0.83	0.83	0.83
RATIOS TO DIGESTIBLE LYSINE	**Specification**				
Dig. Lys	100	100	100	100	100
Dig. Met	50	58	59	59	59
Dig. Met+Cys	91	91	91	91	91
Dig. Thr	70	72	70	70	70
Dig. Trp	21	22	21	21	21
Dig. Arg	104	135	130	129	127
Dig. Ile	80	84	82	81	80
Dig. Val	88	95	93	92	91

Use of supplemental amino acids helps to balance dietary amino acid profile

The principle of least cost feed formulation is that a number of constraints need to be matched by a suitable combination of ingredients allowing for the most economical solution. Amino acids are provided either in form of proteins which are found in cereals, legumes, by-products from food oil production, animal by products etc. or as free amino acids. Currently, DL-Met, L-Lys sources, L-Thr, and L-Trp are commercially available as amino acids. However, based on the analysis of several hundred samples of layer feed, often only DL-Met is used. However, the inclusion of the other amino acids can help reduce dietary protein as well as feed costs.

In Table 5, corn-soybean meal diets with feather meal were formulated using the amino acid specifications obtained from Table 3 and Chinese raw material prices from December 2007. In diet 1 only DL-Met was made available to least cost formulation, whereas in diet 2, DL-Met and L-Lys HCl were made available. In diets 3 and 4, L-Thr and L-Trp also were offered.

In this exercise, the use of the other amino acids beyond DL-Met decreased the use of SBM and increased the inclusion level of corn. As such, dietary protein level was decreased stepwise as these other amino acids were made available. The use of these other amino acids allowed the diet to better match the specified constraints. This is an important effect from an environmental standpoint, because any reduction in dietary protein level reduces nitrogen excretion. Furthermore, these amino acids (L-Lys, L-Thr or L-Trp) did not have to be forced into these diets, suggesting that they were needed to minimise feed cost. Consequently, feed costs were gradually reduced from diet 1 to diet 4. These examples clearly demonstrate that the use of supplemental amino acids allow for minimising feed prices, and for better balancing the dietary amino acid profile.

Summary

- Latest scientific research was considered in revising amino acid recommendations for laying hens.
- Considering that methionine is the first limiting amino acid in laying hen diets, a meta-analysis revealed an optimal digestible methionine intake of 415 mg/hen/d.
- Literature suggested optimal digestible methionine, methionine+cysteine, threonine, tryptophan, arginine, isoleucine and valine to digestible lysine ratios of 50, 91, 70, 21, 104, 80 and 88 %, respectively.
- If dietary metabolisable energy needs to be reduced, then essential amino acids also should be reduced, but to a lesser extent.
- Optimising the dietary amino acid profile and feed cost reduction can only be achieved with the complete set of commercially available amino acids.

Zusammenfassung

Aminosäurenempfehlungen für Legehennen

- Neueste wissenschaftliche Forschungen wurden bei der Revision der Aminosäurenempfehlungen für Legehennen in Betracht gezogen. Berücksichtigt man, dass Methionin die erstlimitierende Aminosäure bei Legehennen ist, so hat eine Meta-Analyse gezeigt, dass die optimale Aufnahme an verdaulichem Methionin bei 415 mg pro Henne und Tag liegt.
- In der Literatur wurden optimale verdauliche Verhältnisse von Methionin, Methionin+Cystin, Threonin, Tryptophan, Arginin, Isoleucin und Valin zu verdaulichem Lysin von 50, 91, 70, 21, 104, 80 beziehungsweise 88 % vorgeschlagen.
- Wenn die metabolisierbare Energie im Futter reduziert werden muss, dann sollten die essentiellen Aminosäuren ebenfalls reduziert werden, wenn auch in einem geringeren Ausmaß.
- Eine Optimierung des Aminosäurenprofils der Diät und eine Reduzierung der Futtermittelkosten kann nur über den kompletten Satz kommerziell verfügbarer Aminosäuren erreicht werden.

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Author's Address:

Dr Andreas Lemme
Evonik Degussa GmbH Bldg 251/112
Rodenbacher Chaussee 4 63457 Hanau-Wolfgang, Germany
andreas.lemme@evonik.com

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Efficacy of probiotic “ToyoCerin®” and phytobiotic “Cuxarom Spicemaster” on growing rabbits

P. Matusevicius and H. Jeroch
Lithuanian Veterinary Academy, Kaunas, Lithuania

Introduction

Until the final ban on antibiotic feed additives in the EU which took effect on 01.01.2006 (EU regulation no. 1831/2003) these feed additives were also added to rabbit feed. Amongst other things they were used to reduce the occurrence of diarrhoea following weaning which is a major cause of losses in commercial rabbit production (TETENS, 2007). As alternatives for antibiotic feed additives FALCAO-E-CUNHA *et al.* (2007) and others discuss probiotics, prebiotics, enzymes as well as organic acids and critically evaluate the literature available concerning growing rabbits. On various occasions phytogenic preparations (phytobiotics, botanicals) are also named as possible alternative substances (e.g. WENK, 2005).

In comparison to pigs and poultry far less scientific publications are available concerning possible alternatives for use in rabbits (FALCAO E-CUNHA *et al.*, 2007). In order to evaluate these substances as supplements in rabbit feed, further trials are urgently needed, as FALCAO E-CUNHA *et al.* (2007) conclude from their literature review. Therefore trials were carried out with the probiotic preparation ToyoCerin® and the phytobiotic preparation Cuxarom Spicemaster. The results are presented below and compared with similar data found in the literature.

Own trials
Materials and methods

Using the preparations ToyoCerin® and Cuxarom Spicemaster 2 trials (1, 2) were carried out in succession, each trial consisting of 3 groups:

- Group I: commercial feed for rabbits with no supplements (control group)
- Group II: commercial feed as group I plus 100 mg ToyoCerin®/kg feed,
- Group III: commercial feed as group I plus 300 mg Cuxarom Spicemaster/kg feed.

In trial 1 each group consisted of 9 animals, while 11 animals were allocated to each group in trial 2. The trial duration was 56 days for each trial.

Both trials were carried out using New Zealand white rabbits. In trial 1 young rabbits reproduced at the Institute and weaned at the age of 30 days were used. For trial 2 the animals were acquired from a commercial rabbit farm. At the beginning of the trial they were 8 weeks old and thus had a higher body weight in comparison to trial 1.

The probiotic preparation ToyoCerin® contains spores of *Bacillus cereus var.toyoi* at a concentration of $1x10^{10}$ cfu/g. The phytogenic feed additive Cuxarom Spicemaster is a mixture of brown algae, several herbs and spices (basil, fennel, garlic, cinnamon) and essential oils (aniseed, thyme). The dosage of both trial preparations per kg feed was in accordance with the recommendations of the contract partner Lohmann Animal Health, Cuxhaven, Germany.

The feed mixtures were manufactured in the compound feed plant UAB “Krekenavos pasawai”, Krekenava/Lithuania. The mineral feed for the feed mixtures for the 3 groups (control / with ToyoCerin® / with Cuxarom Spicemaster) were produced by Basu-Mineralfutter GmbH in Bad Sulza/Germany. The composition of the feed was the same for all 3 groups in both trials. It consisted of the following components (per kg mixture): 174.0 g ground barley, 135.7 g ground oats, 90.0 g wheat bran, 165.0 g sunflower seed meal, 80.0 g soybean meal, 50.0 g dried sugar beet pulp. 260.0 g dried grass meal, 25.3 g mineral compounds, 20.0 g mineral feed (minerals, trace elements, vitamins, tested additives (groups II and III)). The following nutrients and energy contents in the mixtures (per kg with 88% dry matter) were calculated (MAERTENS *et al.*, 2002): 170 g crude protein, 24 g crude fat, 126 g crude fiber, 329 g neutral detergent fibre, 156 g starch, 49 g sugar, 9.93 MJ digestible energy.

The trials were carried out in the vivarium of the Lithuanian Veterinary Academy, Kaunas, i.e. under laboratory conditions. The animals were kept in single cages of a two-deck battery. The trial room was partly air-conditioned. The rabbits were offered the feed in pellet form (4 mm diameter) via automatic feeders ad libitum. Water in drinking-water quality was permanently available via nipple drinkers.

The following data were collected:

- Health status (diarrhoea incidence etc.), losses and possible causes,
- Individual live body weight at the beginning and at the end of each trial,
- Individual feed intake by weighing the amount of feed offered at the beginning of the trial and the amount left at the end of the trial,
- Carcass characteristics of all rabbits of trials 1 and 2 at the end of the trial (DLG-Scheme; PETERSEN, 2004),
- Meat quality parameters for the back and the legs of all carcasses (trial 1).

The feed conversion ratio (kg feed per kg weight gain) was calculated from feed intake and live weight gain. The program STATISTIKA for WINDOWS (STATSOFT, INC., 2007) was used for the statistical evaluation of the trial results.

Results

No problems occurred in either trial. No signs of diarrhoea were determined in any of the animals. No losses occurred which is most likely due to the ideal housing conditions.

The data on fattening performance are shown in table 1. In trial 1 the animals of all 3 groups ate virtually the same amount of feed. In contrast to this, the two feed additives in trial 2 caused a higher intake of feed (by 5% group II, Toyocerin® respectively 7.5% group III, Cuxarom Spicemaster), which, however, is not statistically significant due to the considerable variance between animals in the same group. In both trials the probiotic and phytobiotic feed additives improved the growth of the animals, whereby the effect of Cuxarom Spicemaster (phytobiotic) was even stronger than that of Toyocerin® (probiotic).

Table 1: Feed intake, live weight gain and feed conversion ratio during the trialS

Trial	Group	Feed intake g/animal	Initial live weight g/animal	Final live weight g/animal	Weight gain g/animal	Feed conversion ratio kg feed/ kg gain
1	I (Control)	6906	1034	2807^{a}	1773^{a}	3.90^{a}
	II (ToyoCerin®)	6971	1067	2937^{ab}	1870^{ab}	3.73^{ab}
	III (Spicemaster)	6820	1071	2992^{b}	1921^{b}	3.55^{b}
2	I (Control)	5644	1927	3274^{a}	1347^{a}	4.19
	II (ToyoCerin®)	5918	1948	3413^{b}	1465^{b}	4.04
	III (Spicemaster)	6074	1938	3456^{b}	1518^{b}	4.00

Averages with different superscripts (a, b) differ significantly ($P<0.05$)

In trial 2 the effects of the feed additives were even more evident than in trial 1, although the animals were older at the beginning of the trial. The feed conversion ratio was reduced by both feed additives. With this parameter also, the phytogenic preparation demonstrated higher efficacy than the probiotic, and the reduction in the feed conversion ratio was slightly higher in trial 1 in comparison to trial 2. On the whole, however, the differences in this parameter between the control group (I) and trial groups (II, III) are not statistically significant.

The carcass weight as well as the weight of the valuable carcass parts increased as a result of both feed additives analogously to the increase in live weight at the end of the trial (see table 2). However, the differences in comparison to the control group are only significant in part. In contrast to this, the slaughter yield (%) and the percentage in carcass composition changed only slightly.

Table 2: Results of the carcass analysis

Trial	Group	Slaughter weight g/animal	Yield %1	Foreparts		Back		Thighs	
				g	%²	g	%²	g	%²
1	I (Control)	1573^{a}	56	447	28	603	38	522^{a}	33
	II (ToyoCerin)	1639^{ab}	56	477	29	602	37	569^{b}	35
	III (Spicemaster)	1717^{b}	57	507	30	638	37	572^{b}	33
2	I (Control)	1774^{a}	54	497	28	636^{a}	36	641	36
	II (ToyoCerin)	1886^{ab}	55	563	30	666^{a}	35	658	35
	III (Spicemaster)	1929^{b}	56	547	28	713^{b}	37	675	35

Averages with differing superscripts (a,b) show significant differences (P<0.05)
[1] based on the live weight (empty) [2] based on slaughter weight

The additives tested had no influence on the chemical composition of the back and thigh meat.

Discussion

In both trials ToyoCerin® improved growth and feed conversion ratio, although the results were only significant in part. As no digestive disorders could be determined and no losses occurred, it is not possible to make any statements on the influence of ToyoCerin® on the health status of the animals. Other experiments on young rabbits have been carried out over the last few years with the same probiotic preparation. The information on the influence on growth, feed conversion ratio and mortality is shown in table 3. The results obtained differ substantially, ranging from no effect to an improvement in performance similar to that achieved in our experiments. Only one study reports a considerable decrease in the mortality rate (PASCUAL *et al.*, 2008). KRIEG and RODEHUTSCORD (2004) found no influence of ToyoCerin® on the level of animal losses nor on the share of animals showing symptoms of diarrhoea; they observed, however, that the average duration of the diarrhoea was clearly reduced. In a literature study by FALCAO-E-CUNHA *et al.* (2007) including a total of 20 experiments with various probiotic preparations, positive effects of probiotics on live weight gain, feed conversion ratio and mortality are predominant, but the effects differ substantially (weight gain increased by 1-13%, feed conversion ratio improved by 1-17%, and mortality was reduced by 2-17 percentage points).

In both trials the phytobiotic preparation Cuxarom Spicemaster considerably improved growth and feed conversion ratio, with the efficacy being slightly superior to the probiotic product ToyoCerin® which was tested at the same time. Only KRIEG and RODEHUTSCORD (2004) also tested this feed additive on rabbits (table 4); there was no positive effect on weight gain and feed conversion ratio (the differences in comparison to the control group were insignificant). Thyme oil, a component of

Table 3: Results reported in the literature with the probiotic ToyoCerin® on growing rabbits

Authors	Toyo-Cerin® Dose /kg feed	Trial condition	Differences compared to control group (in %)		Reduction in mortality % points
			Live weight gain	Feed conversion ratio	
ESTEVE-GARCIA *et al.* (2005)	0.2/0.5/ 1.0 g	Laboratory	+1 to +3	-2 to +4	Not specified
KRIEG and RODEHUTSCORD (2004)	0.1 g	Field study	+1	-4	Not specified
PASCUAL *et al.* (2008)	1.0 g	Laboratory	No effect	No effect	-6
TROCINO *et al.* (2005)	0.2/1.0 g	Field study	+4 to +5	-3 to +4	Not specified

Cuxarom Spicemaster (table 4), also demonstrated virtually no influence on the named parameters. However, both additives had a positive effect on the health status of the animals (fewer days with diarrhoea, less animal losses as a result of *E.coli*).

The trial results with further phytobiotic preparations (see table 4) vary significantly. The summary table shows results reaching from considerable effects to insignificant or no improvement in performance and even negative effects. GUGOLEK *et al.* (2006) report a considerable reduction in losses (from 13% to 7%) after supplementing the fattening feed with the phytogenic preparation DIAROAK (a mixture of Andrographis paniculata, Holarrhena antidysnteria, Punica granatum and Berberis aristata). In all other studies shown in table 4 – with the exception of the article by KRIEG and RODEHUTSCORD (2004) – no indication of improved health status of the animals after supplementing the feed with herbal preparations can be found.

The positive effects of both substances tested can also be observed from the slaughtering data. A comparison with the data in the literature, however, is not possible as virtually no appropriate data were collected at the end of the growth trials. Only JEROCH *et al.* (2009) report on numerically increased slaughter and carcass part weights as a result of the herbal feed additive Sangrovit®.

Conclusions

Both preparations showed positive effects under laboratory conditions. The results obtained for the probiotic preparation „ToyoCerin®" again confirm that probiotics can be used as a feed additive in growing rabbits as an alternative to feed antibiotics. In order to give a final evaluation on the phytogenic product "Cuxarom Spicemaster" further trials are needed, particularly trials carried out under field conditions. Laboratory trials generally do not provide any information on the effects on the health status of the animals.

Table 4: Results published with phytobiotic substances in growing rabbits

Authors	Preparation	Trial condition	Differences in comparison to the control group (%)	
			Live weight gain	Feed conversion ratio
CHRASTINOVA *et al.* (2005)	XTRACT (Essential oil extract of capsicum, cinnamaldehyde and oregano)	Institute	-5 to +12	-8 to +9
ERDELYI *et al.* (2008)	Essential oils of *Rosmarinus officinalis* and *Allium sativum*	Institute	+0.5 to +5.0	-4 to 10
GUGOLEK *et al.* (2006)	DIAROAK (mxiture of *Andrographis paniculata, Holarrhena antidysnteria, Punica granatum and Berberis aristata)*	Field study	+7	Not specified
JEROCH *et al.* (2009)	*Papaveraceae*-Preparation (contains sanguinarine and other alkaloids)	Laboratory	+2	0 to -2
		Field study	+1.0 to +3.5	No effect
KRIEG and RODEHUT-SCORD (2004)	Spicemaster	Field study	-2.5	+2.5
	Thyme oil		No effect	-1
SIMONOVA *et al.* (2008)	Dry extract of *Eleutherococcus sentiosus*	Laboratory	+20	-2
ZOCCARATO *et al.* (2008)	Castanea sativa extract	Laboratory	+9 to +10	-6

Summary

In 2 performance trials, each consisting of 3 groups of New Zealand white rabbits, the effects of the probiotic product ToyoCerin® (spores of B. cereus var. toyoi) and the phytobiotic product Cuxarom Spicemaster (brown algae mixed with the herbs and spices basil, fennel, garlic and cinnamon and essential oils of aniseed and thyme) were tested on the fattening performance and carcass characteristics of the animals. Each group comprised 9 (trial 1) or 11 (trial 2) animals, respectively, kept in single cages. In the 56-day trials (commencing after weaning at 30 days in trial 1 and at 8 weeks in trial 2) the growth of the animals and the feed conversion ratio improved considerably as a result of the two additives tested in comparison to the control groups. The additives also had a positive effect on the weight of the carcass and the parts thereof. However, not all effects of the preparations tested are statistically significant.

Zusammenfassung

In 2 Leistungsversuchen mit jeweils 3 Gruppen Mastkaninchen der Rasse Weiße Neuseeländer wurde die Wirksamkeit des probiotischen Präparates „ToyoCerin®“ (Sporen von B. cereus var. toyoi) und des phytobiotischen Präparates „Cuxarom Spicemaster“ (Mischung aus einer Braunalge mit den Kräutern Basilikum, Fenchel, Knoblauch und Zimt sowie den ätherischen Ölen von Anis und Thymian) auf Mastleistung und Schlachtkörpermerkmale geprüft. Jede Gruppe bestand aus 9 (Versuch 1) bzw. 11 Tieren (Versuch 2) in Einzelkäfighaltung. In den 56 Tage dauernden Versuchen (Beginn nach dem Absetzen mit 30 Tagen im Versuch 1 und mit 8 Wochen im Versuch 2) wurden im Vergleich zur Kontrollgruppe das Wachstum der Tiere und der Futteraufwand durch beide geprüften Zusätze

verbessert. Auf die Gewichte der Schlachtkörper und deren Teilstücke hatten die Zusätze gleichfalls einen positiven Effekt. Nicht alle leistungsverbessernden Wirkungen der Prüfpräparate sind jedoch signifikant.

Key words: rabbits, probiotics, phytobiotics, growth, feed conversion ratio, carcass composition

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Authors' Address:

Assoc. Prof. Dr. P. Matusevicius and Prof. Dr. Dr.h.c. Heinz Jeroch,
Lithuanian Veterinary Academy
Tilzes g. 18, LT-47181 Kaunas, Lithuania
E-mail: paulmat@lva.lt

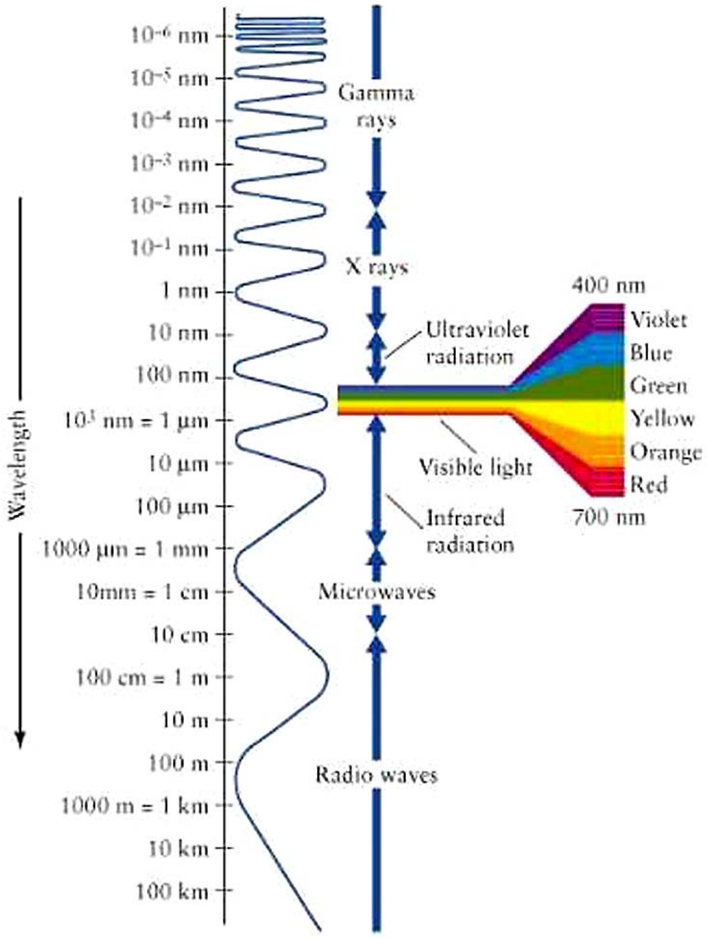
Light Stimulation of Commercial Layers

Hans-Heinrich Thiele,
Lohmann Tierzucht GmbH, Cuxhaven, Germany

Light and the Light Perception of Birds

Light is the visible part of the electromagnetic radiation. It plays an important role for the life of many organisms on earth. Light is perceived by them in different ways.

Figure 1: Wavelength Image

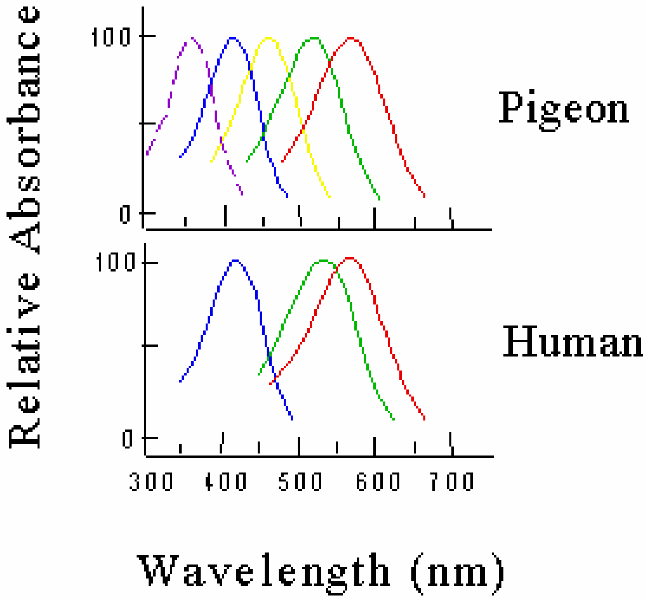


(Wavelength image from *Universe* by Freedman and Kaufmann.)

Source: http://eosweb.larc.nasa.gov/EDDOCS/Wavelengths_for_Colors.html

Most vertebrates perceive light via the eye. Light enters the eye and it is projected onto a light-sensitive panel of cells, the retina. So-called cone and rod cells in the retina detect and convert light into neural signals for vision. The visual signals are then transmitted to the brain via the optic nerve and influence the behavior and the sexual activity of the birds. Furthermore the pineal gland and the hypothalamus have some photoreceptors. Their stimulation influences the bird's life as well. The visual system of birds differs from that of mammals and humans. Birds have perfected the already highly developed visual acuity of their reptilian ancestors. Their visual perception of the environment is different and much sharper than ours. Because of their flying ability and their natural food sources birds are highly vision-dependent creatures with anatomical and physiological features which differ from humans. These include in particular the ability to distinguish longer visual sequences of up to 150-250 individual images per second (humans can only see up to 25-30 individual images per second) and their tetrachromatic color vision (trichromatic in man). The latter is made possible by the presence of superior photoreceptors on the avian retina compared with primates, enabling birds to see colors in a spectral range of 360-400 and 600-700 nanometer wavelengths. Birds can see within a UV range that is not visible to humans. These characteristics have to be taken into consideration in the selection of artificial light sources and the design of lighting programs for pullets and laying hens.

Figure 2: Photopigment absorption spectra for a bird (Columba liva) and a primate (homo sapiens) - Adapted from Bowmaker (1991)

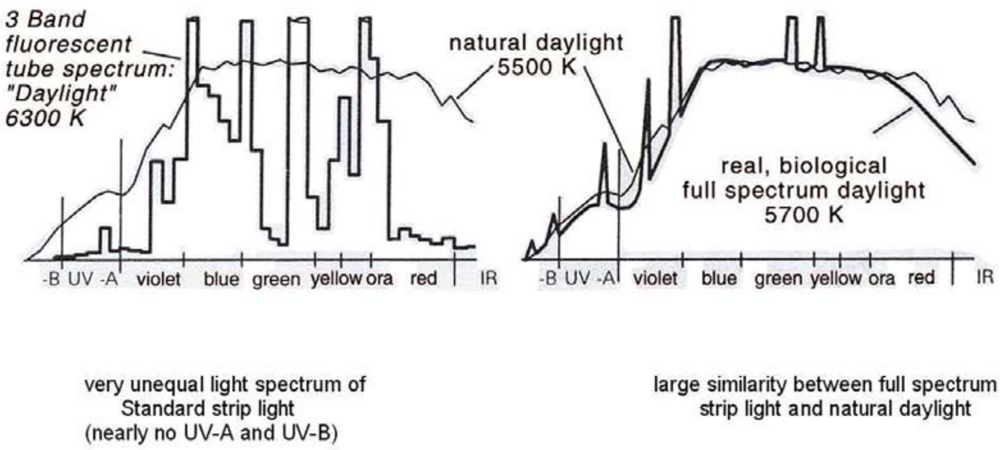


Source: http://www.pigeon.psy.tufts.edu/avc/husband/figure1.htm

Light Sources and Light Quality

Artificial light sources used in rearing facilities for pullets and laying houses include incandescent lamps, tubular fluorescent lamps and more recently energy-saving lamps. Modern, low-cost LED (light emitting diodes) technology is set to become more widespread in the future, especially if they will be further developed to emit a brighter spectrum of light. High frequency light technology, which generates light approximating the natural spectral range ("true light" technology) is already in use in some poultry operations.

Figure : 3. Standard and Full Spectrum Strip Light



Source: Warnking Elektrotechnik GmbH, (2002) In order to prevent stress-induced behavioral abnormalities, the light intensity in light-proof pullet and layer housing is restricted for commercial reasons to about 5 Lux (rearing) and about 10 to 15 Lux (production) when the hens reach four weeks of age.

The light frequency depends on the light source. Fluorescent tubes and energy-saving lamps operating in the low frequency range (50 Hz alternating current) are considered unsuitable for fowl. Because of their sharp vision, hens perceive the flicker of the light, which can have adverse effects on their behaviour (nervousness, feather pecking and cannibalism). Preference should therefore be given to incandescent lamps whose flicker, despite the 50 Hz frequency of the alternating current, is not perceived because of their slowness, or to fluorescent tubes operating at high frequencies (>2000 Hz). Since incandescent lamps cannot convert electrical power to light as efficiently as other types of lamps, they will soon be banned in most developed countries of the world.

Whereas in the past the choice of light source was determined solely by commercial considerations and by the efficiency of the light source (light intensity), more recently the spectrum and frequency of the light emitted by the lamps have also been taken into account. Systems restricting the light in poultry houses to specific colors (spectral ranges) through the use of filters are currently under consideration. The blue, green and red spectrums are believed to exert different effects on the hens. But even without the color restriction virtually all contemporary artificial light sources cover only a portion of the spectral range that is visible to birds. Natural daylight has a frequency of up to 1015 Hz and if there is sunshine an intensity of more than 100.000 Lux. If hens are kept in barns with windows or roam in covered outdoor enclosures and range areas in natural daylight, there is obviously a vast difference between the quality of the artificial and the natural light, which can be perceived by the hens.

Conventional lamps do not cover the UV range (under 350 nm wavelength), although this range seems to be important for certain stimuli, for example those involved in the search for food and the mating behaviour of birds

To summarize, the artificial light produced in poultry houses by conventional light sources is very different in quality from natural light. Pullets reared in light-proof barns and later exposed to natural daylight perceive their surroundings differently after the transfer and may suffer stress as a result.

Lighting Programs

The lighting program (day length and light intensity) to which a flock of laying hens is subjected during the growing and production phase is a key factor in determining the onset of sexual maturity and egg production. Lighting programs for pullets kept in windowless barns can de designed so as to guarantee optimal growth and efficient preparation for the laying period, largely independent of the season.

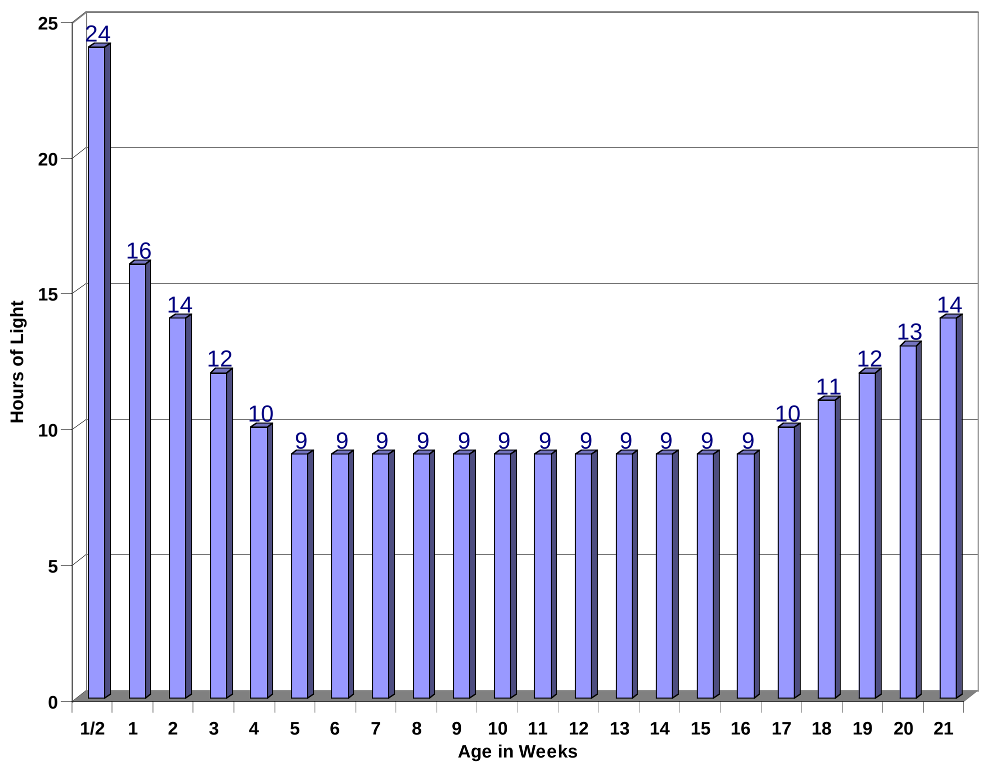
The “golden rule” to follow in designing lighting programs for pullets is that they should never experience an increase in day length until the planned light stimulation starts and never experience a decrease in day length during the production cycle. Following this principle, the day length is gradually reduced after placement of the day-old chicks in the rearing farm; after the minimum is reached, a phase of constant day length follows; and finally light hours are gradually increased to stimulate the onset of lay.

The so-called “step down” procedure in the early days of the chick’s life can be used to make the pullets more sensitive to light. After reaching 10 to 8 hours per day, the birds are kept on constant day length for some weeks. The length of the day during this constant period determines the step-down and the following step-up program, it is of minor importance for the pullets’ sensitiveness to light. The more time the birds have during this constant phase, the more they will eat and grow. In situations where farmers have difficulties to achieve the target body-weights, a longer constant day can help to improve pullet quality. Any step-up procedure or increase in day length when birds get to an age of 14 to 15 weeks will stimulate sexual maturation. A quick step-up will induce an earlier onset of egg production, while a slow step-up will delay the onset of lay. The combination of quick step-down and quick step-up lighting is most effective for achieving early onset of lay; slow step-down and slow step-up will delay it. Many scientific trials and practical experience with different strains of layers have confirmed that number of eggs and egg weight can easily be influenced utilising this tool. If a producer wants early egg production, high total egg number and a moderate egg weight, he should use the quick step-down / step-up variant. To get fewer, but larger eggs, a slow step-down / step-up variant should be chosen.

Parent flocks should never be exposed to the quick step-up / step-down program, because small eggs at the beginning of the laying period cannot be used as hatching eggs and therefore undesirable.

Our experience shows that day length should first be increased in the afternoon hours, followed by further increments in the morning hours. This can be done in steps of 30 or 60 minutes as shown in the lighting program for Lohmann Brown layers. Sometimes modern layer hybrids, even if not selected for low feed intake / appetite like the Lohmann strains, have difficulties to consume enough feed shortly before and during the onset of lay. Increasing the day length by two hours initial step-up will not only push them more quickly into lay, but also offers two additional hours to eat. This can be taken into consideration when designing lighting programs for special flocks or housing conditions.

Figure 4: Standard Lighting Program for Lohmann Brown Commercials

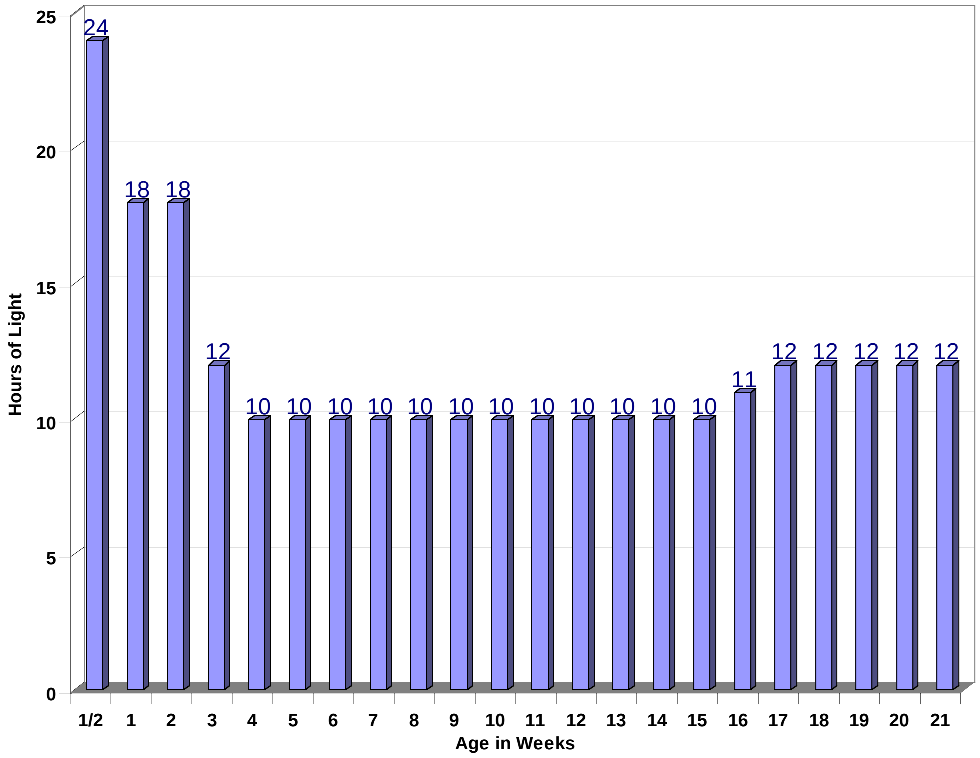


Soucre: Layer Management Guide Lohmann Brown Classic (2008)

After stimulating flocks properly into lay, there is no need to prolong the day beyond 14 hours day length. Depending on the length of the day during the constant period, even 12 hours are sufficient for top egg production as shown in figures 5 and 6.

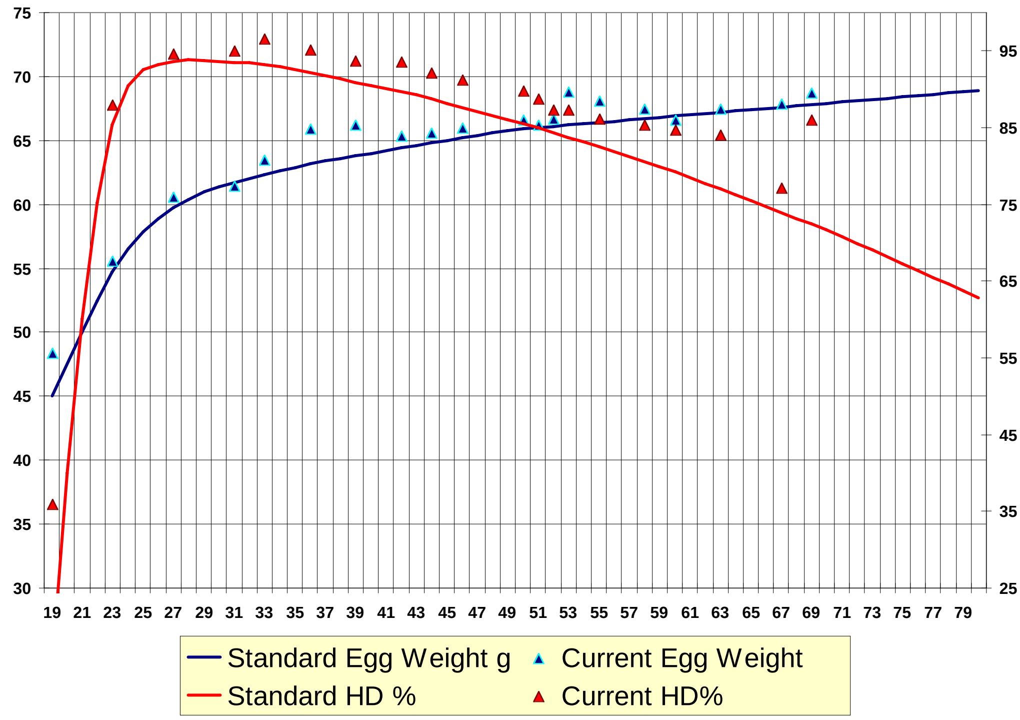
In this case, due to a lower activity, the hens have lower nutrient requirements for body maintenance and will consume less feed per day. A reduction of daily feed intake can also be achieved with so-called "block lighting" programs. After birds come into full production, some egg producers take away parts of the light day. This must be done properly to make sure it does not limit the nutrient intake necessary for egg production. As long as this program is asymmetric, the birds are not disturbed in their circadian rhythm and egg laying times are not influenced. This management tool should only be used by experienced farmers in dark house cage production. It has to be used in accordance with poultry welfare regulations in each country.

Figure 5: Adjusted Lighting Program for Lohmann Brown Classic - German Egg Producer



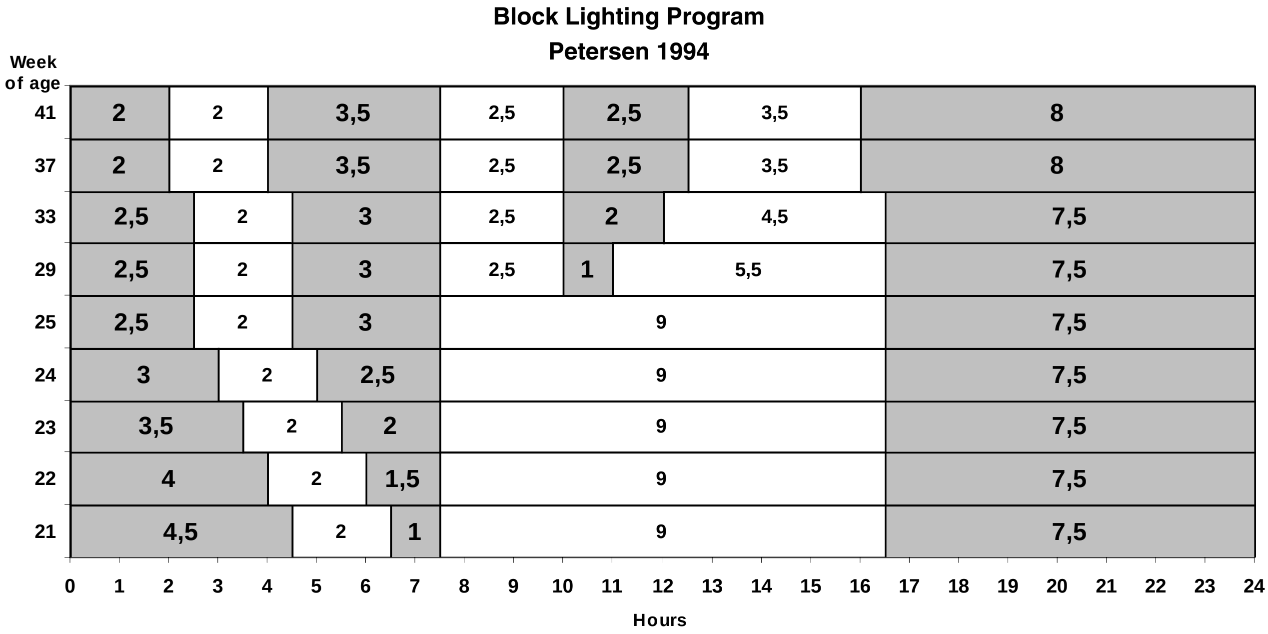
Source: Grote, A. (2002)

Figure 6: Performance of about 5 Million Lohmann Brown Classic Layers (Average of different farms in November 2001):



Source: Grote, A. (2002)

Figure 7: Asymmetric Intermittent Lighting Program (Petersen, 1994)



Source: Budde et al. (2001)

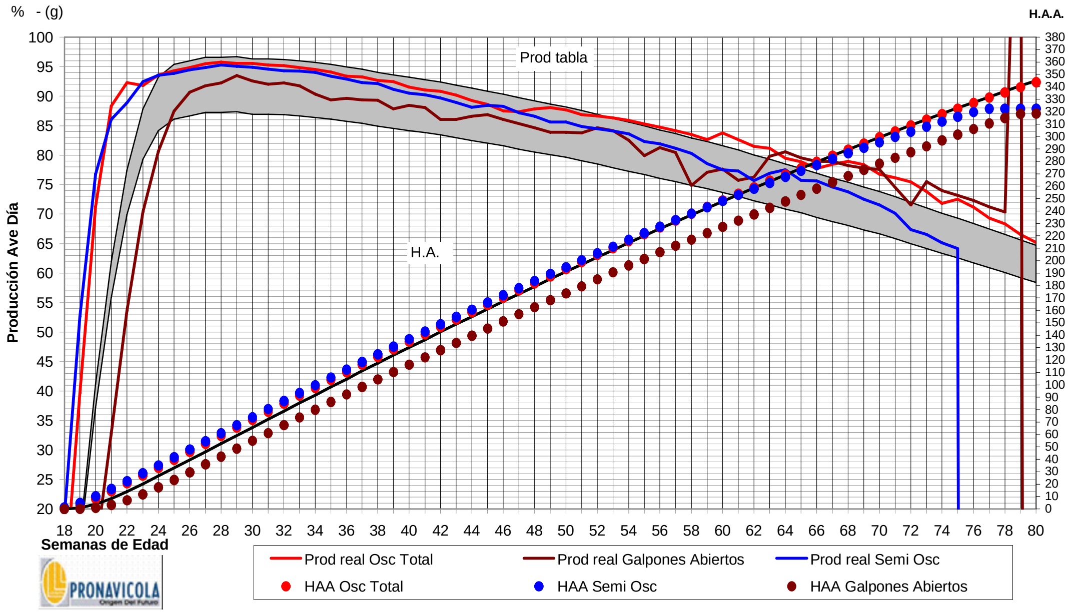
Open Houses

A controlled photo-stimulation of hens should not be abandoned as a management tool in houses with windows. The rearing unit should either be dark-out or the windows should have a facility for blocking out daylight to maintain the lighting program. Shutters can be synchronised with the lighting program and must be seen as very valuable tools.

Even under open house conditions, a “darkening program” can improve the performance of flocks significantly. Lohmann Brown layers, for example, reared in an open pullet barn in Colombia (12 hours day light throughout the year) which was darkened to 8 hours day length, came into production two weeks earlier after transfer to an open layer house and produced 20 eggs more than a control group without the “darkening procedure”.

Figure 8: Darkening an Open Pullet Barn (source: Arranguren, 2002)

Figure 9: Comparison of Lohmann Brown flocks reared with and without the darkening procedure (Armel, 2008)



If the hens are placed in open houses or if they have access to a winter-garden or free range, or if windows, ventilation shafts and other openings cannot be light-proofed to keep out natural daylight, this needs to be taken into account when designing the lighting program. In central Europe the natural day length increases in the course of the calendar year to about 17 hours by the end of June and then decreases to about 8 hours by the end of December. If flocks are moved to production facilities whose windows cannot be blacked-out or where natural light can seep through ventilation shafts („extraneous light"), or if winter-gardens or range areas are accessible to the hens at all times, the lighting program must be adjusted to match the natural day length at the time the flock is moved and must be kept constant throughout the rearing phase. It is important to distinguish between pullets from a light-proof growing facility or pullets reared with blacked-out windows (with proper lighting program) and pullets fully exposed to natural daylight throughout the growing period. When pullets unaware of the natural day length during the growing period (light-proof barn or windows that can be blacked-out) are moved to open laying houses it is essential to prevent stress due to excessive light stimulation by an abrupt lengthening of the day. Light hours should not be increased by more than 2-3 hours. This means that day length should not be reduced to 8 or 9 hours during the rearing of such flocks (see Figure 10).

If the natural day is about 14 hours at transfer (17 weeks of age), a reduction to 12 or 11 hours daylight is appropriate. In the case of hens reared in open housing (see Figure 11) premature stimulation of the pullets can only be prevented if the natural day length at the time of the proposed light stimulation of the flock is taken into account when planning the stepwise reduction of light hours in the early growing period. In the example shown, this would be about 14 hours at 17 weeks of age. In open housing the lighting program during the spring and summer months is determined by the increasing natural day length, which peaks at about 17 hours daylight in Germany. When the natural day shortens from July onwards, the 17-hour day length should be kept constant until the end of the laying period.

Figure 10: Adjusted Lighting Program – Berlin / Hatch December / Dark House Rearing and open House Production

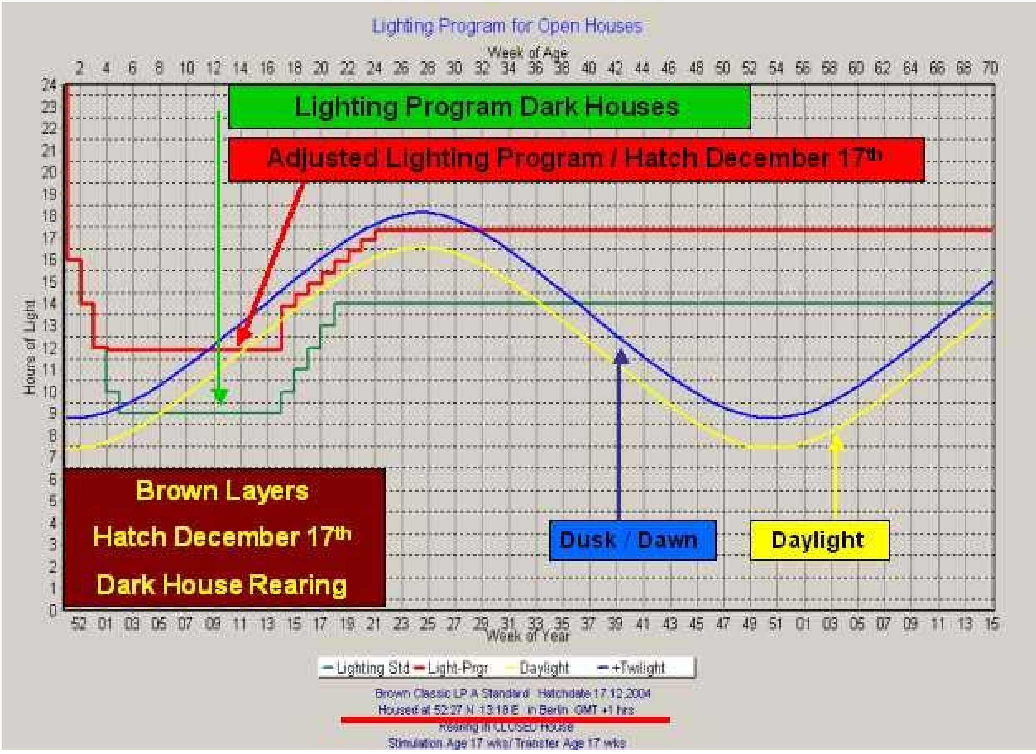
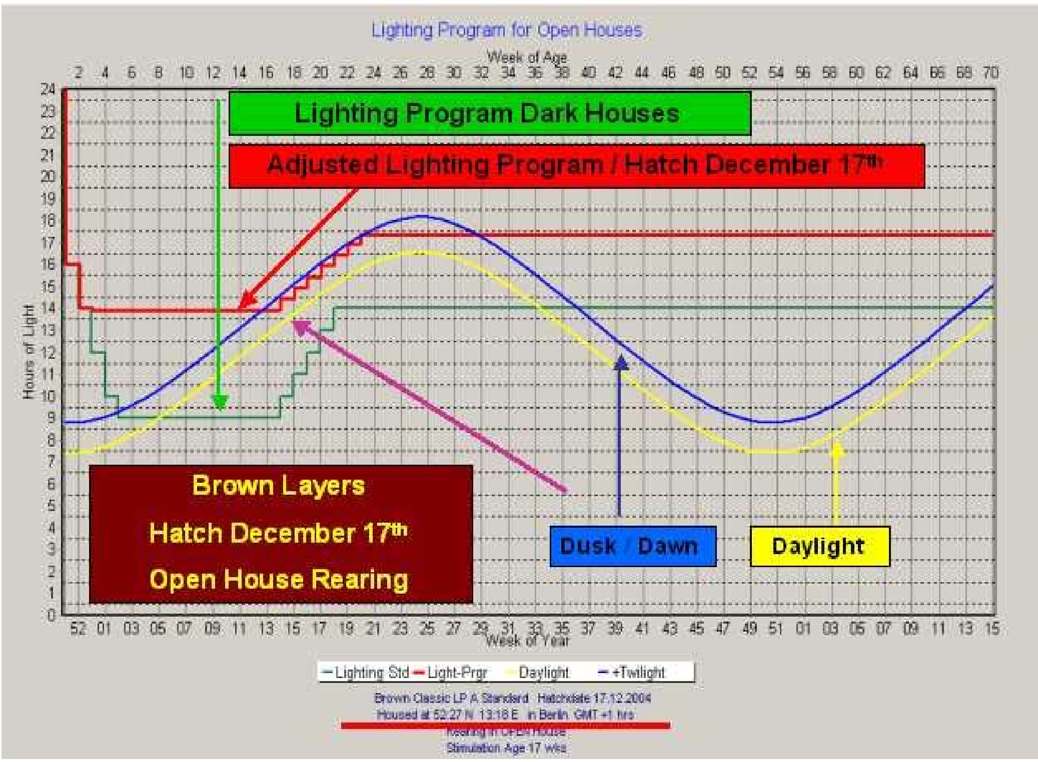


Figure 11: Adjusted Lighting Program - Berlin / Hatch December / Open House Rearing and open House Production



Summary and Conclusion

Birds can see better than humans and are highly susceptible to light, but there is a paucity of scientific data on the visual ability of chickens. Recent research results and practical experience confirm that lighting programs adapted to specific conditions are a valuable tool in the management of laying hens. The main points are:

- Artificial light supplied by incandescent lamps operating in a frequency range at 50 Hz is perceived by hens as having a constant flicker. Incandescent or fluorescent light at high frequency, i.e. over 2000 Hz, is preferable for hens.
- Artificial light from conventional light sources, whether filtered or unfiltered, impairs the visual ability of commercial hens, thus limiting the spectrum that is visible to them.
- Hens reared under artificial light and transferred to natural daylight need time to adapt to the altered perception of their surroundings. The use of „true light" lamps during the growing period, which approximate the natural spectrum, can reduce this effect.
- Stimulation of hens in light-proof houses follows the simple principle of reducing day length until controlled light stimulation is applied and then increasing it. Reducing light hours during the laying period adversely affects egg production.
- Pullets should be reared in light-proof barns or the building should be adapted so that windows can be covered or uncovered according to the lighting program.
- So-called "darkening" of rearing facilities to limit the influence of changing natural day length in the constant period is effective in open house situations and should be used as an option to improve the light stimulation in hot climate countries.
- Open houses for laying hens should have facilities for light-proofing windows, wherever possible. The windows should either be covered and uncovered in step with the lighting program or blacked out completely until the maximum day length is reached.
- Lighting programs for pullets transferred to open barns without the possibility to black- out windows should be adjusted to the hatch date of the flock. To avoid a „light shock" at transfer when the days are very long, the step-down during rearing should be modified so that the increase at transfer is no more than two or three hours.
- Pullets reared in barns that cannot be light-proofed are influenced by the length of the natural day, especially in the spring and summer months. Premature onset of lay can only be avoided by properly adjusting lighting programs, but light stimulation of such hens is difficult and their production often fails to meet standards.

Zusammenfassung

Lichtstimulierung von Legehennen

Vögel sehen besser als wir Menschen und sind stark visuell abhängige Lebewesen. Wissenschaftliche Erkenntnisse zum Sehvermögen der Hühnervögel sind rar. Einige Ergebnisse jüngerer Forschungsarbeiten und praktische Erfahrungen sollten bei der Haltung von Legehennen jedoch unbedingt berücksichtigt werden:

- Künstliches Licht aus Leuchtstofflampen, die im Frequenzbereich von 50 Hz arbeiten, flackert aus Sicht unserer Hennen ständig. Günstiger für die Tiere sind entweder Glühlampen oder Leuchtstoffröhren, die mit Hochfrequenz, das heißt über 2000 Hz arbeiten.
- Künstliches gefiltertes aber auch schon das nicht gefilterte Licht aus herkömmlichen Lichtquellen schränkt das Sehvermögen unserer Hennen ein. Das von ihnen erkennbare Lichtspektrum wird dadurch begrenzt.

- Bei künstlichem Licht aufgezogene, in Ställe mit natürlichem Tageslichteinfluss umgestallte Hennen, müssen sich erst an die veränderte Wahrnehmung ihrer Umwelt anpassen. Die Verwendung sogenannter „True Light" Lampen in der Aufzucht von Junghennen, die fast dem natürlichen Lichtspektrum entsprechen, kann diesen Effekt verringern.
- Die Stimulation der Hennen in Dunkelställen erfolgt nach dem einfachen Prinzip, den Lichttag bis zur gezielten Stimulation der Hennen zu verkürzen, um ihn dann zu verlängern. Eine Verkürzung des Lichttages während der Legeperiode wirkt sich negativ auf die Legerate aus.
- Die Aufzucht von Junghennen sollte in abgedunkelten Ställen erfolgen oder die Ställe sind so einzurichten, dass vorhandene Fenster mit dem Beleuchtungsprogramm synchronisiert geöffnet und verschlossen werden.
- Sogenannte „Verdunkelungsprogramme" limitieren den Einfluss der sich natürlich verändernden Tageslänge in offenen Häusern und können zur Verbesserung der Licht Stimulierung in tropischen Ländern eingesetzt werden.
- Wenn technisch möglich, sollten „offene" Ställe für Legehennen auch über Einrichtungen zum Verschließen der Fenster verfügen. Diese können dann entweder ebenfalls synchron zum Beleuchtungsprogramm geöffnet und verschlossen werden oder bis zu Erreichen der maximalen Tageslänge (entsprechend Beleuchtungsprogramm) gänzlich verschlossen bleiben.
- Für Junghennen, die in „offene" Ställe umgestallt werden, deren Fenster nicht verschlossen werden können, bietet sich die Gestaltung von Beleuchtungsprogramme an, die auf den Schlupfzeitpunkt der Herde abgestimmt sind. Zur Vermeidung eines „Lichtschocks" bei Umstallung zum Zeitpunkt sehr langer Tage (Frühjahr und Sommer), ist dabei die minimale Tageslichtlänge (Step Down) während der Aufzucht so zu variieren, dass die Hennen bei der Umstallung nur einer Tageslichtverlängerung von zwei, maximal drei Stunden ausgesetzt werden.
- Junghennen, die in Ställen aufgezogen werden, die nicht verdunkelt werden können, werden insbesondere in den Frühjahrs- und Sommermonaten von der Länge des natürlichen Lichttages beeinflusst. Frühreife Junghennen sind nur durch angepasste Beleuchtungsprogramme zu verhindern. Eine wirksame Stimulation solcher Hennen mit Beleuchtungsprogrammen ist jedoch nur begrenzt möglich. Das Leistungsniveau dieser Herden bleibt oft hinter den Erwartungen zurück.

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Author's Address

Dr. H.-H. Thiele
Lohmann Tierzucht GmbH
Am Seedeich 9-11
27454 Cuxhaven, Germany

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Lighting for broiler and turkey breeders

Peter Lewis
University of KwaZulu-Natal, South Africa

Photorefractoriness

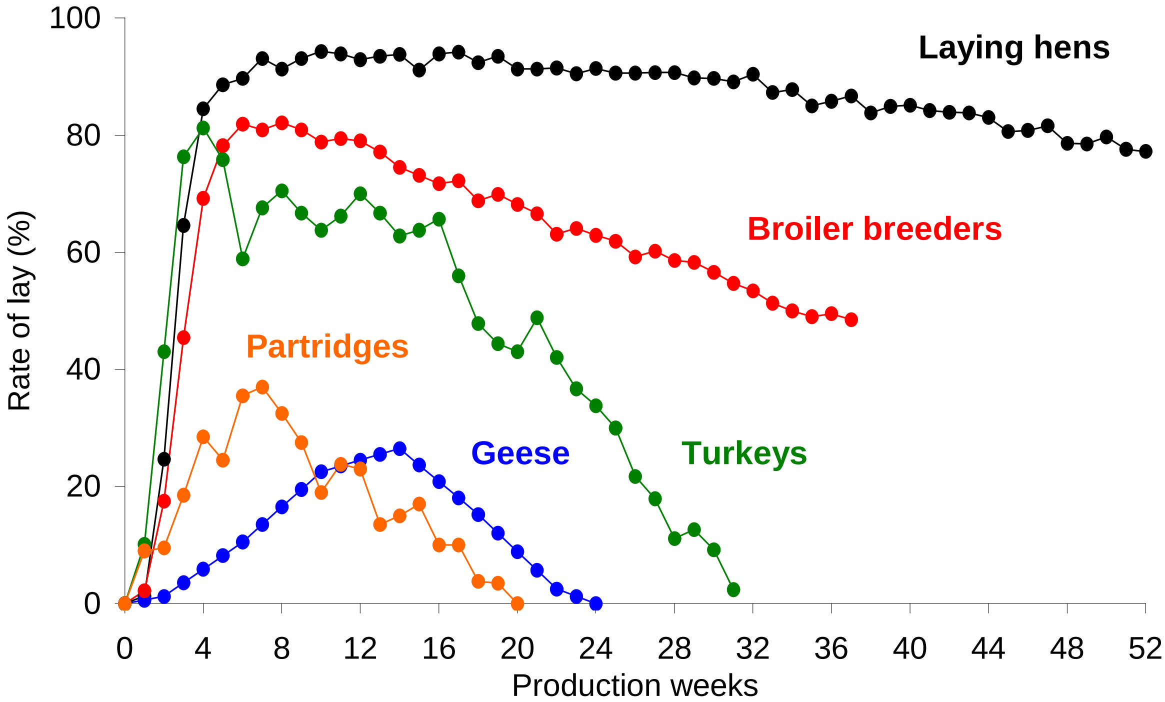
Photorefractoriness is a natural physiological condition that differentiates broiler breeders and turkey breeders from egg-type breeders and commercial layers, particularly regarding their response to lighting. It is a phenomenon which needs to be understood before lighting patterns can be correctly designed for either broiler or turkey breeders. The condition has long been recognised in turkeys but has only recently been acknowledged in broiler breeders and, as a result, broiler breeder lighting recommendations have frequently been incorrect. It is worth noting that egg-laying hybrids no longer exhibited photorefractoriness and therefore have fewer constraints imposed on their lighting requirements.

What is photorefractoriness? It is a long word that simply means the inability to respond to light, but more specifically the lack of a sexual response to an otherwise stimulatory daylength. All seasonal-breeding birds are hatched in a refractory state, termed juvenile photorefractoriness, which generally prevents them from breeding in their first year. The condition is dissipated in full-fed birds by exposure to about two months of short days; these are daylengths which are neutral in their ability to sexually stimulate an animal (note they are not negative) and are usually no longer than 9 hours. Birds, such as broiler breeders, that have their growth controlled by the feeding programme take longer to become photoresponsive. In nature, dissipation of photorefractoriness is achieved by the short days of winter, which allows the bird to commence breeding in the following spring. However, after prolonged exposure to stimulatory daylengths during the summer months, the birds again become unresponsive to light, a condition called adult photorefractoriness, and generally go out of production until they have gone through a second period of short days.

There are two forms of photorefractoriness: an absolute form, as seen in truly seasonal breeding birds like pheasants, partridges and geese, and a relative form, as exhibited by broiler and turkey breeders. In the absolute form, sexual development is severely retarded when birds are reared from hatch on long days, with some individuals never becoming sexually mature. For example, in a study in which red-legged partridge were reared from hatch on 16-hour days, the first bird did not lay its first egg until it was 68 weeks of age and 3 years later more than 60% of the birds were still infertile. In contrast, birds like broiler breeders and turkey breeders which show the relative form are only moderately (2 to 4 weeks) retarded by not being given a period of short days. Interestingly, the intense selection for egg numbers over the past 50 years has resulted in modern egg-laying hybrids no longer showing photorefractoriness. Whereas rates of lay in broiler breeders will typically be below 50% by 60 weeks of age (after about 36 weeks production) and egg laying in turkeys likely to have almost ceased after only 30 weeks, egg production in a flock of commercial egg layers may well still exceed 80% after 52 weeks in lay. Typical rates of lay for poultry species exhibiting the various forms of photorefractoriness are shown in Figure 1.

Flocks of broiler breeders or breeding turkeys will contain birds in varying states of photorefractoriness, especially at the end of the breeding cycle, with some continuing to be sexually active throughout the laying season, some back in lay after having paused and spontaneously resumed egg production whilst still on long days, and others having become photorefractory and not recommencing production without experiencing a period of short days or low light intensity to dissipate the refractoriness. The effects of photorefractoriness on egg laying in females are self evident, but similar effects occur with semen production in males; nature would not design a system in which one sex was fertile while the other was infertile.

Figure 1. Typical rates of lay for laying hens (no photorefractoriness), broiler and turkey breeders (relative photorefractoriness), and geese and partridges (absolute photorefractoriness). Modified from Lewis (2009).



Broiler breeders

Rearing daylength and body weight influences

It is essential to rear broiler breeders from an early age on short days, usually 8 or 9 hours, to ensure that all birds in the flock have had their juvenile photorefractoriness dissipated by the time they are transferred to long days (≥ 11 hours) at about 20 weeks of age. When broiler breeders are reared in open-sided or inadequately light-proofed buildings, and it is not possible for them to be given short days, it is advisable to simply let them experience the naturally changing daylengths, be the photoperiods increasing or decreasing. They should NOT be reared on a daylength equal to the expected longest natural daylength, as frequently recommended in breeder management manuals, because this will unacceptably delay maturity and reduce egg numbers. This may be the correct recommendation for egg-type stock; precocity will not be a problem even when birds are reared on increasing daylengths during the rearing period. The data in Table 1 from a study at the University of KwaZulu-Natal show that there were no significant differences in age at 50% egg production between broiler breeders reared on increasing or decreasing daylengths and others maintained on 14 hours from day old through to 20 weeks. However, the constant 14-hour birds laid fewer eggs, had a smaller average egg weight, and produced a lower total egg output than the birds reared under simulated naturally-changing daylengths. If broiler breeders are reared on 8-hour days and photostimulated at about 20 weeks, as routinely recommended, their sexual maturity will be 3 to 4 weeks earlier and their egg numbers and total egg output higher than birds reared on long days (Table 2). The indisputable answer to poor light control during the rearing period is to lightproof the buildings and not to tinker with the lighting programme.

Table 1. Age at 50% egg production, egg numbers, average egg weight, and total egg output to 60 weeks for broiler breeders reared to 20 weeks of age on a simulated naturally increasing or decreasing daylength programme or maintained on 14-hour days. Data from a study at University of KwaZulu-Natal.

	Increasing from 10 to 14 hours	Decreasing from 14 to 10 hours	Constant 14 hours
Age at 50% egg production (days)	209	209	212
Eggs per bird to 60 weeks	150	150	141
Average egg weight (g)	70.0	69.8	68.9
Egg output (kg per bird)	10.49	10.42	9.68

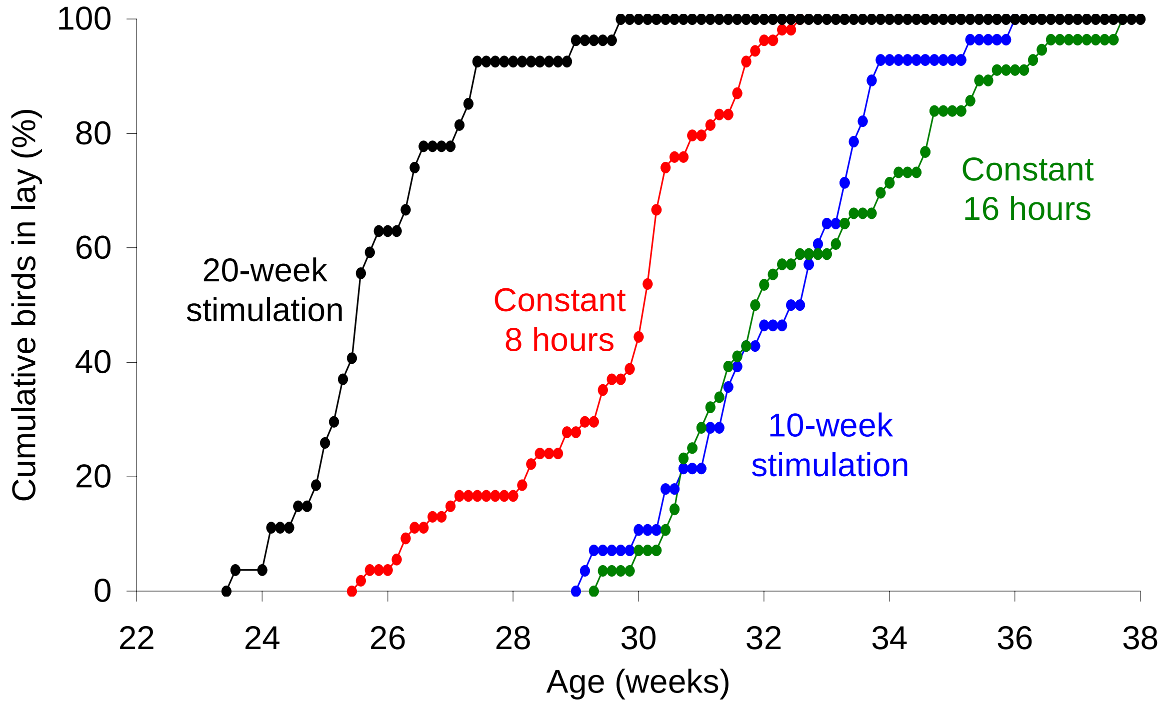
Table 2. Age at 50% egg production, egg numbers, average egg weight, and total egg output to 60 weeks for broiler breeders reared on 8-hour or 14-hour days and transferred to 16 hours at 20 weeks. Data from a University of study at KwaZulu-Natal.

	Rearing daylength	
	8 hours	14 hours
Age at 50% egg production (days)	180	206
Eggs per bird to 60 weeks	147	139
Average egg weight (g)	65.0	67.5
Egg output (kg per bird)	9.55	9.41

The significant reduction in growth achieved in broiler breeders by controlling their feed intake means that none will be responsive before 10 weeks of age and at least 18 or 19 weeks of short days will be required for all birds in the flock to become photoresponsive; a stark contrast to the two months required for full-fed photorefractory species to become photosensitive. Although the time taken for a flock of broiler breeders to complete the attainment of photosensitivity is much longer than the 5 to 9 weeks necessary for full-fed egg-type pullets, the commencement of photoresponsiveness in a flock and the point when all birds are able to respond occur at similar points on their growth curves (0.2 and 0.4 of mature body weight for the first and last birds to respond). If, for whatever reason, a flock of broiler breeders is underweight or uneven (CV more than 10%) when they would normally be transferred to long days, increases in daylength should be delayed by a week or so, depending on the size of the problem.

Photostimulation of a flock that contains under-weight, unresponsive birds will result in a marked delay in those particular birds' sexual maturation and the development of a sexually uneven flock which will be difficult to manage. Even when a flock has satisfactory uniformity (CV less than 10%), photostimulation should still not be contemplated before the average body weight has reached 2.0 kg. Transferring broiler breeders with normal body weights to long days before they have had sufficient short days to fully dissipate juvenile photorefractoriness will result in delayed sexual maturation and sub-optimal egg production. This is because the premature photostimulation will result in the birds maturing as if they have always been on long days (refer Table 2). Research findings show that broiler breeders transferred from 8 to 16 hours at 10 weeks of age, when they were still photorefractory, matured at a similar age to birds maintained on 16 hours but two weeks later than non-photostimulated birds maintained on 8 hours and 7 weeks later than birds transferred to 16 hours at the more usual 20 weeks (Figure 2).

Figure 2. Effect of no stimulation (constant 8 hours), normal stimulation (20-week transfer from 8 to 16 hours), premature stimulation (10-week transfer from 8 to 16 hours), no short days (constant 16 hours) on sexual maturation in broiler breeders. Data from a study at University of KwaZulu-Natal.

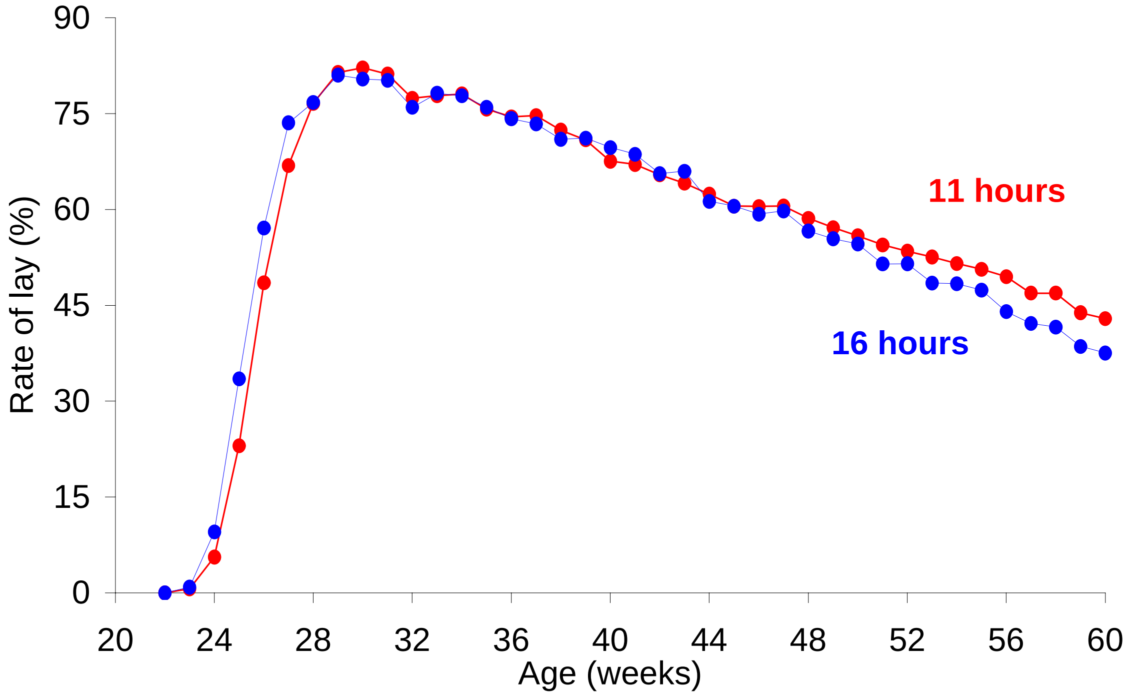


Although accelerating body weight gain in broiler breeders above normal breeder-targets of 2.0 to 2.2 kg speeds up the dissipation of photorefractoriness and enables them to be transferred to long days before 20 weeks, thus advancing sexual maturation and extending the laying cycle, the extra income derived from the increased egg numbers will invariably be cancelled out by the extra feed costs incurred in producing the faster growth and the increased production of un-settable, double-yolked eggs (Lewis, 2006).

Daylength during lay

It has been traditional to give broiler breeders an initial transfer from 8 to 11 or 12 hours at 20 to 22 weeks followed by a series of increases to reach a maximum of 15 to 16 hours at about 27 weeks of age. However, recent research has shown that the onset of adult photo-refractoriness is advanced and rates of lay during the final three months of the laying cycle depressed when broiler breeders are provided with such long days. Studies conducted at the University of KwaZulu-Natal in South Africa have suggested that the ideal programme for broiler breeders, assuming body weights and uniformity are satisfactory, is to increase daylength from 8 to 13 hours at 20 weeks, either abruptly or incrementally, and to maintain this photoperiod for the remainder of the laying cycle. No benefits will be derived from giving further increases to 14, 15 or 16 hours, and shell quality will be depressed. Although 11 and 12 hours have been shown to give superior egg production to 16-hour days (Figure 3), egg-laying time occurs much earlier in the day under these daylengths and the increased proportion of eggs laid before the lights come on is likely to lead to an unacceptable number of eggs being laid outside the nest box. The risk of floor-laying is minimised by giving a 13-hour day.

Figure 3. Rates of lay for broiler breeders transferred abruptly from 8 hours to 11 or 16 hours at 20 weeks of age. Note the poorer terminal egg production for 16-hour birds. Data from a study at University of KwaZulu-Natal.



Light intensity (illuminance)

The effect of light intensity during the rearing period on subsequent laying performance is minimal. Following an initial 2-3 days of bright light, the provision of an illuminance of at least 10 lux will be optimal and ensure that sufficient light is available for the satisfactory inspection of birds (as commonly required by welfare regulations). Whilst there is no interaction between the light intensity used during the rearing period and that given in lay, and there is no effect of light intensity on the rate of sexual development or total egg production so long as the light intensity at bird-head height is at least 10 to 15 lux, the recommended light intensity in the laying period is > 30 lux. This brighter-than-necessary recommendation is not made for biological reasons but to help minimise the number of eggs not laid in a nest box.

Light colour and lamp type

There is no clear evidence that the performance of broiler breeders will be increased by using other than white light, that ultraviolet light provides any benefit, or that any one particular type of lamp is superior to any other. Whilst fluorescent lamps are currently the most economic method of lighting, LED lamps will undoubtedly be the method of the future.

Conclusions

- Unlike egg-type hybrids, broiler breeders exhibit photorefractoriness.
- Restricting growth to a 2.0 to 2.1 kg average body weight at 20 weeks delays the acquisition of photosensitivity until at least 18 or 19 weeks of age.

- Rear on 8-hour daylengths to quickly dissipate juvenile photorefractoriness.
- Do not maintain birds on constant long daylengths during the rearing period in open-sided houses; simply accept the naturally changing daylengths.
- Photostimulate at 20 to 21 weeks and at a mean body weight of 2.0 to 2.2 kg provided the CV is no higher than 10%. Delay photostimulation if the CV is above 10%.
- Increase daylength from 8 to 13 hours abruptly or initially to 11 hours followed by weekly increments of 30 minutes to a 13-hour maximum.
- Maintain 13 hours throughout the laying period; longer daylengths will result in an earlier onset of adult photorefractoriness, poorer terminal rates of lay, and inferior shell quality.
- Use a light intensity of at least 10 lux in the rearing period and at least 30 lux in the laying period (to minimise floor eggs).

Turkey breeders

Daylength

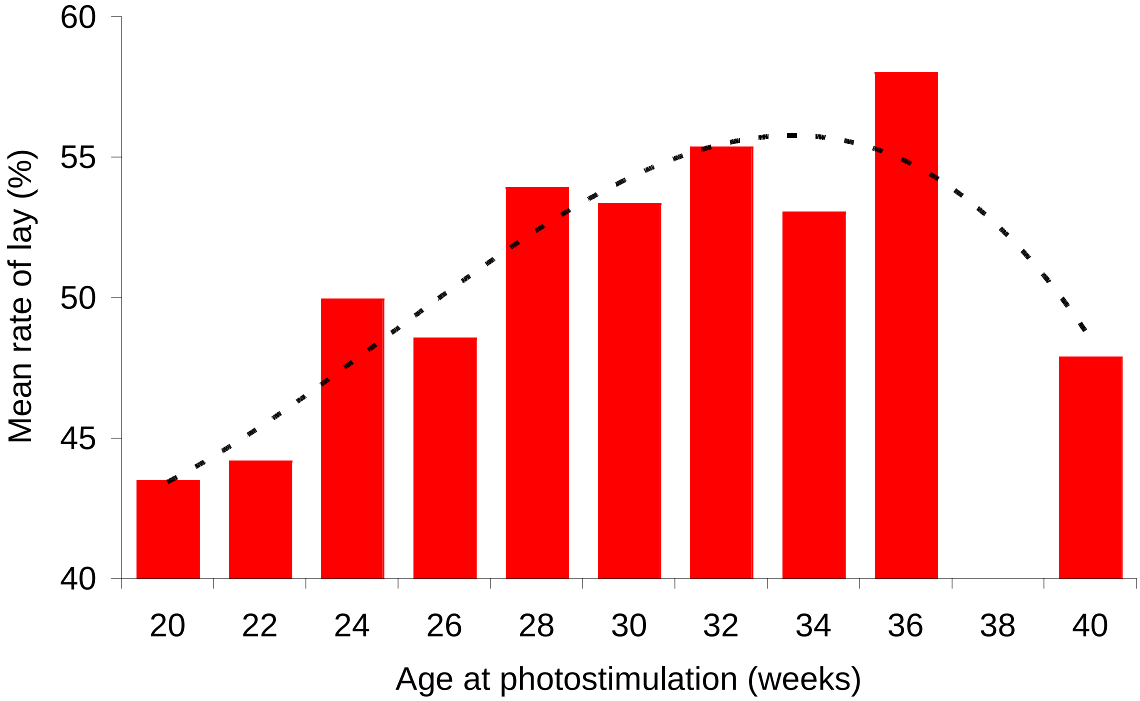
Turkey breeders are not normally control-fed during the rearing period and so, unlike broiler breeders, require only two to three months of short days to dissipate juvenile photorefractoriness. However, because the optimal economical age for the start of egg-laying is 32 to 34 weeks of age (Figure 4), turkey breeders must either be reared on naturally long days or given 14-hour artificial daylengths for the first 3 months of life to slow down their acquisition of photosensitivity; without this period of long days they will commence egg-laying too soon. After the initial natural lighting or artificial long days, it is typical for the daylength of females to be progressively reduced to 6 hours by about 18 weeks and to be maintained at this length until it is increased to 14 hours between 30 and 32 weeks of age. The transfer to long days is made abruptly to ensure a uniform rate of sexual development and the facilitation of timely artificial insemination. Accordingly, the period between photostimulation and peak rate of lay in turkeys is shorter than in either laying hens or broiler breeders (see Figure 1). Although egg production is maximised, as in broiler breeders, by a 13-hour day, many turkeys are kept in poorly light-proofed buildings and longer daylengths should be provided to minimise the effects of decreasing natural daylengths after mid-summer.

Turkey males are also given a pre-breeding period of short days, but these are usually longer than those given to females, such as 10 to 12 hours. However, there appears to be no biological reason for them not being given the same daylength as females. It is probably a case of continuing to do what has always been done, because males were traditionally reared in open-sided pole barns. Males are generally slower maturing than females, so they are transferred to 14-hour days 4 to 6 weeks earlier than the females to synchronise sexual maturation.

Light intensity (illuminance)

It has been conventional to rear turkey breeders on a relatively bright light of 50 to 60 lux during the pre-breeding period to provide an intensity contrast between the desired 6-hour daylength and any natural light that may be infiltrating a poorly light-proofed building. However, the correct course of action is to make the rearing facilities lightproof during this period and not to hope that the turkeys will ignore the extraneous light; any unwanted light during the 18-hour ‘night’ is likely to have a detrimental effect on subsequent egg numbers. If the brighter light intensity is provided to stimulate activity during the short day, then this must be in addition to the provision of adequate light-proofing. Whereas a 50 to 60 lux light intensity at bird-head height in the breeding period is sufficient to maximise egg numbers, separately-housed males are usually kept at a lower intensity of 20 to 30 lux to control aggressive behaviour.

Figure 4. Effect of age at photostimulation on egg production in breeding turkeys (Lewis and Morris, 2006).



Light colour and lamp type

As is the case for broiler breeders, there is no unequivocal evidence to suggest that the performance of turkey breeders will be improved by using other than white light, that UV light provides any reproductive benefit, or that any particular type of lamp is better than any other. White compact fluorescent lamps currently appear to be the most economic option, but LED lighting is likely to be the selected type in future. It should be noted, however, that supplemental UV may be useful for controlling agonistic behaviour when producing commercial male turkeys.

Conclusions

- Turkey breeders exhibit photorefractoriness.
- An initial 3 months of natural light or 14-hour artificial daylengths are necessary to delay photosensitivity.
- Provide a two to three month pre-breeding period of short daylengths to dissipate juvenile photorefractoriness. Light-proofing is essential during this phase.
- Abruptly increase daylength to 14 hours at about 24 weeks for males and at about 30 weeks for females to synchronise maturity.
- Maintain 14 hours throughout the laying period in light-tight buildings; longer daylengths will be required where houses are not light-tight.
- Use a light intensity of at least 50 lux in female housing during the laying period to maximise egg production, and 20 to 30 lux to minimise aggression in male housing.

Zusammenfassung

Beleuchtungsprogramme für Elterntiere von Masthühnern und Puten

Wer sich mit der Optimierung von Lichtprogrammen für Mastelterntiere und Puten beschäftigt, sollte zunächst wissen, dass diese – im Gegensatz zu Legelinien – nur bedingt auf Veränderungen der Tageslänge regieren. Wer im Internet-Wörterbuch eine deutsche Übersetzung für ‚photorefractoriness' sucht, findet ‚keine Ergebnisse' oder bestenfalls ‚Renitenz'. Gemeint ist die Unfähigkeit, auf Lichtreize zu reagieren, in diesem Fall Auslösung der Geschlechtsreife durch zunehmende Tageslänge.

Broilerelterntiere, die mit kontrollierter Fütterung aufgezogen werden, brauchen länger, um auf zunehmende Tageslänge zu reagieren. Wenn die Fütterung auf 2,0 – 2,1 kg Körpergewicht im Alter von 20 Wochen ausgerichtet ist, reagieren die Tiere erst ab ca. 19 Wochen auf eine Steigerung der Tageslänge. Empfohlen wird eine schnelle Absenkung der Tageslänge während der Aufzucht auf 8 Stunden und eine schnelle Steigerung auf 13 Stunden mit 20 Wochen bei einem Gewicht von 2,0-2,2 kg. Die Lichtintensität sollte während der Aufzucht höchstens 10 lux, während der Legeperiode mindestens 30 lux betragen.

Elterntiere von Mastputen werden ohne Futterrestriktion aufgezogen. Empfohlen wird eine Beleuchtungsdauer von 14 Stunden während der ersten 3 Monate, danach eine Phase mit kurzer Tageslänge bis zum Beginn der Lichtstimulation. Zur Synchronisation der Geschlechtsreife sollten Puter bereits mit 24 Wochen, Puten erst mit 30 Wochen auf 14 Stunden Licht umgestellt werden. Zur Maximierung der Legeleistung wird für Puten eine Lichtintensität von mindestens 50 lux empfohlen, für Puter dagegen höchstens 20-30 lux zur Minimierung aggressiven Verhaltens.

Further reading

Lewis, P.D. & Morris, T.M. (2006): Poultry Lighting - the theory and practice. (Andover, Northcot).

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Lewis (2009): Photoperiod and control of breeding. in: Hocking, P.M. (Ed) Biology of breeding poultry, pp. 243-260 (Wallingford, CAB International).