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LOHMANN Information

# LOHMANN INFORMATION

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# Content



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# Dear colleagues and friends,

Lohmann Information follows a long tradition to provide up-to-date knowledge on advances in farm animal research and development. Starting as "Lohmann Post" in August 1959, this publication became known as a useful source of information for students at agricultural and veterinary universities, extension service and farmers. From the beginning, the focus was on modern animal nutrition and poultry production. From 1969 until 2004, Lohmann Information was published in German, and in 1979 Lohmann Information International in English was added to make the contents of selected articles accessible to a wider readership. Since 2006, the publication continues in online format only in English, and most German readers have accepted this change.

Changes in the format of our publication reflect the rapid change of the farm animal industry since the second half of the 20th century. Agriculture in general and livestock farming in particular, previously focused on regional and national food security, became an important part of the international chain of food supply. With increasing trade of goods and services, information has become more easily accessible and no longer requires a library. Articles published in Lohmann Information between 1979 and 1998 are listed by title only in the archive, articles since 1999 as full text pdf (http://www.ltz.de/de/news/lohmann-information.php). A search function allows retrieving information of specific subjects or authors. There is no standstill in communication technique and we will do our best to keep up with this development. This is particularly important for colleagues in the global poultry industry. No other livestock sector has shown comparable changes within the past 50 years, and offers more opportunities for the future.

We start this 50th issue with a historic review on poultry diseases and their control by Dr. Egon Vielitz. The author was actively involved in poultry disease control from the 1950s when Lohmann introduced broiler breeding and layer breeding in Germany. In this article he recalls the chronology of emerging poultry diseases and strategies of their control. Effective disease control has been and will remain a challenge for global poultry meat and egg production.

Prof. D.K. Flock and Dr. K.E. Anderson analyze recent results from tests at North Carolina State University to answer the question why relatively more laying hens are molted in the USA than in Germany. Induced molting may have an advantage in conventional cages for some white-egg strains under U.S. egg and feed price conditions, but the conditions are different in Europe for brown-egg strains in non-cage systems.

Modern laying hens are kept as long as economically justified to make best use of their genetic potential for persistent rate of lay. The review of Mr. Robert Pottgüter is based on theory and extensive practical experience in different countries. Detailed recommendations for feed formulation throughout the lifetime of laying hens are provided by primary breeders for each strain in different areas.

Egg consumers have a choice between eggs from different production systems, weight grades and shell color. The "best before date" is printed on each carton, but "freshness" depends on the temperature at which the eggs were kept since oviposition. Prof. M. Grashorn et al. use data from a recent Master's thesis to predict the probability that the air cell height of eggs tested for "freshness" exceed the legal limit.

Duck meat is traditionally more popular in Asia than in Europe, where it is consumed mainly during winter months. However, consumers prefer a choice of poultry meat throughout the year, and duck meat has to compete directly with broiler and turkey meat in terms of production cost and feed efficiency. Dr. H.-H. Thiele describes a modern breeding program for Pekin ducks and predicts continued genetic improvement.

We thank all authors for their contributions and encourage readers to contact us with comments and suggestions for topics to be addressed in future issues.

Prof. Dr. Dietmar K. Flock

Prof. Dr. Werner Bessei


## Egon Vielitz, Cuxhaven, Germany


Commercial production of poultry meat and eggs would be impossible without disease control. In this review, the author looks back at more than 50 years of close communication between the Lohmann Veterinary Laboratory and international experts to apply the latest scientific and technical knowledge in disease prevention.


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# Evolution of Avian Pathology in Europe during the past 50 Years


## Abstract

With the development of the modern poultry industry, several poultry diseases spread due to vertical transmission and caused high mortality. Mycoplasma gallisepticum (Mg), a trigger of E. Coli, caused substantial losses on broiler farms. Pullorum and Leucosis virus types A in layers and type J in broilers had to be eradicated from breeding stock to stop vertical transmission. New diseases spread during the last decades: In 1969, Biggs identified the cause of the tumor form of Marek's Disease and, together with Witter, developed vaccines based on attenuated Marek herpes virus (Biggs) and turkey herpes virus FC 126 (Witter). The CVI 988 (Rispens) virus has been used since 40 years and is still effective. V. Bülow and Vielitz identified the chicken anemia virus in 1983 as the cause of anemia in broiler flocks. EDS virus and other types of adeno virus were identified as causes of mortality and depressed production and egg quality. Vaccines to control Salmonella infections with S. typhimurium and S. enteritidis were developed and are widely used to reduce the risk of food poisoning. The re-introduction of free range management and the ban on effective drugs to control diseases like Histomoniasis and necrotic enteritis brings us back to disease problems of the 1960s.



## Keywords

poultry diseases, Newcastle, Fowl Pox, AE, IB, Marek's, Leukosis, Gumboro, CAV, Salmonella, ectoparasites, free range management, Avian Influenza


## Introduction

The evolution of avian pathology during the past five decades is closely linked to two major developments in global poultry production:

1. Genetic selection of meat-type and egg-type chickens and other poultry species
2. Development of housing and management for efficient production of poultry meat and eggs in large units

Nowadays commercial white egg and brown egg layers produce more than 300 eggs per year and consume about 120 g of feed per egg, roughly 50% less than 50 years ago. Total egg mass per hen often exceeds 20 kg per year, ten times the hen's body weight. Similarly, meat type chickens are reaching market weight much earlier and on less feed than 50 years ago, in Germany e.g. 2 kg live weight at 35 days of age on less than 1.6 kg feed per kg gain. Before specialized meat-type and egg-type chickens were imported from North America in the 1950s, laying hens laid about 120-150 eggs per year, and it took cockerels 4 months to reach 1 kg live weight as "broilers". The first imports from North America produced almost twice the number of eggs or grew twice as fast, with corresponding savings in feed cost.

Free range management, common in the 1950s, was associated with high mortality rates from predators and numerous parasitic and bacterial infections.

## Straight from the university - challenged to solve industry problems

While studying veterinary medicine, my knowledge of chicken diseases was limited to pullorum disease, coccidiosis and Marek's Disease. When I started to work for Heinz Lohmann in 1959, the first practical lesson to learn was that birds in free range management had to be caught from trees for pox vaccination!

To prevent high mortality due to free range management, environment controlled chicken houses were built in the 1950ies, and the production of poultry meat and eggs became a full-year business focused on utilization of facilities. As a result, mortality was lower, weight gain and feed efficiency improved.

To benefit from advancements in poultry science in North America during WW II, Lohmann had signed agreements with two American primary breeders, Nichols (1956) and Heisdorf & Nelson (1958) to breed and distribute broilers and laying hens, respectively, in Germany and subsequently in Europe and world-wide. With these contracts, American know-how in applied poultry science was also imported.

## Newcastle Disease (ND)

In 1960 we had the first severe outbreaks of ND in Germany, with 30-40% mortality in broiler flocks. Only inactivated ND vaccines existed in Germany in those days, requiring individual injection. We learned of a live Newcastle virus vaccine in the United States, based on the Hitchner B1 lentogenic virus that could be administered in the drinking water. Importing and applying this vaccine soon brought the disease under control. As a result of these experiences we became convinced that only live vaccines are powerful enough to protect the birds sufficiently.

## Fowl Pox

In the early 1960ies fowl pox disease was also detected in Germany. At that time a live vaccine of the Behringwerke based on an attenuated fowl pox virus strain proved to be very successful and the disease disappeared for a long time. Unfortunately the awareness of fowl pox risks also vanished and live vaccination against fowl pox was eliminated from the vaccination schedule for many years. The disease appeared again in 1999, with more than 60 flocks affected in Germany, and live pox vaccination was re-introduced successfully.

## Avian Encephalomyelitis (AE)

In the early 1960ies breeding stock of layers and broilers were generally kept in well isolated houses with best possible hygienic conditions. These flocks remained free of a number of natural infections during rearing. However these infections could be introduced during hatching egg production, after the birds were transferred to laying houses. This resulted in 1961 in the first epidemic disease in unprotected broiler progeny. The chicks showed paralysis and tremor, and the condition was diagnosed as avian encephalomyelitis (AE), also called epidemic tremor. This is a viral infection, transferred vertically from the mother via the hatching egg to the offspring.

Since American poultry consultants like Dr Donald Zander (H&N-Laboratory, USA) had already had experience with this disease, diagnostics and preventive treatment were quickly introduced. Parent birds were prevented from shedding the AE-virus before they started to produce hatching eggs. Brains of symptomatic chickens were homogenized and administered to the parent birds via the drinking water during rearing. This was the first autogenous vaccine we produced!

## Feed related diseases: encephalomalacia and fatty liver syndrome

Feed born encephalomalacia due to insufficient supply of vitamin E and antioxidants was diagnosed as a major problem in broilers. This condition disappeared when the feed formulation was corrected. Another real problem was the fatty liver syndrome, typically found in high producing caged laying hens. In collaboration with Prof. Köhler (10) from the pathology institute in Vienna we were able to identify feed composition as a major cause. The incidence was substantially reduced by replacing carbohydrate energy by fat (unsaturated fatty acids) in feed formulation.

## Infectious bronchitis (IB)

With the introduction of laying cages in the early 1960ies the stocking density per unit and the general bird density in certain regions also increased. This apparently contributed to more and more cases of IB in laying hens shortly after the AE-epidemic was solved. A large number of vaccination trials were carried out between 1963 and 1964, using attenuated

IB strains of the American Massachusetts type of virus (H120, H52). These vaccine strains protected sufficiently well against the German field strains, whereas in the Netherlands variant virus strains of IB such as IB 274 and IB 1466 were isolated. IB-vaccines were commonly attenuated and manufactured on chicken embryos. A negative impact was the presence of maternal antibodies against IB-virus within the eggs that caused the virus yield to be low. This situation was significantly improved, when eggs free of specified antibodies and antigens (VALO eggs) were introduced (26).

## Marek's Disease (MD)

In the course of the 1960s a new form of Marek's disease occurred in southern Europe. Until then we had known only the classical form causing paralysis and iridocyclitis. With the new form the birds developed tumours in organs, and mortality was extremely high. In Spain up to 50% of the chickens died. As a consequence a number of chicken breeders intensified resistance breeding. Geneticists of H&N and Lohmann decided to split the odds and selected parallel lines (i) only for conventional traits, (ii) only for MD resistance and (iii) on an index with similar emphasis on egg production and MD resistance. The results of cumulative genetic progress in 5 years were published by Flock et al. (8) and showed a reduction of MD mortality by 20% in the MD selected sub-lines vs. 2 kg increased egg mass in the main lines.
The competition between geneticists and veterinarians to control this disease was decided when the virus was identified as a herpesvirus by Dr Biggs in 1969 and Dr Witter in 1970 found the HVT virus in turkeys to be non-virulent and protective against Marek's Disease in chickens. The first European HVT vaccine against Marek's Disease was introduced into Spain in 1971 (1, 20, 35).

In The Netherlands Dr Bart Rispens used a non-pathogenic Marek herpesvirus he had isolated from chickens, as a vaccine strain. He called this virus CVI 988 (Central Veterinary Institute). At that time we in Germany were satisfied with the HVT based vaccine (22, 23).

At the end of the 1970ies in southern Europe and North Africa the first cases of Marek's Disease were claimed despite HVT vaccination. Especially in Egypt this resulted in great losses. It was striking that the bird shipments from Holland did not develop the disease. These birds had been vaccinated with the Rispens strain CVI 988 in the Dutch hatcheries. We quickly switched from HVT to the Rispens vaccine and thus solved the problem (5, 8, 9, 11, 17, 22, 23, 25, 27, 29).

## Gumboro and Egg Drop Syndrome (EDS) and IBD

In 1967, the first cases of Gumboro disease occurred in white layers in Germany, characterized by low mortality rates (18).
In 1976, in The Netherlands, a new disease called Egg-drop syndrome (EDS) occurred, the cause of which was a Duck adenovirus. This virus was introduced through contamination of duck fibroblast cultures used in Marek vaccine production in The Netherlands. The Lohmann vaccine remained free from it because the vaccine was prepared in primary SPF chicken embryo fibroblast cultures.

In the late 1970s Prof. Becht and his research student Mrs. Cursiefen from the University of Giessen described a mutant of the virulent Gumboro strain Cu-1. The Cu-1M virus was a mini-plaque variant and as such was non-pathogenic but very invasive. In 1978 Lohmann developed a live Gumboro vaccine using this virus strain Cu-1M (6, 7).

In the early 1980s layer flocks suffered from losses of up to 70% caused by so called vv-IBDV. These field strains can break through much higher maternal antibody levels than so called intermediate Gumboro vaccines. Therefore it became necessary to vaccinate birds earlier with stronger live IBD-vaccines (28).

## Mycoplasmosis (MG and MS)

Ever since I worked with poultry, avian mycoplasmosis was an issue. Especially in the presence of management stress or other respiratory pathogens broilers showed depressed weight gain and layers a significant drop in egg production due to Mycoplasma gallisepticum. Subsequent Coli-infections caused heavy losses. Therefore the permanent aim of the global poultry industry was the eradication of this microorganism. Well managed farms were completely depopulated, extremely thoroughly cleaned and disinfected before new birds were placed. To remove the mycoplasmas from the hatching eggs, tylosin was injected on the 9th day of incubation. This enabled us to eradicate MG infections from our broiler breeders in 1968/69 (16).
In contrast, our layer breeders were infected with tylosin-resistant MG. These Mycoplasms were non-pathogenic, but the birds became serologically positive. The eradication succeeded later by in-ovo injection of Baytril. Mycoplasma synoviae (MS) is a very contagious microorganism and is still found in many farms. For a long time we could not verify any pathogenicity, but more recent evidence indicates that MS is responsible for low egg shell quality ("apex") and respiratory problems.

## Laryngotracheitis (ILT)

In 1980/81, when infectious laryngotracheitis (ILT) occurred in Germany, we developed a vaccine based on embryonated eggs. This vaccine proved to be extremely effective, but possessed a certain residual pathogenicity. This was probably the reason for the good efficacy. The residual pathogenicity only came up when the vaccine was administered via the drinking water. The same virus individually administered by eye drop, caused no losses.

## Gangrenous dermatitis and chicken anemia virus (CAV)

In Bavaria a new disease in broilers occurred in 1982, diagnosed as gangrenous dermatitis. It was noticed that always the offspring of young parents was affected. It soon became clear that vertical spread was going on. The parents became infected in the beginning of the egg production period due to contact with staff and equipment from hatcheries. In the rearing period they had remained seronegative, because they were very well isolated. So it was obvious that the suspected pathogen should already be administered during rearing in order to develop a protective immunity before the egg laying period started.

The seroconversion of the parents would have to provide protective antibodies to the offspring and at the same time stop the horizontal and vertical spread of field virus. The causative agent was unknown to us. We suspected a virus. So we transferred litter of older flocks whose progeny already showed this disease to young flocks. This of course contradicted the general rules of hygiene, but solved the problem. We then started a research program. Together with the Free University of Berlin and Prof. von Bülow we worked intensively on the viral culture, and he was able to identify and propagate in cell culture the chicken anemia virus (CAV). We discovered that even our SPF-flocks were infected. Thus our SPF-flocks possessed maternal antibodies. Transmission of the disease (3rd Koch's postulate) to SPF animals could therefore not succeed. By working with Mr. von Bülow, we finally were able to produce CAV free SPF-flocks. These were the first flocks worldwide possessing the status „CAV-free". In the further course of our project we were able to reproduce Chicken anemia in SPF embryos and eventually produced a live vaccine. We called the vaccine „Thymovac" because the chicken anemia virus atrophied the thymus besides affecting the bone marrow. This vaccine was licensed in Germany in 1990 and was the first live CAV chicken vaccine worldwide (2, 3, 4, 21, 30, 31, 32).

The epidemiology of anemia virus was thus similar to that of the AE and the adenovirus infection: The infection took place during egg production. The virus is transmitted vertically, followed by disease of the chicks in the first weeks of life. I saw serious cases of adeno virosis in Kuwait with up to 40% losses in chicks hatched from imported Dutch hatching eggs, carrying the disease.

## Viral Arthritis

In 1983 increasing cases of viral arthritis occurred in broiler flocks due to Reo virus infections. This happened although their parents were vaccinated with conventional inactivated Reo virus vaccines. We isolated variant Reo viruses, which were then typed by Prof. van der Heide. In order to gain protection in the progeny we developed inactivated Reo vaccines from these variants for parent vaccination.

From 1985, we could differentiate for the first time serotype specific antibodies by means of micro-IB-SN-tests. The development of this test was part of the doctoral thesis of M. Voß at the Free University Berlin (33). The test allowed the serological differentiation of IB virus variant infections.

## Leukosis

In the late 1970s we intensified the screening of all egg lines at the pedigree level to eliminate all virus shedders. This eradication apparently contributed significantly to the fact that entries of commercial LSL layers from different parent flocks averaged more than 300 eggs per hen housed to 500 days of age in German random sample tests. The eradication of ALV from primary breeder stocks was an essential prerequisite for the introduction of feather-sexing White Leghorn crosses. The disease almost disappeared in commercial layers. Leukosis became important once more in broiler breeders in the early 1990s (ALV-J); the virus strain was eradicated within two years.

## Inclusion body hepatitis (IBH) and hydropericardium

In 1987 progeny of broiler breeders suffered from high losses due to inclusion body hepatitis (IBH) and hydropericardium. At the same time a similar outbreak of the same disease was observed in Pakistan, which was called Angara Disease. As a causative agent an Adeno virus could be isolated from infected progeny. Again the progeny was protected, when parent birds had seroconverted before beginning of lay. The disease was transmitted vertically. Therefore the Adeno virus was amplified and a live vaccine was administered to the next parent bird generation during rearing via the drinking water.

## Salmonella

In 1989 the British Minister of Health Edwina Currie declared: "We do warn people, that most of the egg production in this country, sadly, is now infected with Salmonella". Also in Germany it was a big threat to the poultry industry in the 90ies when Salmonella infections of poultry resulted in Salmonella outbreaks in man. The causative agents were Salmonella enterica enteritidis and Salmonella enterica typhimurium. In Germany live Salmonella vaccinations of poultry were introduced based on research of Prof. Linde in Leipzig. The vaccination against Salmonella in chicken layers became obligatory in Germany in 1994. Only a few years later the Salmonella vaccinations were also introduced in the UK. The Salmonella metabolic drift mutants of Prof. Linde were a great success, resulting in a significant reduction in the prevalence of Salmonella in poultry products and in human outbreaks (12-14).

## Ectoparasites: Red mites and black beetles

In the 1990s red mites (Dermanyssus gallinae) became an increasing problem, especially among densely housed layers. Reduced egg production, nervousness of flocks and increasing mortality, up to 30%, were the consequences. This problem is unsolved until today. Cleaning, thorough washing and the application of pesticides is only reducing the problem. Intensively housed broilers on the other hand can be accompanied with black beetles (Alphitobius diaperinus), that appear in billions in the litter. Both ectoparasites can harbour a number of different bacterial and viral infectious agents. The parasites and with them a number of diseases spread from flock to flock.

## Free range management

Despite the negative experience with free range management in the late 1950s, free range housing was introduced again in the 1990s. Advantages and disadvantages of different housing conditions of layers are compared in the following table.

As shown in this summary, cage management is preferred in terms of health and product quality, but does not meet animal welfare demands and has therefore been banned in some countries. Floor husbandry provides better conditions in terms of bird welfare, but at the expense of product quality and animal health.

## Bacterial infections and autogenous vaccines

Many bacterial infections such as E.coli, Pasteurella and Erysipelothrix re-occurred under free range conditions. Also Ornithobacterium rhinotracheale as a respiratory disease agent and parasites such as Histomoniasis have been detected. Among those bacteria a number of isolates have been found that cannot be typed by conventional methods. Therefore no registered vaccines are on the market and autogenous inactivated vaccines currently fill these gaps.

Autogenous vaccines are also increasingly used since the overuse or misuse of antibiotics has been linked to the emergence and spread of antibiotic resistant micro-organisms. Their treatment is ineffective, and they pose a serious risk to public and animal health. Autogenous vaccines have become a real alternative to antibiotics. Well known examples of antimicrobial resistant micro-organisms among the chicken population are multi-resistant Staphylococcus aureus and E. coli.

Regarding the use of antibiotics in livestock the old paradigm is still applied today: "If the microbes are exposed over time to a suboptimal concentration of antibiotics, they defend themselves by developing resistance. Therefore attack bacteria with a high dose of antibiotics over a short time." However this is questioned today,

**Table 1: Comparison of different housing conditions of layers (34)**

| | Conventional cages | Enriched cages | Aviary | Barn | Free range |
|---|---|---|---|---|---|
| Animal Health | | | | | |
| • Infection | + + + | + + | - | - | - - |
| • Disease | + + + | + + | - | - | - - |
| • Parasites | + + + | + + + | - | - | - - |
| • Injuries | + | +/- | - - - | - | - - |
| Animal Welfare | | | | | |
| • Movement | - - - | - | + + | + + | + + + |
| • Social order | + + + | +/- | - - | - - - | - - |
| • Choice of nest | - - - | + + | + + + | + + + | + + + |
| • Sand bathing | - - - | + + | + + + | + + + | + + + |
| • Cannibalism | + + + | - - | - - - | - - - | - - - |
| Product Quality | | | | | |
| • Contamination | + + + | + | - | - - | - - |
| • Egg Quality | + + + | + + + | + + | + | +/- |
| • Drug residues | + + + | + + | - | - | - |

**+++ = best; - - - = worst**

since it only seems to be true in-vitro, but not in-vivo (24). In-vivo it may well be just the other way round. In the animal, low doses given over a long period of time allow the healthy flora to develop again, which it doesn't do under high antibiotic concentrations.

## Avian influenza (AI)

The first description of avian influenza dates back to 1878 by Perroncito in northern Italy. Highly pathogenic avian influenza (AI) virus known as H5N1 was discovered in 1997 on a goose farm in China. Since 1997 H5N1 has spread to over 40 countries in Asia, Africa and Europe. Severe outbreaks occurred in the beginning of the new millennium in Italy, then in The Netherlands and Germany. The virus is endemic in wild water fowl and can spread to domestic birds.

In the case of low pathogenic strains such as H9N2 birds often only shed the virus without any clinical symptoms. The virus can even spread to humans or other mammals. Highly pathogenic AI viruses are a permanent threat to the poultry industry, because in case of outbreaks the whole flocks are killed (stamping out policy in the EU). In Europe vaccination against highly pathogenic AI viruses (H5, H7) is banned. A number of research projects based on genetically modified live AI-viruses failed due to the very frequent genetic shift and drift of the virus. At the moment the vaccine industry has declared the inactivated AI vaccines to be the gold standard against the disease.

## Outlook

During past decades, general hygiene, biosecurity and vaccinations contributed to a significant reduction of mortality from a range of poultry diseases. Adapted to local disease risks, these principles remain essential for disease control. The methods will be further refined, and the Veterinary Laboratory of Lohmann Tierzucht will continue to play a significant role in the application and promotion of new knowledge.

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Slides presented at the Meeting in Evora, Portugal, may be obtained from the author.

# NOTES

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The Avian Influenza outbreak last year forced many egg producers in the USA to molt uninfected flocks to overcome the shortage of pullets. In the present paper we analyzed data of two recent tests in North Carolina and tried to answer the question why molting is more popular in the USA than in Europe and under which conditions molting may be economically justified.

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# Molting of Laying Hens: test results from North Carolina and implications for US and German egg producers

## Abstract

Induced molting is a management tool to extend the productive life of laying hens. National statistics on molting from previous years indicate that about 20% of the laying hens were molted in the USA (table 1), compared to less than 10% in Germany (table 2). Information from the industry and independent poultry consultants in the USA suggests that currently most flocks are being molted, while egg producers in Germany are more concerned about objections from animal welfare and the response of hens in non-cage systems. Since 1986, the North Carolina Cooperative Extension Service has designed and carried out Layer Performance and Management Tests to compare different strains under different management systems. Results of the latest two tests were analyzed to study the potential benefit of molting compared to single cycle management in terms of annual egg production and egg income over pullet and feed cost. A non-fasting molt was induced at 69 weeks of age, with target weight reduction by 25% in the 38th NC test and 20% in the 39th NC test. Under the conditions of these tests and the assumptions made, economic benefits of molting are obvious if molted hens are compared to non-molted hens kept to the same age of 109 weeks. However, annual egg production will always be higher and egg income over pullet and feed cost seldom lower if the single cycle is extended to about 60 weeks of production.

## Keywords:

laying hens, molting, economics, animal welfare

## Introduction

Before egg production became the full-year round business we know today, chickens followed a similar annual cycle as all birds: reproduction in the spring, rearing through summer, and molting in the fall. Shortage of eggs during winter months generated a strong interest on the part of egg producers and researchers to develop ways and means to shorten the molt period and/or to change the time of molting to benefit from seasonal demand and corresponding egg prices. Primary breeders of egg-type chickens responded to the challenge by focusing on improved persistency of egg production and shell quality.

Decisions on molting must be based on the performance profile of commercial layers, approved methods of molting, and the demand for eggs at heavier weights.

Table 1: USDA (2015) Statistics on pullets, laying hens and molting in the USA

| | | |
|---|---|---|
| 302.2 | mio | egg type layers on hand, first day of the month |
| 108.1 | mio | pullets on hand, first day of the month |
| 24.1 | mio | pullets added during the month |
| 14.7 | mio | layers sold for slaughter |
| 7.6 | mio | layers died, destroyed, composted or disappeared for other reasons |
| 18.46 | % | of all layers molt completed, first day of the month |
| 2.63 | % | of all layers being force molted, first day of the month |

About 30 years ago, Wolford (1984) reviewed the literature on induced molting, with focus on questions which required further research. The oldest reference cited in this review is Bulletin 258 of the Cornell Experiment Station (Rice et al., 1908). However, Rice (1905) had already published on molting three years earlier. Details of the non-anorexic (non-fasting) method of molting applied in the North Carolina Layer Performance and Management Tests are described in each report and special publications of the North Carolina Cooperative Extension service and may be downloaded from the internet. We will present statistics on the frequency of molting and analyze results of the 38th and 39th NC Test for traits of primary interest. Reasons for molting and differences between the egg industry in the USA and Germany will be discussed.

## Frequency of Molting in the USA and Germany

In the USA, each State reports data on egg production to the Census Bureau on a monthly basis from farms with at least 30,000 birds. These statistics are summarized and published annually by the USDA. Table 1 shows the average population of pullets and laying hens in 2013-14.

If we multiply the percentage of layers recorded on the first day of the month (18.46%) by 4 (number of weeks for a molting program), we may assume that 74% of the hens were molted. Anderson (2015) recently noted that "current industry practice is to molt over 80 percent of the caged egg type hens in the United States" – mainly in response to the Avian Influenza outbreak in 2015. In case of major disease breaks, shortage of pullets and restrictions on bird movement, the option to molt has obvious advantages.

In Germany, monthly data are reported to the Federal Statistics Office for flocks with at least of 3,000 hens. The statistics in table 2 were published by MEG (2015) to show developments since the exit from conventional cages in 2009. Molting appears to have increased slightly since the transition to non-cage systems.

Table 2: December statistics on laying hens in Germany (MEG, 2015)

| Year | Total | | 1st Period | | 2nd Period | | |
|---|---|---|---|---|---|---|---|
| | Farms | Hens Mio | Farms | Hens Mio | Farms | Hens Mio | Hens % |
| 2014 | 1,453 | 39.635 | 1,394 | 35.975 | 310 | 3.456 | 8.7 |
| 2013 | 1,307 | 38.438 | 1,243 | 35.052 | 295 | 3.325 | 8.7 |
| 2012 | 1,237 | 36.553 | 1,193 | 34.008 | 257 | 2.534 | 6.9 |
| 2011 | 1,169 | 33.977 | 1,126 | 31.554 | 253 | 2.382 | 7.0 |
| 2010 | 1,080 | 29.861 | 1,047 | 27.706 | 219 | 2.086 | 7.0 |
| 2009 | 1,046 | 26.846 | 1,010 | 25.139 | 197 | 1.673 | 6.2 |

Different grading systems and assumptions regarding egg prices must be kept in mind when assessing the potential benefits of molting in the United States and in Germany. The egg prices used in the NC tests to calculate egg income are based on current production year and applying a 3 year average egg price on egg production and quality evaluation. Table 3 shows average prices across both tests.

In the NC Layer Performance and Management Tests, the egg size distribution is determined at 28-day intervals, weighing all eggs produced within the previous 24 hours and grading according to USDA standards. All eggs above 63.8 grams were classified as "extra large", and there was no incentive to produce more "Jumbo" eggs. In Germany, by contrast, eggs above 73 g can generate extra income for producers, provided shell quality is acceptable. From the difference in egg prices, one would expect more molting in Germany than in the USA, but the opposite is true.

## Results of 38th NC Test: molting with 25% target weight loss

The non-fasting method of molting applied at the North Carolina Experiment Station in conventional cages has been described by Anderson (2015) and can be downloaded (http://content.ces.ncsu.edu/print/induced-molting-of-commercial-layers). The 38th NC Management Test focused on a comparison of molted vs. non-molted hens from 17 to 109 weeks

Table 3: USDA vs. European Egg Size Grading Standards and Egg prices assumed in the 38th and 39th North Carolina Tests

| Egg size grading standards | | | | Egg prices in US$/dozen | |
|---|---|---|---|---|---|
| USA | | Europe | | USA | Germany |
| Jumbo | >70.9 | XL | >73 | 1.40 | 1.82 |
| Extra large | 63.8–70.9 | L | 63-73 | 1.40 | 1.02 |
| Large | 56.7–62.7 | M | 53-63 | 1.36 | 0.95 |
| Medium | 49.9–56.6 | S | <53 | 1.10 | 0.72 |
| Small | 42.5–49.5 | – | – | 0.92 | – |

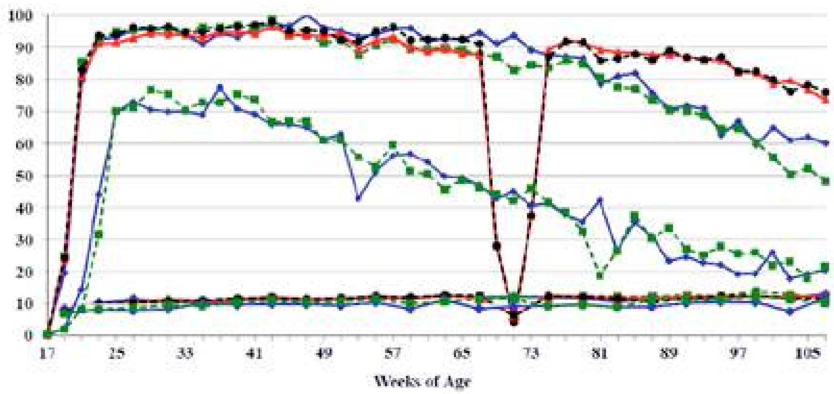
of age (92 weeks of lay). Molted and non-molted hens were kept in different rows of the same house and exposed to the same reduction of light hours.

Table 1 shows the bi-weekly rate of lay of molted vs. non-molted hens of a modern commercial white-egg strain and the Barred Plymouth Rock control line maintained at the North Carolina State University as a measure of genetic progress. The non-molted hens should have been more persistent if the day length had been kept constant and the difference is overestimated, but modern layers respond less to reduced day length than perhaps expected. The desired interruption of egg production requires a dramatic change in feed composition, and this was achieved with the feeding program used.

In table 4, the results of white-egg and brown-egg strains before, during and after the molt are summarized for annual egg number per hen housed and egg income over pullet and feed cost for different lengths of laying period, with and without molting. US$ 4.00 are assumed for 17 week old pullets and two weeks between flocks for maintenance, cleaning and disinfection. The figures for egg income and feed cost are taken from the final report; the formula for conversion to annual income over pullet and feed cost is shown below table 4. Similarly, hen-housed egg production is converted to annual results.

Under the conditions of the 38th NC test, significantly more eggs per year would be produced with replacement after 52 or 56 weeks of production than with molting. Egg income over pullet and feed cost would be slightly lower for white egg strains, but higher for brown egg strains after 56 weeks of production than with molting and a second laying period to 109 weeks of age. Average egg weight was about 3 grams higher for hens kept until 109 weeks of age, regardless whether they were molted or not. Although molting is generally expected to improve shell quality, the difference in terms of % cracks was small to 109 weeks of age. Mortality was about 1% lower in molted than non-molted hens, which indicates that the molting procedure applied did not compromise the welfare of the hens in terms of livability. These results confirm that molting is economical if hens are kept to 109 weeks of age, while even better results may be obtained with single cycle management and more than 56 weeks of production.

Fig. 1: Combined effects of feed composition and reduced day length on rate of lay in molted vs. non-molted commercial white egg layers (Lohmann LSL Lite) and a control line (NC Barred Plymouth Rock); combined from graphs 4 and 19 in the final report of the 38th NC Test




## Results of 39th NC Test: molting with 20% target weight loss

In the 39th NC Test, all hens in conventional cages were molted without a non-molted control, and the target weight loss during the molt was 20%. Significantly higher egg production and egg income over feed cost than in the previous test suggests that 20% weight reduction should be preferred and 25% weight loss may be too much. The results are summarized in the following table 5.

Livability was somewhat better at the lower density, but the effect on egg income over pullet and feed cost would not be sufficient to convince egg producers to reduce the stocking density unless dictated by animal welfare standards. The calculated advantage of molting across both types of layers and cage densities was 1.08 $ per hen per year, compared to a short cycle of 52 weeks. However, the difference

**Table 4: Annual egg production per hen housed, egg income over pullet and feed cost (AIOC*) and average egg weight for different placement schedules in the 38th NC Test, assuming 2 weeks for depletion, cleaning and service before housing the next flock**

| Strain Average | Annual Cycle (52+2 wks) | | | | |
|---|---|---|---|---|---|
| | Eggs/HH | AIOC ($) | Egg wt. (g) | Cracks (%) | Mortality (%) |
| Av. White | 292 | 9,99 | 60,6 | 1,65 | 5,4 |
| Av. Brown | 286 | 8,84 | 61,0 | 1,75 | 5,5 |
| NCSU BPR | 181 | 2,77 | 52,6 | 2,20 | 7,1 |
| | Extended Single Cycle (56+2 wks) | | | | |
| | Eggs/HH | AIOC ($) | Egg wt. (g) | Cracks (%) | |
| Av. White | 303 | 10,34 | 60,9 | 1,72 | 6,2 |
| Av. Brown | 296 | 9,31 | 61,2 | 1,71 | 6,2 |
| NCSU BPR | 179 | 3,84 | 53,2 | 2,12 | 7,1 |
| | Non-molted (92+2 wks) | | | | |
| | Eggs/HH | AIOC ($) | Egg wt. (g) | Cracks (%) | |
| Av. White | 267 | 9,08 | 63,8 | 2,50 | 14,8 |
| Av. Brown | 255 | 8,00 | 63,8 | 2,15 | 14,4 |
| NCSU BPR | 146 | 1,02 | 56,5 | 2,25 | 10,6 |
| | Molted (92+2 wks) | | | | |
| | Eggs/HH | AIOC ($) | Egg wt. (g) | Cracks (%) | |
| Av. White | 268 | 10,38 | 63,6 | 2,10 | 13,8 |
| Av. Brown | 255 | 9,14 | 63,7 | 1,95 | 12,6 |

may be non-significant compared to single cycle management with optimum length of laying period.

## Interactionsbetween strains and moltability

In the final report of the 38th and 39th NC Tests, detailed results for different cage systems, bird densities and age periods are documented in 90 tables, separate for white-egg and brown-egg layers (https://poultry.ces.ncsu.edu/layer-performance/).

In the following table 6, hen-housed egg production and egg income over feed cost is summarized from 12 tables in the final report of the 39th NC Test and corresponding results from the 38th NC Test for 8 white-egg strains and 7 brown-egg strains represented in both tests.

The strains are sorted on the last column to show the apparent benefit of molting for different strains. Annual egg income over cost (AIOC) during the first 52 weeks is highly correlated with AIOC in 92 weeks (r = 0.87), because the first period is part of the total, but AIOC during the first 52 weeks is a poor predictor of the additional gain after the molt (r= 0.11). Nevertheless,

**Table 5: Annual egg production per hen housed, egg income over pullet and feed cost (AIOC*) and average egg weight for different placement schedules in the 39th NC Test, assuming 2 weeks for depletion, cleaning and service before housing the next flock**

| Strain Average | Cage density | Annual Cycle (52+2 wks) | | | |
|---|---|---|---|---|---|
| | | Eggs/HH | AIOC ($) | Av. Egg wt. (g) | Mort (%) |
| Av. White | 445 cm²/hen | 298 | 15,40 | 60,4 | 4,3 |
| | 774 cm²/hen | 304 | 15,13 | 60,2 | 3,4 |
| Av. Brown | 445 cm²/hen | 291 | 14,43 | 59,9 | 5,8 |
| | 774 cm²/hen | 306 | 15,40 | 59,4 | 3,3 |
| | | Molted (92+2 wks) | | | |
| | | Eggs/HH | AIOC ($) | Av. Egg wt. (g) | Mort (%) |
| Av. White | 445 cm²/hen | 300 | 16,93 | 60,5 | 10,0 |
| | 774 cm²/hen | 299 | 16,80 | 60,4 | 8,6 |
| Av. Brown | 445 cm²/hen | 287 | 14,22 | 60,8 | 11,5 |
| | 774 cm²/hen | 292 | 16,72 | 61,2 | 8,9 |

egg producers will be more likely to molt flocks with low mortality and superior performance during the first cycle.

## Discussion

The potential benefit of molting in terms of annual egg income over pullet and feed cost depends on many factors, including regional demand for eggs at specific weights, available rearing capacity or replacement cost for pullets, availability of suitable components for molt feed and total feed cost. Under the conditions of the NC Tests, most white-egg strains produced more egg income over pullet and feed cost during the first 52 weeks of production, and the additional gain from molting also favored white-egg strains.

Preferences for shell color and egg weight are usually dictated by the regional egg market. Primary breeders offer a range of strain crosses with different average egg weight and advice how to optimize the egg grading results with a combination of different management tools, including feed formulation, house temperature and placement schedule. Egg producers keeping weekly records on egg income and feed cost can monitor cumulative egg income over pullet and feed cost and use this information to optimize future placements.

Arguments pro or con molting may be seasonal fluctuations in egg prices or cash flow, long-term contracts with pullet growers or limitations in getting spent hens slaughtered. The apparent well-being of the hens may be an argument (pro or con), especially if consumers like to know under which conditions eggs are produced and are willing to pay for the additional cost. In another context, Vukina et al. (2013) studied the economic impact of investments in improved living conditions for laying hens in the National Organic Program and

**Table 6: Annual egg production and egg income over pullet and feed cost for 15 strains represented in the 38th and 39th NC tests, assuming 2 weeks for depletion, cleaning and service before housing the next flock**

| | (52+2 wks) | | (92+2 wks) | | Difference | |
|---|---|---|---|---|---|---|
| | Eggs/HH | AIOC($) | Eggs/HH | AIOC($) | Eggs/HH | AIOC($) |
| Hy-Line W-36 | 292 | 11,87 | 269 | 13,81 | -23 | 1,94 |
| Novogen White | 306 | 12,36 | 286 | 13,84 | -20 | 1,48 |
| Lohmann LSL Lite | 306 | 12,67 | 287 | 14,00 | -19 | 1,33 |
| DeKalb White | 308 | 12,96 | 289 | 14,03 | -19 | 1,07 |
| H&N Nick Chick | 305 | 13,06 | 286 | 14,12 | -19 | 1,06 |
| Bovans White | 302 | 12,41 | 284 | 13,43 | -18 | 1,02 |
| Shaver White | 305 | 13,49 | 287 | 14,37 | -18 | 0,88 |
| Babcock White | 312 | 13,50 | 292 | 14,08 | -20 | 0,58 |
| TETRA Brown | 289 | 10,15 | 257 | 10,83 | -32 | 0,68 |
| Novogen Brown | 296 | 11,73 | 267 | 12,24 | -29 | 0,51 |
| Bovans Brown | 304 | 12,49 | 281 | 12,98 | -23 | 0,49 |
| ISA Brown | 301 | 12,56 | 279 | 12,91 | -22 | 0,35 |
| TETRA Amber | 296 | 11,05 | 266 | 11,39 | -30 | 0,34 |
| Hy-Line Silver | 302 | 12,14 | 280 | 12,47 | -22 | 0,33 |
| Hy-Line Brown | 296 | 12,49 | 273 | 12,41 | -23 | -0,08 |
| **Average White** | **306** | **13,13** | **288** | **13,96** | **-18** | **1,17** |
| **Average Brown** | **298** | **11,80** | **273** | **12,18** | **-25** | **0,37** |

***AIOC 52 = 52 x (EI - FC - PC)/54; AIOC 92 = 52 x (EI - FC - PC)/94**

concluded that the current market prices reflect the willingness of consumers to pay for the cost of animal well-being. Keeping the birds calm during the molt with reduced day length and light intensity helps to minimize mortality, but may be in conflict with poultry welfare regulations. Providing low density feed and access to water should assure low mortality and acceptable hen welfare.

The optimal strategy for target weight reduction during the molt is subject to further studies and field experience with different strains. Comparing the results of the 38th and 39th NC tests, 20% weight loss seems to be better than 25%. Since properly fed laying hens have no fat to lose when the molt is induced, and pullet weight just before onset of lay may be a better target than pre-molt body weight (Drinoczy, 2016). The impact of flock uniformity before the molt and individual weight changes during the molt would be of interest in future studies.

We are not aware of experimental results with molting in enriched cages or non-cage systems. Since the ban on conventional cages, most egg producers in Germany changed to aviaries. Official statistics for eggs produced in 2014 were: 63.3% barn, 17.3% free range, 10.5% Kleingruppenhaltung (enriched cages), and 8.9% organic (DGS 3/2016). In other European countries, enriched colony cages are preferred over floor systems. In Lower Saxony, the State with the highest concentration of poultry in Germany, about 10% of the hens are molted on farms between 3,000 and 30,000, about 9% above 30,000 hens. In Northern and Eastern Germany, average farm size is larger and the percentage of molting is lower than in Southern Germany, where smaller flocks with direct marketing are more common (Oltmann (2016). Small producers may prefer to buy spent hens from flocks with excellent first cycle performance to produce mainly extra large or "jumbo" eggs with superior shell quality after the molt instead of competing in the usually oversupplied market for medium and large eggs (cf. table 3).

In a previous study, Schulte-Drüggelte and Thiele (2013) used data from the 38th North Carolina layer performance and management test and production standards for LSL Lite layers for an extended single cycle laying period. In the present study we included additional data from the recently published 39th NC Test and tried to answer the question why molting is more widely practiced in the USA than in Europe. Due to the European grading system, average egg size in the lifetime of most flocks in the EU is about 63 g to meet the demand for the volume trade of discounters. Different strain crosses and management (nutrition, length of laying period and house temperature) have to be combined to meet egg demand and maximize farm income.

## Summary

Results of the 38th and 39th North Carolina layer performance and management tests were analyzed and implications for US and German egg producers discussed. Decis-

ions on molting will be mainly based on the demand for eggs in different weight grades and economic evaluation of production cost per marketable egg. Under the conditions of these tests in conventional cages, most white-egg strains outperformed most brown-egg strains in terms of egg income over feed and replacement cost when molted and kept to 109 weeks of age. With a weight loss of 20% (compared to pre-molt weight), better results were obtained than with 25% weight loss. In Germany and other European countries, single cycle management with about 60 weeks of production is more common than in the USA, which is partly explained by the prevalence of brown-egg layers and a lower share of egg production for the breaking industry. The non-fasting molting program used in North Carolina had no negative impact on bird welfare in terms of livability.

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Egg producers who want to make full use of the genetically improved persistency of egg production and shell quality pay extra attention to nutrition throughout the lifetime of each flock. Maximum lifetime productivity requires optimal pullet development and adaptation of feed composition according to changing nutrient requirement with increasing age.

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# Feeding Laying Hens to 100 Weeks of Age

## Abstract

Genetically improved persistency of commercial laying hens enables egg producers to keep flocks longer in production, provided egg shell quality can be maintained. Only healthy birds with a functioning calcium metabolism can show their genetic potential for lifetime number of salable shell eggs. Optimal management for lifetime production of shell eggs starts during the rearing period. Pre-lay feeding at transfer to the laying house is critical to meet the changing nutritional needs of birds as they start to lay eggs. Feeding and nutrition to assure liver and gut health supports egg shell quality. High quality limestone with fine and coarse structure should be adapted to the changing needs of the hens with progressing age and during each day. Split feeding has been developed and is increasingly applied in practice to meet the varying demand for calcium during the day. Limiting the increase of egg weight in extended production cycles helps to maintain shell quality.

## Keywords

laying hens, nutrition, egg shell quality, calcium supply, persistency

## Introduction

Modern white egg and brown egg layers exhibit a very high production potential in different housing systems and may be kept up to 80 weeks in production, without molting. Egg producers recognize the results of ongoing genetic selection in terms of increasing persistency of rate of lay and feed conversion ratio. The increase in hen-housed egg production is mainly due to longer clutch length and improved uniformity of layer flocks. A popular goal is 500 eggs in one cycle, and this has already been surpassed in many flocks. Most egg producers realize declining egg shell quality as a limiting factor toward the end of a long laying cycle and focus on calcium nutrition earlier in the life of the next flock. The "post-peak-dip" is another challenge early in the production period. Optimal nutrition can help to minimize problems at these two critical times in the life of a flock, to secure a good start of production, a high peak rate of lay close to 100% and best possible egg shell quality beyond 90 weeks of age.

## Importance of rearing and pre-lay phase

Optimal layer nutrition for a lifetime starts directly after hatch. This means to fulfil the nutritional demand for rapid growth during the first half of the rearing period followed by slow growth and nutritional consequences in the second half of the rearing period. The feeding program during the first half of the rearing period needs to focus on an optimal supply of digestible amino acids and minerals to ensure the basic growth of the inner organs, muscles and skeleton (Leeson and Summers, 1997). During the second half of the rearing phase the physiological development of the pullet continues at a slower rate, which offers the chance for training feed intake behavior of the pullets, which is critical for the following start of egg production, when today's layers tend to eat too little. During the second half of the rearing phase the reduced demand for protein and amino acids offers a chance to include raw materials with lower density and higher crude fiber content. Provided suitable raw materials are available, I recommend at least 5.5 % crude fiber during this phase. At the end of the rearing period, the birds change from a pullet to a laying hen, and nearly all metabolic processes change. While the medullary bones develop and all metabolic processes change to egg production, the birds must continue to gain weight. The development of the medullary bones takes roughly ten days, requires additional calcium and is called the pre-lay period (Coelho, 2001).

Pre-lay rations support a smooth transition from developer feed to layer feed, with 2 – 2.5 % calcium, while the other nutrients are similar to a layer feed. The major challenge to implement pre-lay feeding is logistics and correct use on the farm. As shown in table 1, I suggest using pre-lay feed for about ten days, with a maximum of 1 kg per pullet. Common mistakes are feeding pre-lay feed too early or for too long, which may result in poor peak rate of lay.

Pre-lay rations help the birds to adapt to the high calcium content of layer feed and to maintain sufficient daily feed intake. Higher levels of protein and amino acids allow late maturing birds to catch up in development, with positive effects on the uniformity of the flocks, and the calcium content prevents decalcification of bones of early maturing hens. Positive results of pre-lay feeding have been shown around the world in different production systems, and it is highly recommended to implement pre-lay feeding as a general practice for pullet flocks.

## Support of liver health

After an optimal start into the laying period the liver is the most important organ of the hen. Feeding on liver health is not only a veterinary issue but an important nutritional topic as well. The liver provides nearly all basic nutrients for the development of the yolk and albumen and supports the development of the egg shell: the liver provides the protein in the egg shell, which contributes to elasticity of the egg shell. Adding fat and oil or crude fat in layer diets is a well-known tool to reduce the incidence of "fatty liver syndrome". Recommended and widely used in practice is also added choline chloride in layer diets to support liver metabolism. Every fatty liver supplement is based on choline chloride and vitamins like K3, E, B12, B1 and folic acid. Sometimes Methionine and Betaine are used to relieve liver metabolism.
Contamination of layer feeds with mycotoxins may be the cause of liver damage. Don't wait until a veterinary laboratory confirms liver damage in post-mortem examination and be aware of the potential risk of mycotoxin contamination. Recommendations for feed additives vary, and egg producers must decide when to use a mycotoxin binder.

## Source and quality of limestone

Limestone is the most important and usually cheapest ingredient of layer rations to support egg shell quality, but the quality is not always optimal. As a laying hen's demand for calcium varies during a 24 hour day, fine and coarse limestone with different solubility should be offered as standard practice (Zhang et al., 1997). Another source of calcium for egg shell formation is the complex of medullary bones, which store and release calcium during the night when the hens normally have no feed intake. Relying too much on the medullary bones, however, leads to a loss of phosphorus and bone strength. Therefore the feeding strategy should focus on sufficient limestone supply "just-in-time" from the gut and minimizing the utilization of calcium from the medullary bones for egg shell formation (Rao and Roland, 1990). The average retention of calcium from limestone in layer feeds varies between 40 - 60%, which means that about 50% of the limestone intake will be excreted with the feces.

Solubility depends on particle size. I therefore recommend using two sources of limestone in layer diets, with at least 2/3 as coarse limestone. Table 2 shows the recommendations of Lohmann Tierzucht for LSL Classic white-egg layers. The effect is similar to adding oyster shells on top of compound feed when egg shell quality deteriorates with increasing age of the flock and decreasing efficiency of calcium metabolism. In deep litter and aviary systems feeding coarse particle size of limestone appears to have a positive effect on bird behavior, and flocks on this program

**Table 1: Suggested use of pre-lay feed**

| Age at transfer | | Feeding program | | |
|---|---|---|---|---|
| | | Developer feed | followed by | Pre-lay feed |
| week | days | kg | | kg |
| 15 | 105 | 1,0 | > | 1,0 |
| 16 | 112 | 0,5 | > | 1,0 |
| 17 | 119 | 0,0 | > | 1,0 |
| 18 | 126 | 0,0 | > | 0,5 |
| >18 | >126 | > immediately start layer feed, phase 1 | | |

seem to be more docile. A similar effect can be observed when flocks are offered grit, i.e. small insoluble stones, to support gizzard activity as a natural grinder.

## Daily calcium intake and timing during the day

Nutritionists should know the daily demand for optimal egg shell development and take the actual feed intake of a specific flock into account to ensure sufficient intake of calcium. For example, when 4.1 gram of calcium intake per hen per day is the target, then a ration with 4.5% Ca will be required in case of 90 gram daily feed intake or 3.4% Ca for 120 gram daily feed intake. Unless the actual daily feed intake is taken into account, many laying hens may be harmed at an early stage of the laying period (Roland and Gordon, 1999). Observations of feed intake behavior suggest that the hens consume roughly 1/3 of the daily amount during the first half of the day and 2/3 during the second half of the day. Feed composition during the afternoon is important to meet the higher demand for calcium during the night when most of the egg shell formation takes place. Many layer farms are therefore using a top dressing of 1-2% coarse limestone in compound layer feed for the last feeding of the day. Another possibility is "split feeding", with a lower Ca morning feed and a higher Ca afternoon feed. Either approach can be recommended from a nutritional point of view. The major challenge for implementation in practice is related to feed logistics and equipment in the layer house.

## Controlling egg size

Shell strength is negatively correlated with egg size. At the beginning of a laying cycle, all hens lay smaller eggs with thicker shells, at the end of the laying cycle larger eggs with thinner shells. To some extent the increase of egg size in aging flocks can be controlled by nutritional management, and this helps to maintain adequate shell quality in extended production cycles when the calcium metabolism becomes less efficient. A recent survey involving 30 flocks of Lohmann Brown Classic in France has shown a variation of +/- 2.5 gram of average egg weight between flocks with the same genetic background. If a nutritionist is asked to formulate feed rations which help to reach 55-60 grams as early as possible and to limit the increase beyond 63 grams, he would first consider the content of Methionine and Sulphur amino acids and crude protein to balance the amino acid profile. Added fat and oil or crude fat and the content of linoleic acid are the next variables to consider. The basic demand for linoleic acid is about 1% in layer diets and can easily be met in practice. Scientific experiments and field experience from many countries have shown that egg weight will increase with linoleic acid levels of 2% or even 3% in commercial layer diets (Garrelfs, 2010). Therefore it is suggested to start with a higher linoleic acid level at the beginning of the laying period and to decrease the content toward the end of the laying period. It has become common practice to reduce the nutrient density of the feed during the laying period in order to reduce feed costs and at the same time control the egg size. But laying hens will try to adjust their feed intake to meet their energy demand and will respond to the reduction of nutrient density and energy of the formula by increased feed intake, with more amino acids and crude protein than they need. Therefore I would recommend to keep the level of energy constant throughout the laying period and to reduce amino acids and crude protein.

**Table 2: Recommended ratio of fine and coarse limestone**

| Feed type | Fine limestone <1,5 mm | Coarse limes 1,5 - 3,5 mm |
|---|---|---|
| Layer phase 1 | 30% | 70% |
| Layer phase 2 | 25% | 75% |
| Layer phase 3 | 15% | 85% |

## Feeding with focus on gut health

Gut health has become a popular topic in connection with the reduced use of antibiotics and novel feed supplements with antibiotic activity. A healthy gut ensures optimal nutrient and mineral absorption and is essential for shell quality (Roberts, 2008). The feed industry and nutritionists are offering feed additives and many ideas to support gut health; feed enzymes are widely used; herbs, spices and essential oils; acidifiers and organic acids; probiotics and prebiotics (MOS); medium and short chain fatty acid products; inclusion of non-digestible fiber (Lignin).

The gizzard deserves more attention for its grinding function before the digestive process can start. The gizzard is basically a muscle which needs stimulation. If the gizzard is filled with coarse feed, it will grind and mix feed particles before passing them on into the intestine. If the gizzard is filled with too much fine feed, it cannot function properly and may cause diarrhea, wet litter and dirty eggs. Therefore a coarse feed structure is recommended. Larger feed particles have an increased retention time in the crop and the gizzard, which stimulates the ph drop and has a bactericide effect. An excess of feed particles smaller than 1mm causes a shortcut through the gizzard without utilization.

Most laying hens around the world get mash feed. Coarseness and homogeneity of this type of feed affect a healthy digestion, dry litter and clean eggs. Homogeneous structure limits the birds' preferential intake of larger particles and reduces competitive behavior at the feeders. An attractive structure supports sufficient intake of all essential nutrients. Pelleting and crumbling compound feed may help to utilize fine feed components, but the best results are usually obtained with mash feed.

## Summary and conclusions

The recommendations for optimal feeding of layers for extended laying periods of 100 weeks include:

- ➔ start during the rearing phase to prepare pullets for a long productive life
- ➔ optimize the conditions during transfer with pre-lay feeding
- ➔ assure sufficient daily nutrient intake during the early stage of production
- ➔ pay special attention to liver health and gut health throughout the life cycle
- ➔ use high quality Ca sources with fine and coarse structure and adapt ratio
- ➔ control egg weight in aging flocks

Egg shell quality determines how long a layer flock can be kept. Nutritionists and veterinarians can advise the management how to increase the profitability of egg production. For an extended production cycle of laying hens, optimal nutrition starts just after hatch to develop a pullet flock with optimal body weight, uniformity and feed intake capacity. During the physiological transition period when pullets become sexually mature and ready to lay the first egg it is important to minimize stress connected with the transfer from rearing to the layer house. Pre-lay feeding is highly recommended to assure sufficient nutrient intake to meet the growing demand before rate of lay approaches a peak near 100%. Throughout the laying period, optimal quality of fine and coarse limestone should be used, in a ratio adjusted to the age of the flock and, where possible, applying the concept of "split feeding" to maximize the availability of Ca for shell formation during the night. Feed structure affects feeding behavior and nutrient intake and should be designed to support a healthy gut.

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Freshness of eggs is considered by consumers as the most important criterion of egg quality. Data for this study were collected and analyzed as part of a master's thesis by A. Juergens. Combined effects of storage temperature and duration of storage for white-egg layers at different age are analysed and used for the prediction of changes in quality criteria.

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# Effects of storage conditions on egg quality

## Abstract
Freshness of eggs is a major concern of the consumers. The main criteria of freshness are Haugh Units, weight loss and air cell size. It was the aim of the present study to predict the development of these criteria in response to the main influencing factors: storage temperature, storage duration and hen age. A sample of 569 eggs from two flocks of a commercial white egg strain , 35 and 65 weeks of age and kept under the same management and feeding conditions, was assigned to two treatments: storage temperature (6, 15 and 22 °C) and storage duration (3, 18 and 28 days). Weight loss, air cell size, Haugh Units, shell thickness and yolk color were recorded at 3, 18 and 28 days of storage. Data was analysed using a complete three-factorial design with batch as block and hen age, storage temperature, storage duration and their interactions as effects. Multiple regression was used to analyze the response of the criteria to storage duration and temperature. There was a small but significant reduction of egg shell thickness in response to hen age. Air cell size, weight loss and Haugh Units were significantly influenced by storage duration and the interaction of storage duration with storage temperature. There was only a slight increase in air cell size and weight loss at 6 °C storage temperature. The response was much higher at 15 and 22 °C. Haugh Units decreased with increasing storage duration and storage temperature. The probability that air cell size exceeded 6 mm (the critical limit for grade A eggs) was calculated by logistic regression. More than 10 percent of eggs with air cell size larger than 6 mm will be expected from eggs stored for extended periods even at low storage temperature. Both weight loss and air cell size may cause problems of compliance with existing marketing regulations. The present data can be used to predict changes in egg weight, air cell size and Haugh Units within the range of 28 days of storage and at temperatures from 6 to 22 °C.

## Keywords:
egg quality, hen age, storage duration, storage temperature

## Introduction
Chicken eggs are of excellent nutritional value for human consumption and the only food of animal origin which can be stored for several weeks in their natural condition without losing specific characteristics. The ability of eggs to be stored for several weeks evolved through their function as source of nutrients for the developing embryo. Under natural conditions the hen collects a clutch of about 10 eggs before starting to brood. Therefore, the egg content has to be protected against spoilage for more than a week before brooding begins and another three weeks

Table 1: Mean initial egg weight (N) of the two batches and flock age

| Batch | Age | | Total |
|---|---|---|---|
| | 35 | 65 | |
| 1 | 66.1 (150) | 66.5 (135) | 66.3 (285) |
| 2 | 66.4 (150) | 66.3 (134) | 65.9 (284) |
| Total | 66.5 (300) | 66.5 (269) | 66.5 (569) |

until the chicks hatch. Most nutrients for the embryos are located in the egg yolk. The albumen`s main functions are to supply water and to prevent microbes from entering the egg and multiplying. In addition albumen protects the embryo against mechanic insults. The yolk and albumen are enclosed by the eggshell, which allows the exchange of carbon dioxide, oxygen and water through its pores. The eggshell has about 10,000 to 20,000 cone shaped pores with the smaller diameter at the inner position. The cuticle on the surface of the mineral shell contains proteins, polysaccharides and lipids. Inside the pores the cuticle material forms a block which closes the opening. This arrangement allows the exchange of gases and at the same time prevents intrusion of microbes. An intact cuticle is therefore of utmost importance for the shelf life of eggs. According to EU regulations, eggs of class A must have an intact cuticle and the air cell must not be larger than 6 mm. It is assumed that eggs stored up to 4 weeks still comply with the regulations, and the shelf life (best-before date) printed on retail egg packages is 28 days after packing. However, the effect of storage temperature and humidity during storage should be taken into account. Low temperature and high carbon dioxide (CO2) concentration during storage may be used to minimize the enlargement of the air cell (Scholtyssek, 1988), but the albumen height will decrease continuously even at low storage temperature and increased CO2 content of the surrounding air. As water and CO2 escape through the egg shell, pH of the albumen increases. The binding capacity of ovomucine and lysozyme decreases with storage time, resulting in reduced viscosity of albumen (Acker and Ternes, 1994). The size of the air cell depends on the storage conditions and is thus not a reliable criterion for the age of the egg. Albumen height is more reliable in this regard, but depends on egg size. The commonly used "Haugh Units" are albumen height corrected for egg size.

Other factors which influence the interior egg quality are egg size, egg shell thickness and hen age. These factors are often confounded. Eggs from older hens are usually larger and have thinner egg shells (Akyurek and Okur, 2014; Bozkurt and Tekerli, 2009; Maciel et al., 2011; Ramos et al., 2010; Sung Heon and Kying Woo, 2014). The nutrition of the hens, especially supply of calcium, phosphorus and vitamin D, influence eggshell thickness and resistance to breakage. Albumen quality mainly depends on genetic factors and can only be marginally influenced by nutrition. Low pH in the drinking water may improve albumen height. Organic acids in the feed however, do not affect this criterion (Grashorn and Simonovic, 2009). Respiratory diseases like infectious bronchitis and egg drop syndrome have negative effects on both eggshell thickness and albumen viscosity.

The present study of internal egg quality is focused on the effects of egg storage time and temperature at different hen ages?. The results can be used as reference data for the prediction of internal egg quality after storage.

## Materials and Methods

A total of 569 eggs of grade A and weight class L (63–72g) from a barn system were used. 300 eggs from 35 weeks old and 269 from 65 weeks old LSL Classic hens were obtained for the study. Both flocks were kept in the same farm and under the same feeding and management conditions. The study involved two collection days (batches). At arrival in the laboratory, 45 eggs were assigned to each of three storage temperatures (22, 15 and 6 °C) and three storage durations (3, 18 and 28 days). Treatments and number of eggs are shown in table 1.

Eggs should not be kept below 5 °C at any time, and since it is not compulsory to cool eggs in the EU, retailers may keep them under moderate cooling at about 15 °C. The low temperature of 6 °C corresponds to the EU regulation EG 589/2008, which defines 5 °C as minimum storage temperature for eggs, plus a safety margin of 1 °C; the high temperature of 22 °C corresponds to room temperature. Large refrigerators with air exchange were used for the lower temperatures.

The first analysis was carried out 3 days after oviposition. At this age the eggs should qualify as "extra fresh", i.e. the air cell size should not exceed 4 mm. The next level of storage duration, 18 days, corresponds to the EU regulation that eggs can only be sold until that age without prior cooling, while 28 days storage corresponds to the "best-before" date printed on egg cartons. Measurements on each egg included egg weight, air cell height, shell weight, shell thickness, Haugh Units and egg yolk color (DSM fan). Haugh Units were calculated according to the following equation

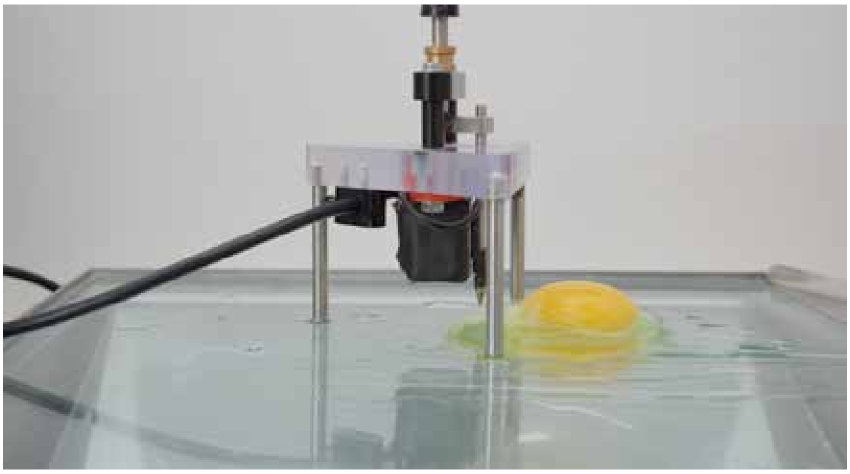

Fig. 1: Measurement of albumen height (Photo LTZ)

(Haugh, 1937; cited by Wells, 1968):

**HU = 100log (h - 1.7G $^{0.37}$ +7.6)**

**where**
**HU = Haugh Unit;**
**h = albumen height (mm-2);**
**G = egg weight (g)**

## Statistical analysis

A preliminary check for normal distribution confirmed that none of the traits except yolk color deviated significantly from normality. The data were then subjected to a 3-factorial analysis of variance, with batch as blocked variable, hen age (35 and 65 weeks), storage duration (3, 15 and 28 days) and storage temperature (6, 15 and 22 °C) as main effects and all interactions between the three effects. A 2-factorial analysis of variance was conducted for the initial egg weight of the two batches and age groups. When the F-tests of the analysis of variance showed significant effects ($P > 0.05$) for the factors or interactions, the respective means were tested using Student´s t-test. Yolk color was analysed using ordinal logistic regression. Multiple linear regressions for weight loss, air cell height and Haugh Units were fitted in response to storage duration and temperature. The probability that air cell height exceeded 6 mm with increasing storage duration and temperature was estimated using nominal logistic regression and inverse prediction. The software JMP/SAS 11 was used for the statistical analysis.

## Results

Initial egg weight on the day of egg collection and sample size are shown in table 1. A preliminary 2-factorial analysis of variance revealed that the eggs of batch 1 were lighter than those of batch 2. Neither the effect of hen age nor of the interaction between both factors was significant. The results of the analyses of variance for air cell height, weight loss, Haugh Units and eggshell thickness are shown in table 2. The effect of batch was significant for all criteria except yolk color. Hen age showed a significant effect only on shell thickness. Storage duration significantly influenced air cell height, weight loss, Haugh Units and shell thickness but not yolk color. Significant interaction effects on air cell size, weight loss and Haugh Units were found between storage duration x storage temperature, hen age x storage duration and storage temperature.

Table 3 shows the eggshell thickness (with shell membranes) for different hen age and storage duration. There was a slight but significant decrease of shell thickness in 65 weeks old hens versus 35 weeks old hens. Shell thickness decreased continuously with storage duration in both age groups; the difference between 3 and 28 days storage was significant. This reflects the shrinkage if shell membranes during storage. Weight loss increased linearly with storage duration, and the slope was steeper at 15 and 22 °C than at 6 °C (figure 2). The linear fit showed a high coefficient of confidence at 15 and 22 °C storage tem-

Table 2 Results of the analysis of variance: Degrees of freedom (DF) and p-values-values of the different variance sources

| Source | DF | Air cell size | Weight loss | Haugh Units | Shell thickness |
|---|---|---|---|---|---|
| Hen age (HA) | 1 | 0.696 | 0.893 | 0.533 | <0.001 |
| Storage Duration (SD) | 2 | <0.013 | <0.001 | <0.009 | <0.037 |
| Storage Temperature (ST) | 2 | 0.098 | 0.860 | 0.910 | 0.225 |
| HA by SD | 2 | 0.521 | 0.875 | 0.693 | 0.257 |
| HA by ST | 2 | 0.489 | 0.819 | 0.564 | 0.111 |
| SD by ST | 4 | <0.001 | <0.001 | <0.001 | 0.624 |

Table 3 Egg shell thickness ( means in µm-2) in response to hen age and storage duration

| Age (weeks) | 3 | 18 | 28 | Mean |
|---|---|---|---|---|
| 35 | 418 | 412 | 411 | 414 a |
| 65 | 409 | 404 | 401 | 405 b |
| Mean | 413 a | 408 ab | 406 b | 409 |

**Means with different letters differ significantly (p<0.05)**

peratures but not at 6 °C. The means per storage temperature and storage duration are shown in table 3.

Up to 3 days of storage, storage temperature had no significant effect. During 18 and 28 days of storage, weight loss increased significantly with storage temperature. When the eggs were stored at 6 °C the weight loss did not exceed 1 g, but at 15 and 22 °C weight loss reached 2.58 g and 4.54 g respectively. Air cell size and Haugh Units showed a similar response to storage temperature and storage time as weight loss (figures 3 and 4).

When the eggs were cooled at 6 °C, average air cell size remained below 4 mm at 28 days of storage. At 22 °C the average air cell size exceeded 6 mm after 25 days of storage. The Haugh Units changed only marginally with storage time at 6 °C storage temperature. The slope was moderate at 15 °C and very high at 22 °C. Since the individual egg quality varies considerably within the experimental groups, the means are unreliable criteria of quality. The probability that the critical limit of 6 mm air cell size is exceeded was therefore calculated using nominal regression. The percentage of eggs exceeding 6 mm are presented as predicted values for a range of storage temperature from 6 to 22 °C. The results are shown in figure 4.

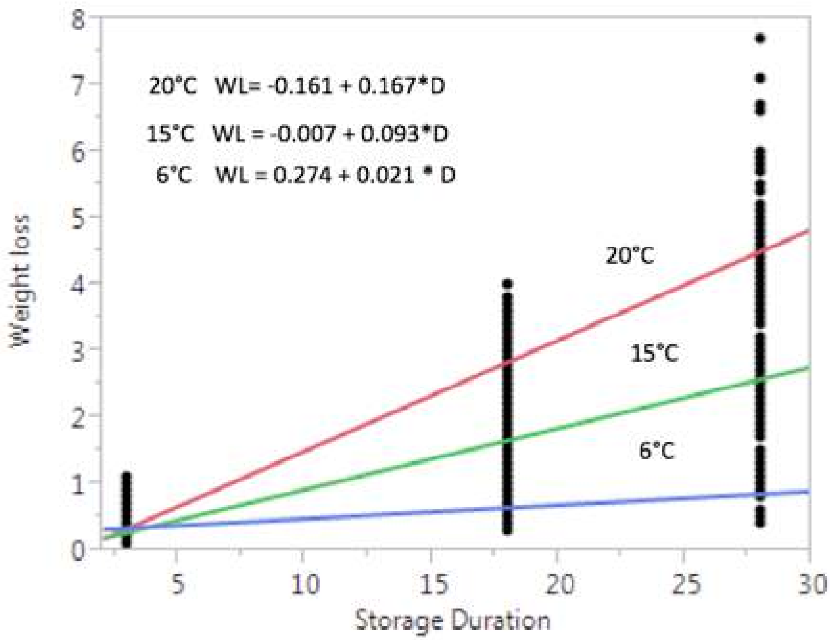


Figure 2 Linear regressions of weight loss (g) in response to storage duration (days) and temperature (6, 15 and 22 °C)

Up to 10 days of storage the probability that the air cell size is greater than 6 mm was close to zero for all storage temperatures. Thereafter the air cell size increases exponentially.. All regressions had high coefficients of determination between 0.92 and 0.99.

## Discussion

Consumers consider freshness as the most important criterion of egg quality. “Freshness” implies a short time from the day of oviposition to egg consumption and is usually measured in terms of the size of the air cell or Haugh Units. Since the air cell is easy to measure, it has become the main criterion to check the freshness of eggs. Weight loss may also be considered as a criterion, but is difficult to determine under practical conditions. Awareness of possible weight loss during storage is important from a marketing point of view, because eggs are graded soon after oviposition and may reach the consumer at a lower weight than declared on the egg package/carton. The present data show that weight loss is negligible when the eggs are stored at low temperature but will increase significantly if they are not kept in the cold store.

Weight loss and increase of the air cell are caused by the diffusion of water through the eggshell. The permeability of the eggshell depends on the thickness of the shell, number of the pores and the quality of the cuticle. Since shell thickness declines with hen age and egg weight, the latter factors are usually reported as causes of weight loss and increased size of air cell. Egg shell thickness decreased significantly with increasing hen age (table 3). Eggshell thickness was also negatively influenced by storage duration. This effect has not been observed in other egg storage experiments (Ramos et al., 2010; Maciel et al.,

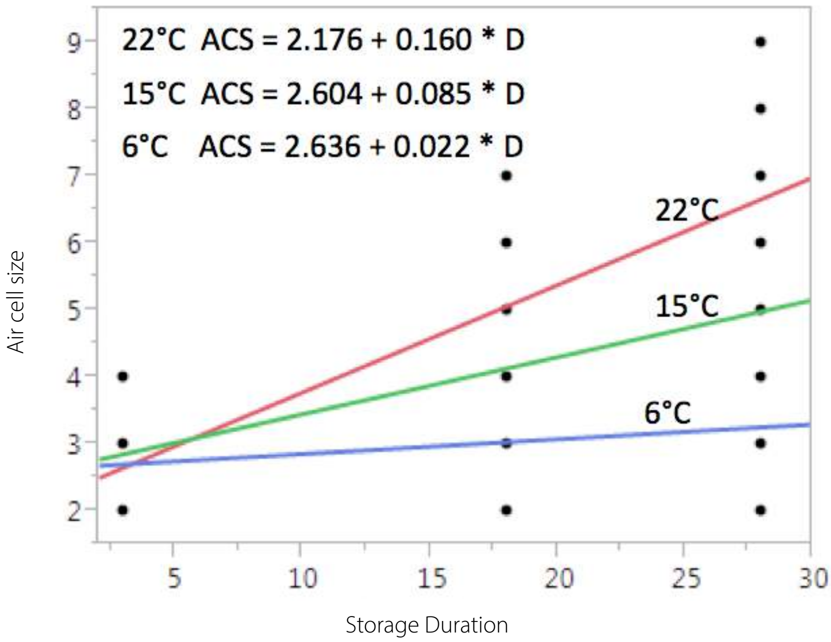


**Figure 3 Linear regressions of air cell size (ACS. mm) in response to storage duration (days) and temperature (6, 15 and 22 °C)**

2011) and may be caused by shrinking of the inner egg membrane and/or cuticle. The magnitude of the changes in egg shell thickness was, however, very small, and even at a hen age of 65 weeks shell thickness still exceeded 400 µm. In other experiments (Batkowska et al., 2014) thinner egg shells have been reported even in younger hens. Hen age in the present experiment showed no significant effect on weight loss and air cell size. This is in contrast to other studies (e.g. Bozkurt and Tekerli, 2009) and probably due to the fact that eggs of the same weight class have

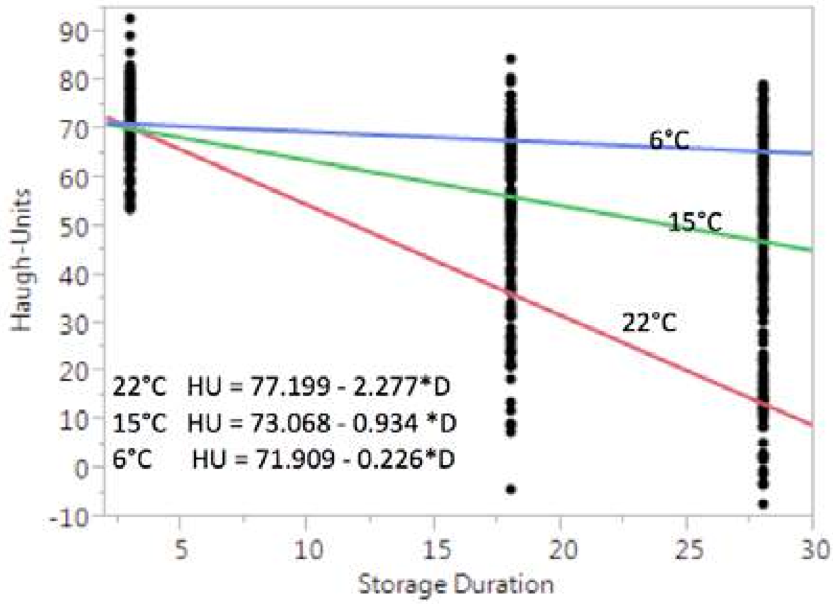


**Figure 3 Linear regressions of Haugh Units (HU) in response to storage duration (days) and temperature (6, 15 and 22 °C)**

been used and age effect was not confounded with egg weight. Size of the air cell is a key criterion in the determination of egg freshness. According to EU marketing regulations eggs of grade A should have an air cell size of less than 6 mm. Only 7 percent of the eggs are allowed to exceed 6 mm when the eggs are checked at point of sale. The regulations assume that air cell size and other quality criteria will not change significantly within a storage time of 28 days. However, as our results show, air cell size remains small through 28 days of storage only if the eggs are kept at 6 °C, but increases rapidly at 15 and 22 °C. When kept at 22 °C room temperature, the mean air cell size exceeded 6 mm after 3 weeks of storage (figure 2). The increasing percentage of eggs with air cell size over 6 mm can be estimated using nominal regression procedures. The risk of exceeding the critical size is close to zero at all temperatures within the tested range. The critical value of 7 percent of eggs exceeding 6 mm is approached at 15 to 25 days of storage, depending on storage temperature. At 28 days of storage at 22 °C more than 10 percent of the eggs are predicted to have air cells greater than 6 mm, which may be claimed by the controlling authorities. Haugh Units as criterion for inner egg quality and freshness are determined by the stability of the protein chains of the albumin (Acker and Ternes, 1994). During storage, $CO_2$ passes through the pores of the eggshell, the pH of the albumen increases, the complex forming capacity of ovomucine and lysozyme deteriorates, and the viscosity and Haugh Units decreases. In the present study, the Haugh Units remained close to 70 throughout the experiment when the eggs were stored at 6°C. This value is considered acceptable, but rather low for fresh eggs. Haugh Units decline rapidly with storage duration at 15 and 22 °C. The slope of the regression in

Figure 4: Eggs with air cell size > 6mm predicted by nominal regression in response to storage duration and temperature

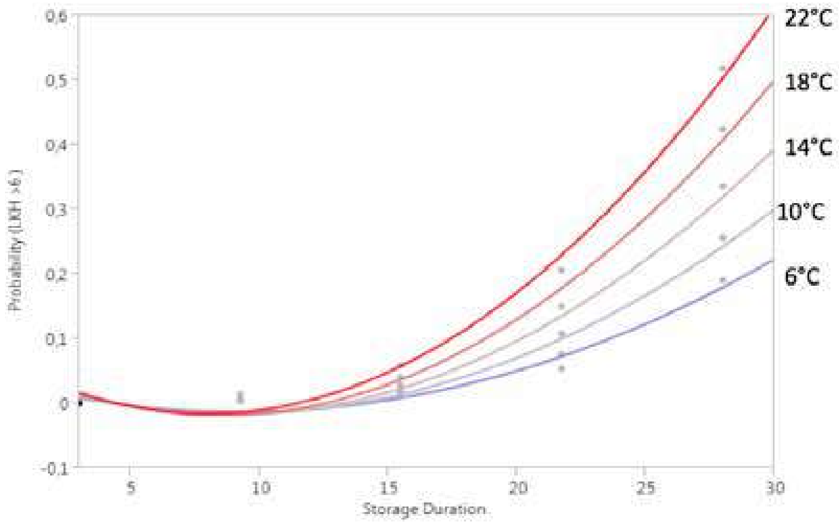


figure 3 shows that the negative effect of storage duration at 22 °C on Haugh Units is even more pronounced than on weight loss and air cell size. The decline of Haugh Units can also be considered an indicator of reduced lysozyme activity (Trziszka, 1994), known as important agent to protect the egg contents against microbial contamination.

## Conclusions

The main factors influencing internal egg quality are duration and temperature of storage, and there is a significant interaction between these two factors. Within 28 days of storage the changes in egg weight, Haugh Units and air cell size are not critical if eggs are kept at 6 °C, but there is a rapid loss of quality at temperatures of 15 and 22 °C. Haugh Units change more rapidly at high temperatures than air cell size. There is a significant decrease of egg shell thickness with increasing hen age. The critical limit for grade A eggs, i.e. the probability of exceeding 6 mm air cell size, is predicted for 10 percent of the eggs at 17 days when stored at 20 °C or at 25 days when stored at 6°C. Degradation of internal egg quality may be faster when other factors, such as disease or inadequate nutrition compromise shell quality. Cooling of eggs from the beginning of storage is therefore recommended whenever eggs are not sold and consumed within short time.

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## Hans-Heinrich Thiele

In this review of modern duck breeding, the author uses data from a leading French duck breeding company to describe priorities of the breeding program and the application of modern data recording to predict future progress in growth potential, feed efficiency and carcass quality.

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# Breeding Pekin Ducks for Meat Production

## Abstract

The global production of duck meat was roughly 4.3 million tons in 2012. It represents a valuable source for human consumption especially in Asian countries. Most of this duck meat is produced by growing Pekin Ducks. To improve the efficiency of this business, breeding companies have been selecting for superior performance in all traits of economic importance. Selection is focused on daily gain, meatiness and feed efficiency of broiler ducks, without neglecting the number of ducklings per female housed. Using more precise data recording tools, as for instance RFID based data recording and more powerful IT technology to estimate genetic parameters and breeding values, the performance has been much improved over the last 20 years.

## Keywords:

Pekin Ducks, performance testing, genetic parameters, breeding value estimation, breeding

## Introduction

The production of duck meat increased remarkably during the last 20 years, up to about 4.3 million tons in 2012. The main producer is China, producing more than 80% of all worldwide duck meat (FAOSTAT, 2015). According to information of Guémené et al. (2011) roughly 90% of it is based on fattened Pekin Ducks. Only 4% of is produced by Muscovy Ducks and 6% of it is available as a by-product from Mule Ducks, used for the fatty liver production.

Ducks have been very popular in Asia since historical times and they remain popular until today. The Chinese not only like the high nutritive value and tastiness of the duck meat, but also utilise their feet, tongues and other by-products for human consumption and appreciate the high quality of the feathers. The duck varieties, especially the Pekin Ducks, are very robust and can be kept under various climatic conditions, often in very simple housing.

Several breeding companies are selecting ducks for meat production. Although most of them are based outside of Asia, their market share in Asian countries is high and their breeding work has to con-

**Table1: Selection traits of meat type Pekin Ducks**

| Male Lines | Female Lines |
|---|---|
| Bodyweight | Bodyweight |
| Feed Efficiency | Feed Efficiency |
| Muscle Growth | Muscle Growth |
| Liveability | Liveability |
| Fertility | Laying Performance / L. Persistency |
| – | Egg Weight |
| – | Shell Strength |
| – | Hatchability |

Fig. 1: For regular recording of body weight the ducks are placed in a special funnel fitted on a digital scale

sider market demands in Asia. This paper will focus on the selection of Pekin Ducks for meat production.

## Relevant traits and performance testing

Similar to meat type chicken breeding programs, Pekin Ducks are selected in specialized male and female lines, which are combined at the grandparent and parent level to produce commercial broiler ducks. In the male lines, the main focus of selection is on growth rate, feed efficiency, carcass yield and meat quality, while the female lines are also selected for egg production and hatchability.

At 40 to 45 days, the broiler performance of all progeny of all pure lines and their crossbred offspring are tested. Increasing the daily gain and reducing the slaughter age at the same time, was, like in meat type chicken, the main tool to accelerate the production efficiency. When processing ducks with a genetically extended growing capacity at a younger age the feed efficiency will be improved (Klemm, 1985). Those more juvenile ducks have less breast meat and less fat compared to the more matured ones. They used less nutrients and feed to form their body and have a characteristically different growing curve and "physiological age" compared to their early maturing counterparts. To improve or at least to maintain the meatiness of ducks, while selecting on feed efficiency, the focus has to be set on meat quality as well. At least the time for testing the bodyweight of pure line birds and crossbred progeny has to be adjusted to that younger age. In the ORVIA breeding program all birds are additionally graded to judge the carcass quality via the conformation. The depth of the breast muscle is precisely detected by using an ultrasonic device. Cup-up tests where full sibs or half sibs are slaughtered to record the total body composition would bring additional information but are always combined with a complete loss of valuable pure line birds. The data recorded by the selection crews are incorporated directly into the data bases. Since this is done very precisely with modern recording devices, the data are immediately available for parameter and breeding value estimation.

## Improvement of feed efficiency by selection

Feed efficiency has become more and more important for all kinds of animal production, in response to rising feed cost and awareness of limited resources and environmental issues. Therefore, individual feed intake of the birds is measured and used in selection programs. In the past, individual feed intake of meat type poultry has been recorded in single cage systems, (Thiele, 1995), but this system is unfavourable for the ducks and may not reflect feeding behaviour under commercial floor conditions. The modern RFID technology enables the breeding companies nowadays to record even small meals of individuals under nearly practical housing conditions. In these testing units not only the amount of feed consumed can be recorded, it opens the possibility to observe also the feeding behaviour of the ducks, with the frequency

Fig. 2: Breast Thickness is measured using ultrasonic technique

**Fig. 4 & 5: Feeding Station to measure individual feed intake in free moving flocks.**
**Left: Entrance of the feeder station is designed so that only one duck has access to the feeder. Ducks in the feeding station are identified using RFID technique.**
**Right: Feed hoppers are fitted to electronic scales. Feed consumption is being recorded and stored on a PC.**

of meals and the size of a single meal (Bley, 2003; Howie et al. 2009). The availability and utilisation of these "feeding stations" accelerates the genetic progress in feed efficiency. Companies which invested in this technology already several years ago gained a huge advantage, while further developing their pure line breeding stock.
Records of daily feed intake can be used to improve feed efficiency in combination with weight gain during the testing period as the commonly known FCR or, independent from metabolic body weight and weight gain, as Residual Feed Intake (RFI) (Aggrey et al., 2010; Herd and Arthur, 2009):

The laying performance is usually tested over a period of 35 production weeks. Traditionally laying birds are kept in single cage systems. ORVIA is developing a fully automatic nest system to replace single cages in future. With the new nests the laying performance can be recorded in floor pens. During the testing period, time wise information about egg weight, shell strength, fertility and hatchability are recorded. Sperm quality is analysed before males are used for pedigree reproduction. For testing the fertility and hatchability of females, the use of pooled sperm is preferred.

Estimates of heritabilities and correlations among traits are summarized in table 3. All selection criteria except liveability have a sufficiently high heritability to predict further improvement. Residual feed intake is (by definition) independent from body weight and a useful parameter to judge the conversion of feed to body mass. As in other poultry species, liveability has also limited genetic variation in Pekin Ducks and will be a preferential candidate for genomic selection.

With the exception of egg weight and shell density, the reproductive traits have a lower heritability compared to the broiler performance traits, but sufficient variation to make future progress possible.

## Estimation of genetic parameters and breeding values

In these days very powerful IT technology and software tools are available which enable the geneticists to estimate the breeding values. A quick and precise data recording combined with those possibilities enables the specialists to select the progeny of each pure line. Based on line-specific indices, the quality of males and females is judged to select and mate ducks for the next pure line pedigree generation. All economically relevant traits have to be combined in such a way, that the strategic importance of each line and its position in the crossbreeding program is taken into consideration. The main target is to improve the performance of the final product, while maintaining or improving the performance in the parent stock as well.


**Fig. 5 & 6: Testing Egg Production in Single Cages:**
**Left: single cages with nests**
**Right: Identification of individual hatching eggs is essential for pedigree reproduction**

**Table 2: Heritabilities (bold figures on the diagonal), genetic and phenotypic correlations between parameters of broiler performance traits (Male line ORVIA breeding program; n=16900)**

Genetic Correlations

| Heritability | Body Weight | Breast Thickness | Conforma-tion | Feed Efficiency[1] | Liveability |
|---|---|---|---|---|---|
| Body Weight | 0.49 | 0.50 | 0.55 | 0.01 | 0.55 |
| Breast Thickness | 0.65 | 0.32 | 0.95 | 0.07 | -0.29 |
| Conformation | 0.57 | 0.81 | 0.30 | 0.09 | -0.04 |
| [1]RFI | 0.03 | -0.02 | -0.01 | 0.39 | -0.02 |
| Liveability | -0.03 | -0.07 | 0.02 | -0.02 | 0.02 |

Phenotypic Correlations

[1] Residual Feed Intake

## Results

The parent performance of the heavy package is around 230 to 240 ducklings in 52 weeks of production. Heavy hybrids have an outstanding broiler performance. They grow in 6 weeks of age to a bodyweight of 3300-3500 g. Depending on the nutrient density of the supplied feed; the feed conversion is below 2 kg feed per kg bodyweight. Concerning meat quality, those broiler ducks produce 32-35% of muscles (skin included) of their live bodyweight and have at slaughter 72-75% yield.

The annual selection progress for heavy packages can be predicted with 50-70 g higher bodyweight at 6 weeks, 30-50 g less feed for 1 kg gain and about 1 more egg per parent.


## Summary

Pekin Ducks contribute substantially to the production of food for human consumption, especially in Asian countries. The breeding activities can enhance the effectiveness of that special part of poultry production. Comparable to other poultry species the genetics are concentrated in only a few but highly specialised companies. Duck specific performance testing and breeding value estimation is done with sophisticated tools and will be constantly further developed. Genetic progress will continue in all economically important traits.



## Acknowledgement

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Pictures to illustrate data collection were kindly contributed by the Group ORVIA, the leading French duck breeding company.


**Table 3: Heritability (bold figures on the diagonal), genetic and phenotypic correlations of growth and laying performance traits (Female line ORVIA breeding program; n=20220)**

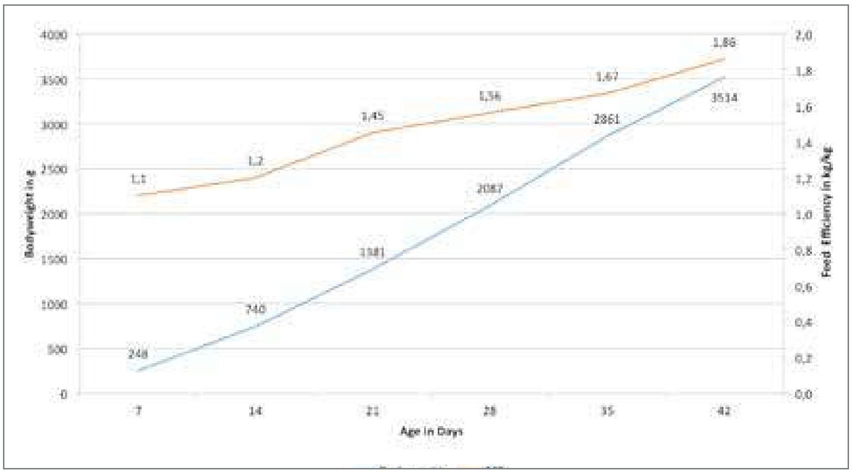
Genetic Correlations

| $h^2$ | BW | AUS | CONF | RFI | LP | PERS | EW | LIV | FERT |
|---|---|---|---|---|---|---|---|---|---|
| BW | 0.66 | 0.55 | 0.58 | -0.07 | -0.31 | -0.34 | 0.57 | 0.13 | -0.31 |
| AUS | 0.56 | 0.49 | 0.91 | 0.06 | -0.10 | -0.12 | 0.23 | 0.13 | 0.05 |
| CONF | 0.49 | 0.74 | 0.38 | 0.12 | -0.13 | -0.14 | 0.24 | 0.15 | -0.04 |
| RFI | -0.03 | 0.07 | 0.05 | 0.33 | 0.05 | 0.01 | -0.40 | 0.37 | 0.11 |
| LP | -0.19 | -0.08 | -0.08 | -0.01 | 0.29 | 0.92 | -0.26 | -0.02 | 0.69 |
| PERS | -0.18 | -0.06 | -0.07 | -0.06 | 0.78 | 0.28 | -0.24 | -0.08 | 0.67 |
| EW | 0.37 | 0.13 | 0.12 | -0.19 | -0.09 | -0.09 | 0.68 | -0.05 | -0.35 |
| LIV | 0.00 | 0.01 | 0.01 | 0.53 | -0.02 | -0.01 | -0.03 | 0.05 | -0.35 |
| FERT | -0.10 | -0.01 | -0.04 | 0.00 | 0.25 | 0.21 | -0.10 | 0.01 | 0.12 |

Phenotypic Correlations

BW=Body Weight; AUS=Breast Thickness; CONF=Conformation; RFI=Residual Feed Intake; LB=Laying Performance; PERS=Persistency; EW=Egg Weight; LIV=Liveability FERT=Fertility

Fig.7: Body weight development of ST5 Heavy from 7 to 42 days of age - Field Test Indonesia (Source: ORVIA 2014)

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# NOTES

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