Lohmann Information

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Prof. Dietmar Flock, Editor

Editorial

While writing this editorial, I am wondering whether **YOU** are finding this publication useful. Since 2006, when we started publishing Lohmann Information on-line, the address file for direct mailing has grown to over 2700 "readers" in 129 countries, and the number of "visits" of individual articles gives us a general idea which topics and which authors are of most interest. You can help us to make Lohmann Information even better in the future by suggesting topics and authors for future papers.

Depending on priorities in allocating time for reading and travel support to attend meetings, everybody can benefit from the growing body of knowledge. I had the privilege to work for a poultry breeding company which encouraged publications and enabled me to participate in WPSA meetings throughout my active years and beyond retirement. As editor of Lohmann Information, I am trying to reach especially those readers who cannot find time to attend the meetings but should be interested to keep up with some of the current issues.

I just returned from the 19th Baltic and Finnish Poultry Conference in Riga, Latvia. For me this was the 8th time since 2002 to attend this regional meeting, which may serve as an excellent example how to communicate across language barriers, bringing together colleagues and friends from industry and academia.

This issue of Lohmann Information offers the following papers as "food for thought":

1. Primary breeders have to look beyond current demand, to anticipate and respond to changing markets. **Prof. Dr. Rudolf Preisinger**, managing director of Lohmann Tierzucht GmbH, shows how increasing emphasis on poultry welfare in Europe affects data recording and practical breeding, but concludes in his article **"Layer breeding in the light of future requirements"** that the focus will remain on efficient egg production in a growing and increasingly divers global market.
2. To meet the growing demand for "organic" eggs in Germany and other countries, egg producers have to reduce feed cost while observing the limitations for organic feed formulation. **Robert Pottgüter** and **Dr. Matthias Schmutz**, Lohmann Tierzucht GmbH, offer professional advice: **"Organic egg production – how nutritionists and primary breeders can help producers to achieve better results"**.
3. Results described by **Dr. Klaus Damme**, Kitzingen, Mrs. **Ingrid Simon,** Münster, and **Dietmar K. Flock**, Lohmann Tierzucht, in their article **"Analysis of German Random Sample Tests 2010/11 with floor management and enriched cages"** suggest that the adaptability reflects genetic differences between strains, which may also be altered by selection. The LB experimental entry in these tests was in fact the new strain cross "Lohmann Brown PLUS", developed for organic egg production.

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LOHMANN TIERZUCHT

4. To maximize egg income over feed cost under any production conditions, eggs must have a strong and attractive shell, especially if sold as shell eggs. Geneticist **Dr. David Cavero *et al.***, Lohmann Tierzucht, review the subject of **"Attractive Eggshell Color as a Breeding Goal"** and present the shininess of eggs as a new candidate trait for further improvements.

5. Livability of laying hens in modern production systems has been improved over the years with the use of better diagnostic tools, prevention programs and management, but considerable variation remains. **Donald Bell**, poultry extension specialist at the University of California, reviews causes of mortality and illustrates the range of results with a single strain of layers: **"Experiences with Lohmann Selected Leghorn (LSL- Lite) Layers - Part 3: Livability"**.

6. In the final part of this series, **Donald Bell** uses field data from 74 LSL Lite flocks in the USA to show how a program developed at the University of California can be used to compare the profitability of different flocks in terms of an Index, which includes all major traits: **"Experiences with Lohmann Selected Leghorn (LSL- Lite) Layers - Part 4: Economic Evaluation of Flock Performance".** Readers interested in using the indexing software may contact the author to get tables 4A and 4B as excel files, which should enable them to modify the input data for their own modelling.

7. Differences in the air quality are often seen between housing systems. In their report **"Airborne moulds, dust and endotoxins in four alternative housing systems for laying hens"**, authors **Dr. A.C. Springorum** and **Prof. Dr. Jörg Hartung**, Veterinary Faculty of the University Hannover, report results from a recent project and quantify the statistically significant differences.

8. Poultry nutritionists around the world are challenged to design rations for specific groups of poultry on the basis of the "needs" for maintenance, growth and egg production, taking the availability and price of components into consideration. Special attention has to be paid to the quality of components, e.g. in terms of toxic loads. **Prof. Dr. Halis Oguz**, Selcuk University, Konya, Turkey, updated the literature on possibilities to reduce the negative efects of aflatoxins in his paper **"Detoxification of aflatoxin in poultry feed: a review from experimental trials"**.

With kind regards,

Prof. Dietmar Flock,
Editor

Layer breeding in the light of future requirements

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The world population passed the mark of 7 billion last year and continues to increase at a rate of about 80 million people per year; the demand for eggs is increasing at least at the same rate. The global production of eggs, estimated at 65 million tons in 2005, is predicted to increase to about 75 million tons by 2015, i.e. by 1 million tons annually within the current 10-year period. To satisfy the increasing demand, at least 50 million hens have to be added each year, assuming management conditions to support the genetic potential for 20 kg egg mass per hen.

Current per capita egg consumption and the rate of change differ considerably between continents and countries within continents, depending on traditions, purchasing power and the availability of other sources of food. Europe and North America has little growth potential, while the demand in China, India, Latin America and selected countries in Africa is expected to grow considerably, especially due to changing consumer habits of educated urban people with the necessary purchasing power.

Consumer habits and preferences for specific egg characteristics like shell colour and egg size also differ between countries and between consumers within a country. Japan, for example, has maintained one of the highest levels of consumption with more than 300 eggs per capita for decades. The custom of breaking a raw egg over a bowl of rice for breakfast helps to explain the focus on egg quality: white-shelled eggs with superior internal egg quality and guaranteed freedom from Salmonella. White eggs are also preferred in North and Central America, the Middle East, India, Taiwan and the Philippines, whereas brown eggs are preferred in most of Latin America and Europe. Tinted eggs, produced from crosses between White Leghorns and brown-egg breeds, are popular in Japan and China, but seldom seen in Europe.

The layer breeding industry has gone through significant changes during the past decades and has a remarkable record to cope with new challenges. Increased egg production, improved feed efficiency and adaptation of egg quality to consumer preferences have contributed significantly to the success of the poultry industry. Without these genetic improvements and corresponding improvement of nutrition, disease control and general farm management, the poultry industry would not have achieved its current position in the global food market. While the focus has to remain on maximizing the genetic potential for producing high quality protein at competitive cost, additional requirements of the egg industry, changing consumer habits and public opinion have to be taken into account.

Primary breeders have to look beyond current requirements and anticipate changing needs and opportunities at least five years into the future. Close communication between breeders and distributors is necessary to introduce new varieties at the right time to benefit from growing niche markets. For the global layer business, diverse markets have to be served and each of these may prefer different performance profiles of the commercial layers. This requires extensive gene pools with large elite lines which can be combined to generate strain crosses with specific attributes to meet market needs as closely as possible. Maintaining and developing new lines, testing, selection and reproduction of primary stocks involves high fixed costs in the operation and requires superior skills in quantitative genetics as well as internal organization to keep track of the availability of different sub-lines for niche markets. Genetic development, marketing and technical support have to communicate closely with local distributors to provide the best possible service for the current market and to benefit from changing requirements.

Housing systems vary between continents and within Europe. In Switzerland, Austria, Sweden and Germany, commercial layer cages have been banned for several years. Enriched cages, considered by poultry scientists as an acceptable compromise between demands of animal welfare organizations and the “needs” of laying hens, are currently being installed in many countries as an alternative to conventional battery cages. In Germany, however, major discounters have stopped selling eggs from “Kleingruppenhaltung”, and animal welfare groups continue to lobby for a complete ban on cages in Germany. In other countries, enriched cages are only used to produce table eggs for export to Germany and for the egg processing industry.

To supply the best possible combination for each market with specified optimal egg weight and most common housing system, Lohmann Tierzucht offers five different strain crosses, which are all selected with focus on efficient egg production, but with different emphasis on individual selection traits.

For line improvement, pure-line and cross-line hens are being tested in different environments: in single, small group and family cages as well as under floor conditions with a new kind of “trap-nesting”. To comply with German poultry welfare regulations, all cages had to be enriched with perches, nests and scratching areas. Daily egg production is recorded with the aid of barcode readers, various egg quality traits (mainly egg weight, shell stability and shell colour) and plumage condition are recorded on a sample basis across the production cycle. Individual feed intake and daily egg mass are determined at peak production, i.e. during the time of maximum performance, so that selection for improved efficiency reflects the capacity for sufficient feed intake at a time of greatest nutrient demand.

Testing under floor conditions with trap-nesting to measure individual egg production and egg quality was practiced in the breeding program of Lohmann Tierzucht until about 1970, but was replaced by more efficient single cage and group cage testing. Almost ten years ago, testing individual performance in floor systems has been resumed, using a specially adapted transponder technique and the Weihenstephan Funnel Nest Box to obtain individual information on egg production, nest acceptance and utilization of outdoor facilities (winter garden or free-range). The data are used in family selection for “number of saleable nest eggs”, penalizing families with poor nest acceptance which tend to produce floor eggs. The moderate heritability of “nest eggs” recorded in these floor systems suggests that further progress can be made. However, egg producers should not expect miracles from genetic selection and must pay proper attention to rearing conditions, a timely transfer to the production house and optimal nest arrangement to minimise the number of displaced eggs. Critical are also an adequate lighting regime adjusted feed formulation and feeding.

For the foreseeable future, we can safely assume that general breeding goals such as egg number, feed efficiency and egg quality traits will remain priorities. Behaviour patterns and especially behaviour anomalies are likely to get more attention outside the Western world. Suitability for floor housing and free-range systems has become more important, and this includes attention to a whole range of traits: acceptance of nests and free-range, persistent plumage cover to the end of lay, resistance to common diseases and minimal tendency to develop feather-pecking or cannibalism. National laws and regulations will reflect continuing attempts to define priorities and “sustainability” in terms of adequate nutrition for the growing human population, protection of the environment and natural resources, ethical standards for animal farming, and – last but not least – economics.

Lohmann Tierzucht will continue to invest in additional testing capacities which reflect typical field conditions in different markets. At the same time, the genetic basis of the elite lines will be expanded to accommodate the demand of growing markets, which in turn will minimise the rate of inbreeding and the risk of losing valuable genetic variation. A special program to match selected males and females at the pedigree level assures that inbreeding effects are minimized and genetic progress continues art a predictable rate.

Advances in molecular biology have contributed new techniques for selection. Using informative genetic markers, geneticists can identify individuals and families with special characteristics early in life and thereby accelerate improvements in egg production, egg quality, behaviour and liveability. These innovations complement traditional performance testing and evaluation methods based on phenotypic selection indexes of production, efficiency and quality parameters.

Combining all available performance records from relatives in several generations, locations and housing systems requires powerful computer programs, but assures that the best males and females are selected and mated to generate the next generation. Additional information based on DNA analysis is combined with traditional breeding to select males at an earlier age and to differentiate among full brothers, which used to have identical breeding values before DNA information became available. The combination of performance testing as described above and genome wide analysis is a promising tool for developing new strain crosses with a performance profile tailored to specific requirements.

The current rate of genetic progress for total efficiency of egg production appears to be even greater than it was 20 years ago. An improved structure and increased size of breeding populations, the application of new testing and recording technologies and more powerful computer systems for breeding value estimation have contributed to more efficient use of existing genetic variation. The application of new technologies will play an even greater role in improving the rate of genetic progress for layers used in conventional and none-cage environments.

Finally, we should realize that increased genetic potential needs to be "translated" into reality in commercial practice. Disease control, farm management and nutrition have to keep pace with genetic improvements, and more efficient production is no guarantee for farm income in case the markets are oversupplied.

Zusammenfassung

Legehennenzucht für den künftigen Weltmarkt unter Bedingungen deutscher Tierschutzauflagen

Der rasch wachsende Weltmarkt für Eier und Eiprodukte verlangt eine breitere Palette von Linienkombinationen mit einem an die jeweiligen Märkte angepassten Leistungsprofil. Kostengünstige Produktion von Eiern mit marktgerechter Eiqualität bleibt das Hauptziel der genetischen Entwicklungsarbeit, wobei neue Techniken der Datenerfassung und Zuchtwertschätzung weitere genetische Fortschritte erwarten lassen. Die zunehmende Belastung der Legehennenzucht in Deutschland durch strengere Auflagen des Tierschutzes wird durch erweiterte Testkapazität mit konventioneller Haltung in Ländern außerhalb der EU und Umstellung auf EU-konforme Haltung in Deutschland beantwortet.

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Organic egg production – how nutritionists and primary breeders can help producers to achieve better results

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Introduction

Consumers in Europe are increasingly prepared to pay more for food with a quality label, assuming that this food tastes better, is healthier for them or is produced on farms certified for improved animal welfare and/or protection of the environment. For example, in Germany average consumers spend less than 11% of their available income for food, and discounters are trying to increase their margins by offering a choice of organic food with various "Bio" labels.

The share of organically produced eggs in Germany has been steadily increasing in recent years and reached more than 7 % in 2011. The increasing demand has not escaped the attention of primary breeders who are offering efficient laying hens for any kind of egg production system. To be sure, the regular white-egg and brown-egg strains bred by Lohmann have shown excellent results under different conditions, but the results on organic farms tended to be more variable, and there was an apparent need to assist organic egg producers with recommendations for optimal feed formulation and, if possible, laying hens adaptable to the limitations of organic feed.

Contacts between DEMETER, one of the leading associations in Germany promoting organic food production, and Lohmann Tierzucht GmbH as a primary breeder of modern laying hens started in 2008 to discuss whether and how organic egg production could be realized with commercial strain crosses developed for efficient egg production in conventional systems. Although the discussions were focused on adequate feed formulation, DEMETER made it clear that they were interested in offering their members (and other organic farming associations) commercial chicks from parents managed according to the strict specifications of organic egg production.

General considerations from the nutritionist's point of view

Assuming affluent consumers prefer organic eggs and are prepared to pay for the higher price, the poultry nutritionist is challenged to design the "best possible" feed, introducing the restrictions of organic production in his matrix for least-cost feed formulation: no synthetic amino acids (mainly methionine) and no extracts from oil production (soya, canola, or sunflower), which are normally used as protein sources. Unfortunately, formulation of balanced feed for laying hens without essential sulfur amino acids (SAA) is quite difficult, because they need additional SAA to build and sustain their feather cover. The natural SAA content of conventional components is never sufficient to meet the physiological requirements of laying hens in rearing and production.

Alternative sources of essential amino acids

Instead of extracts, so-called cakes or expellers from oil seeds may be used. These are derived from cold pressed oil seeds and have a variable content of residual oil, always higher than in the extracts. Cakes and expellers always contribute cell-bound oil and additional energy into the compound feed. Linear feed programming would then suggest little or no added oil or fat, and as a result we would get a dusty feed structure, which is not desirable because this limits feed intake. Sometimes molasses is added to offset this effect, i.e. to bind the fine feed particles and to improve the acceptance of the feed.

In many cases the deficit of methionine in organic feed is being compensated by an excessive amount of crude protein, which means the hens need more organic feed to meet their SAA requirements. At the same time, the energy content of organic feed easily exceeds the recommended level (11.5 ME MJ/kg) due to the inclusion of oil cakes. Since the high energy level limits daily feed intake, the hens are unable to meet their SAA needs, which is a common cause of poor productivity, excessive mortality, feather pecking and cannibalism. To minimize these problems, we suggest to include less oil cake in the ration in order to keep the energy level lower than in our standard recommendations for barn systems (11.6 – 11.4 ME MJ/kg) to stimulate higher feed intake. We are sometimes seeing encouraging results with even less than 11.0 ME MJ/kg in organic feed, but this should not be understood as the general target.

An additional advantage of low energy rations is also the higher content of crude fiber compared to high energy diets. We have seen flocks on low energy organic feed with up to 7% crude fiber which kept their feather cover much better than organic flocks on higher energy feed. Lignocellulose may also be used as a source of crude fiber in case other feed components contain little fiber. The demand for good organic feed cannot be me met by current production potential, and the quality of organic feed tends to be variable, especially due to shortage of sun flower cake. Due to its low energy content, this component is much more suitable for organic feed than soya cake or full fat soya beans which may be used as protein source, but obviously create problems in the nutrition of organic hens.

Organic feed and egg weight

Most flocks of laying hens start with more “small” eggs and often end with more “extra large” eggs than can be sold with a satisfactory margin. To maximize egg income over feed and other cost for the lifetime of a flock, producers of organic eggs must try to reach the preferred average egg weight as early as possible and keep it from increasing thereafter. If pullets for organic egg production are reared properly, most hens should have some “reserves” in body mass and appetite to develop quickly from “pee-wee” to “small” to “medium” egg size. A more common problem is that hens on organic feed continue to increase in average egg size, while consumers may not be prepared to pay a premium for large and extra large organic eggs.

For reasons explained above, organic flocks may consume as much as 130 g per hen per day or more, especially if they are poorly feathered and/or make use of the free range during times of low temperature. In this case egg size will increase beyond the marketable size, and there is no added egg income to cover the higher feed cost. Using oil cakes and full fat soya beans in organic feed will increase the linoleic acid content, with the known additional effect to boost egg size. Producers of organic eggs therefore prefer laying hens with a lower genetic potential for egg weight, e.g. Lohmann Brown “Lite” instead of “Classic”, and the introduction of Lohmann Brown PLUS is the next step in offering producers of organic eggs a combination of genetic potential and advice for fed formulation to maximize egg income over feed cost.

Lohmann Brown PLUS: genetic adaptation to support organic egg production

A long history of reciprocal recurrent selection has resulted in highly efficient lines with a desirable performance profile for most purposes and plenty of remaining variation to pursue new targets for special demand. The concept of developing sub-lines was already used in the 1960s to select for Marek’s resistance (Flock 1974) and repeatedly since then.

When Lohmann Tierzucht GmbH decided to cooperate with DEMETER, sub-lines were established from the best families of male and female lines of LB Classic and LB Lite, using a special index to increase feed intake and body weight. The first parents of this new strain cross were housed at the end of 2009 on the farm of Mr. Schubert near Erlangen in Southern Germany. So far, this is the only distributor in the EU who keeps Lohmann Brown PLUS parent stock under organic conditions and can supply commercial pullets to producers of organic eggs.

The first generation of commercial LB PLUS layers was not expected to deviate significantly from LB Classic layers in most traits, except being somewhat heavier. Hatching eggs from this first parent flock were entered in two German random sample tests as “experimental” entry. Results are shown in the following paper by Damme *et al.* (2012) in this issue. Meanwhile, selection for higher body weight has continued, and differences from LB Classic and LB Lite should become more obvious in the years ahead.

DEMETER would also like to see the males of this strain cross to be used for “ethical” poultry meat production, but the difference in weight gain and feed efficiency compared to slow growing broiler strains is too large to expect a significant demand for this product.

Zusammenfassung

Produktion von “Bio-Eiern”: Unterstützung durch genetische Entwicklungen und verbesserte Nährstoffversorgung

Die Nachfrage nach Bio-Eiern in Europa wächst offenbar schneller als die Produktion, und variable Praxisergebnisse sind eine dauernde Herausforderung für Fütterungsberater. Seit 2009 bietet Lohmann Tierzucht GmbH Unterstützung für Biobetriebe nicht nur durch Fütterungsberatung, sondern auch eine speziell für Bedürfnisse der Biohaltung angepasste Linienenkombination unter dem Namen Lohmann Brown PLUS an. Seit 2010 bietet der Vermehrungsbetrieb Schubert Küken und Junghennen aus Elterntierherden an, die nach den Richtlinien von DEMETER gehalten werden. In diesem Beitrag werden Probleme optimaler Nährstoffversorgung für Hochleistungshennen ohne synthetische Aminosäuren erklärt und Empfehlungen für die Formulierung von Biofutter gegeben. Bei Einhaltung der Richtlinien von DEMETER kann der Bedarf essentieller Aminosäuren nur annähernd gedeckt werden, wenn die Hennen genügend Futter aufnehmen. Selektion auf höheres Körpergewicht und niedrigerer Energiegehalt des Futters sind die beiden Hebel, die Genetiker und Fütterungsexperten in enger Zusammenarbeit mit der Praxis ansetzen, um die Legehennenhaltung zur Produktion von Bioeiern zu erleichtern.

Literature:

Damme, K., I. Simon and D.K. Flock (2012): Adaptability of Laying Hens to Different Environments: Analysis of German Random Sample Tests 2010/11 with floor management and enriched cages. Lohmann Information 47 (2),

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Adaptability of Laying Hens to Different Environments: Analysis of German Random Sample Tests 2010/11 with floor management and enriched cages

K. Damme, Ingrid Simon and D. K. Flock

Introduction

Official random sample tests (RST) were organized in Germany during the 1960s and served egg producers as an independent source of information on the performance of different strains of hybrid layers. Over the years, the management of these tests was modified to reflect commercial management of laying hens as much as possible. These tests stimulated global competition among the leading primary breeders (Tixier-Boichard *et al.* 2012). Results from different tests were subjected to statistical analyses across several years to get more reliable estimates of genetic differences (e.g. Heil and Hartmann 1997) and to estimate time trends (Flock and Heil 2002). Egg producers used to be able to choose a strain on the basis of results from individual tests obtained under similar conditions as on their own farm (similar beak treatment, lighting program and nutrition), or they could draw conclusions from more reliable summaries.

Most tests in Germany and other countries have been discontinued since the 1990s. Concentration of primary breeding has led to a situation today where two global players dominate the world market, each with a range of different white-egg and brown-egg strains (Lohmann Tierzucht in Germany and Hendrix Genetics in The Netherlands), while two small breeding companies (Babolna with Tetra in Hungary and Hubbard with Novogen in France) are trying to increase their market shares.

In the late 1960s and early 1970s, when testing stations in Germany changed from floor management to conventional cages, a similar question was raised as currently with the change from conventional cages to enriched cages and floor systems: are some strains better adapted to floor conditions, while other strains perform better in modern cage systems? A direct comparison at Eickelborn (1973/74) suggested that HNL Nick Chicks performed relatively better under floor conditions, whereas other white-egg strains performed better in cages.

In 2010/11, two random sample tests in Germany were jointly planned to look again at possible interactions between strains and management systems, this time with floor vs. enriched cages. The individual results of each station have been published in DGS 18/2012 und 22/2012. In the present summary, we will examine the strain differences under conditions of floor management (Kitzingen) vs. enriched cages (Kleingruppenhaltung) in Haus Düsse, with focus on the practical question: which combination of strain and management offers the best overall results?

Data

Hatching eggs from 6 strain crosses were supplied to the testing station Kitzingen, where all chicks hatched 08/04/2010 and were reared under identical floor conditions to 18 weeks (126 days). At this age, 496 pullets per strain (4 pens with 124 each) were housed in Kitzingen, 120 pullets per strain transported to Haus Düsse, where they were housed in a *Eurovent* Big Dutchman unit of enriched cages (6 replicates with 20 hens each). All pullets were beak treated at 10 days of age. The rearing unit was equipped with A-frames, feed and water was offered ad libitum at elevated levels. The lighting program during rearing followed commercial standards, light intensity was kept at levels required by German poultry welfare regulations.

All records were kept per replicate: for egg production, feed intake and mortality on a daily or weekly basis, for egg quality traits on a sample basis; details have been published in previous reports. The design of the two simultaneous tests is shown in table 1.

Table 1: Design of Test

Strain	Haus Düsse (enriched cages)		Kitzingen (floor pens)	
	Hens per unit	Replicates	Hens per unit	Replicates
Tetra SL	20	6	124	4
Novogen Brown	20	6	124	4
LB Classic	20	6	124	4
LB Experimental	20	6	124	4
Burford Brown Exp.	20	6	124	4
LSL Classic	20	6	124	4

Statistical analysis of data and summary of results

The individual records per replicate (60 experimental units) were analyzed with standard SAS software, treating testing stations (T) and strains (S) as fixed effects; the model is shown at the bottom of table 2. Highly significant differences (P<1%) were found between testing stations for all traits except egg weight. Strain differences were also highly significant for all traits except mortality (P<5%). A significant interaction was only found for hen-housed egg production. As indicated by the R^2 values in the last line of table 2, the repeatability of results between replicates of the same strain in the same test varied considerably between traits: 93% of the variation in hen-housed eggs, but only 44% of the variation in mortality could be explained by the model, i.e. between 56% (mortality) and 7% (HH egg production) of the variation was "random".

Table 2: Analysis of variance with F-test for significance of main effects and interaction[1)]

Source of variance	DF	Eggs HD	Eggs HH	Egg wt.	Egg mass	Feed g/d	FCR g/g	Mort. %	IOFC[2)] HH
Testing Station	1	45.8**	43.5**	1.4	48.8**	50.9**	111.8**	14.4**	87.7**
Strain	5	108.4**	55.4**	12.0**	71.4**	14.0**	71.3**	3.6*	40.8**
Interaction TxS	5	3.3*	1.0	0.5	1.2	2.4	1.9	1.8	1.2
Error/R^2	48	0.93	0.88	0.57	0.90	0.74	0.91	0.44	0.92

1) Model: $Y_{ijk} = u + T_i + S_j + (TxS)_{ij} + e_{ijk}$
2) Egg income minus feed cost = Total kg egg mass - 0.3 x feed consumption per HH

The F-values from the analysis of variance indicate which traits were most or least affected by the factors in the model. For example, differences between testing stations were most important for feed conversion ratio and egg income minus feed cost and negligible for egg weight; differences between strains were most important for hen-housed egg production and least important for mortality.

Differences in performance due to management system

The environment in which the hens were tested can be characterized in terms of management system, group size, lighting conditions and nutrition. The experimental Big Dutchman Eurovent unit in Haus Düsse meets EU requirements for enriched cages and is a modification of German requirements for

Kleingruppenhaltung (KGH): it has perches on one level (Germany requires two levels)and 20 hens in 1.6 m² cages (Germany requires at least 2.5 m² for 30-60 hens) with 800 cm² per hen.

In Kitzingen, two floor systems were used for the test: Fienhage and Big Dutchman, both with 8 hens/m², average pen size 15.5 m², and 124 hens per section. The lighting programs during the laying period were identical („step-up" from 9L:15D at 18 weeks to 14L: 10D at 24 weeks of age), whereas the floor unit in Kitzingen had no control over seasonal changes in natural day length and daily light intensity (tinted window, 3% of floor space), whereas Haus Düsse had a windowless house with controlled light intensity and vertically installed high frequency fluorescent tubes.

In Haus Düsse, the same all-mash layer feed was provided ad libitum in troughs during the entire testing period (17.5 % CP, 0.4% Meth., 11.6 MJ ME and 3.6% Ca), whereas Kitzingen had a pan feeding system and applied phase feeding as follows:

Phase 1 (18-48 weeks of age): 18.0 % CP, 0.42% Meth.; 11.6 MJ ME and 3.75% Ca.
Phase 2 (49-72 weeks of age): 17.5 % CP, 0.40% Meth.; 11.4 MJ ME and 3.85% Ca.

Table 3: Trait means per testing station and significance of difference

Trait	Unit	Haus Düsse	Kitzingen	Difference
Eggs/HD	No.	314	299	15 **
Eggs/HH	No.	310	290	20 **
Rate of lay/HD	%	86.3	82.1	4.2 **
Rate of lay/HH	%	85.1	79.6	5.5 **
Av. Egg wt.	g	64.4	64.2	0.2
Total Egg mass	kg	19.96	18.61	1.35**
Feed cons.	g/HD	118.7	124.1	-5.4**
Feed cons.	kg/HH	43.2	45.2	-2.0**
Feed conversion	kg feed/kg egg	2.16	2.43	0.27**
Mortality	%	3.1	9.5	-6.4**
IOFC/HH	EUR	7.00	5.06	1.94 **

Table 3 shows the means per station and average differences between testing stations. The difference in hen-housed egg number (20 eggs) in favor of the cage system in Haus Düsse is partly explained by the higher mortality under floor conditions in Kitzingen, but hen-day production also differs by as much as 15 eggs. Feed consumption differed by 2 kg per year or 5.4 g per hen-day, which is partly explained by lower energy in phase 2 feed and more exercise in the floor systems at Kitzingen. Other possible factors for which we cannot offer quantitative data are different house temperature, feather loss, feed wastage and uncollected eggs laid outside the nests in floor systems.

Total mortality in the cage system at Haus Düsse was low (3.1%) and mainly due to egg peritonitis (10 out of 22). Total mortality in the floor system at Kitzingen was three times as high, mainly due to cloaca pecking and cannibalism (60% of total mortality), followed by peritonitis and bacterial infections. Egg income minus feed cost was 7.00 EUR in Haus Düsse vs. 5.06 EUR in Kitzingen. This difference is statistically highly significant and relevant for commercial egg production.

Less dust in the laying house and separation of the hens from their droppings in the cage system minimizes the risk of infection and recontamination. This explains why no losses in Haus Düsse were diagnosed as due to bacterial infections. The small group size of 20 hens in the *Eurovent* system allows the establishment of a fairly stable peck order, and losses due to cannibalism are less likely than in larger units.

Average strain differences for key traits

Least-squares strain means for 8 traits of major interest are summarized in table 4. The statistical significance of differences between strains was tested with a multiple T-test (Tukey test) and confirmed significant differences for all traits except mortality. To establish strain differences in traits with low heritability and repeatability like mortality, many tests with larger numbers of hens per test would be needed.

Table 4: Least squares strain means across both testing stations[3)]

Strain	Egg No. HD	Egg No. HH	Egg wt. g	Egg Mass kg/HH	Feed kg/HH	FCR kg/kg	Mortality %	IOFC EUR/HH
Tetra SL	307_{d}	300_{c}	64.1_{b}	19.22_{b}	45.18_{a}	2.298_{c}	11.1	5.66_{b}
Novogen	313_{cd}	306_{bc}	65.4_{a}	20.05_{a}	44.76_{a}	2.188_{b}	5.1	6.62_{a}
LB Classic	318_{bc}	314_{ab}	64.6_{b}	20.28_{a}	44.27_{a}	2.162_{b}	3.1	7.00_{a}
LB Exp.	322_{ab}	320_{a}	64.2_{b}	20.56_{a}	45.06_{a}	2.179_{b}	2.2	7.04_{a}
Burford	250_{e}	245_{d}	62.9_{c}	15.42_{c}	41.76_{b}	2.668_{d}	4.8	2.89_{c}
LSL	329_{a}	313_{ab}	64.5_{b}	20.16_{a}	44.00_{a}	2.071_{a}	11.2	6.96_{a}

3) different superscripts indicate significant differences between strains

Differences between commercial strains in egg income minus feed cost will be of major interest for egg producers. Since hatching eggs for the experimental LB entry were supplied by the breeding company, the results may suggest the direction of current genetic improvement. The Burford Brown layer is a cross involving the Maran breed to produce chocolate brown eggs for a niche market which is prepared to pay a premium price to recover the higher production cost per egg.

Interaction between strains and test environments

According to the results of analysis of variance shown in table 2, interactions between testing stations and strains were only significant for hen-day egg production (*p< 5%). For all other traits, the changes in ranking were negligible. Table 5 shows the difference in hen-day egg number between testing stations for each strain.

Table 5: Significant TxS interaction for hen-day egg production

Strain	Haus Düsse	Kitzingen	Difference
Tetra SL	315	300	15
Novogen Br.	326	300	26
LB Classic	332	304	28
LSL Classic	330	328	2
LB Ex p.	328	316	12
Burford Exp.	254	245	9

Discussion

The obvious conclusion from this analysis is that differences between management systems were more important than differences between commercial strains, except for highly heritable traits like egg weight. This may be of interest for egg producers outside Germany who are still free to decide in which system to invest to comply with current EU regulations and trends in other countries to replace conventional cages. Egg producers in Germany, however, who are no longer free to invest in modern cage systems, need to know which strains are coping better with existing floor systems, especially in terms of saleable eggs per hen housed and feed efficiency.

Assuming that mortality is accepted as a relevant criterion for hen wellness, we can expect breeding companies and equipment companies to focus on reduced mortality and nesting behavior. Competition among primary breeders (and different strain crosses of the same breeder) will continue, while equipment companies will offer a range of solutions which promise to harvest as many salable eggs as possible from a given unit. Interaction studies like the present test can contribute useful information and should be repeated with technical solutions which have shown promising results in practice.

Experiment stations must be free to deviate from national regulations if the design is likely to reduce mortality. Mortality will not always be as low as found in Haus Düsse, but if 3.1% can be achieved with 20 hens per unit of enriched cages, we should not accept 9.5% as a price to be paid for “hen welfare” according to German regulations. Common causes of high mortality in floor systems are known, and they should be taken into account when regulations are critically reviewed on the basis of international experience with alternative designs.

It may be of interest to compare present results with a similar test almost 30 years when German random sample tests changed from floor management to cages. In 1973/74 the Station at Eickelborn compared 12 white-egg and 17 brown-egg entries in both systems, before the floor test was terminated. All pullets were beak-treated at 8 days of age and reared in separate floor pens to measure feed intake per entry. For the laying period, 2 floor pens per entry were used with 50 pullets at a density of 4.5 per m²; 80 pullets per entry were housed in 4-bird cages at 492 cm² bird density, with replicates of 20 birds randomly distributed in the house. Results for 4 white-egg and 6 brown-egg strains are shown in table 6.

Table 6: Floor vs. cage performance of 10 strains in RST Eickelborn 1973/74

Strain	Mortality %		No. eggs/HH		Egg Mass, kg/HH		Feed Conversion	
	Floor	Cage	Floor	Cage	Floor	Cage	Floor	Cage
Babcock	4.5	6.3	240	253	14.57	15.30	3.02	2.85
Hisex white	5.0	10.0	252	265	15.29	16.24	2.91	2.71
HNL Nick Chick	**8.0**	**8.1**	**263**	**263**	**15.88**	**15.73**	**2.73**	**2.70**
Kimber white	7.0	8.1	245	261	14.96	15.96	3.01	2.84
Amber Link	6.5	4.4	234	257	14.12	15.35	3.19	3.04
Hisex brown	10.0	11.3	222	240	13.66	14.64	3.28	3.04
Hubbard GC	12.0	5.0	197	241	12.15	14.76	3.44	2.88
Kimber brown	5.5	5.6	200	249	12.94	15.44	3.69	2.87
Selaf	16.6	12.7	183	215	11.28	12.92	3.47	3.18
Warren SSL	4.0	5.0	225	258	13.93	15.84	3.31	2.90
Average	**7.9**	**7.6**	**206**	**250**	**13.88**	**14.21**	**3.20**	**2.90**

Similar to the LSL entry in the 2010/11 tests, the HNL strain had essentially the same performance in both systems, whereas other strains probably “lost” some eggs in the floor system which had been laid outside the nests, but could not be collected from the litter. In this historical test, cannibalism was negligible, and differences in total mortality could not explain the lower hen-housed egg production.

Summary and conclusion

Two random sample tests in Germany were designed to compare the performance of six strain crosses under conditions of enriched cages and floor management.

The analysis of variance confirmed highly significant differences between strains and between testing stations. Egg income over feed cost in the enriched cage system was almost 2 EUR per hen higher than in the floor management system.

Statistically significant interactions were only found for hen-day egg production. This interaction was explained by the observation that the white-egg strain LSL Classic laid almost the same number of eggs in both systems, whereas the brown-egg strains "lost" between 9 and 28 hen-day eggs in the floor system compared to enriched cages.

Zusammenfassung

Untersuchungen zur Anpassungsfähigkeit verschiedener Legelinien an Käfig- und Bodenhaltung: Ergebnisse deutscher Legeleistungsprüfungen 2010/11 mit einem Rückblick auf 1973/74

Junghennen von 6 Herkünften wurden nach gemeinsamer Aufzucht in Kitzingen auf zwei Gruppen für die Legeleistungsprüfung aufgeteilt: Bodenhaltung in Kitzingen und Kleingruppenhaltung in Haus Düsse. Die pro Untergruppe erfassten Daten wurden in Kitzingen varianz-statistisch ausgewertet und brachten folgende Ergebnisse:

(1) mit Ausnahme des hoch erblichen durchschnittlichen Eigewichts wurden in der Käfiganlage signifikant bessere Ergebnisse erzielt als in Bodenhaltung (Tab. 3).

(2) abgesehen von einer Versuchskreuzung waren die Unterschiede zwischen den Linien geringer als zwischen den Haltungssystemen (Tab. 4).

(3) Wechselwirkungen waren nur für das Merkmal Eizahl je Durchschnittshenne signifikant (Tab. 5). Zum Vergleich werden Ergebnisse aus 1973/74 angeführt (Tab. 6). Schlussfolgerungen für politische Rahmenbedingungen, Praxis und Wissenschaft werden diskutiert.

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Attractive Eggshell Color as a Breeding Goal

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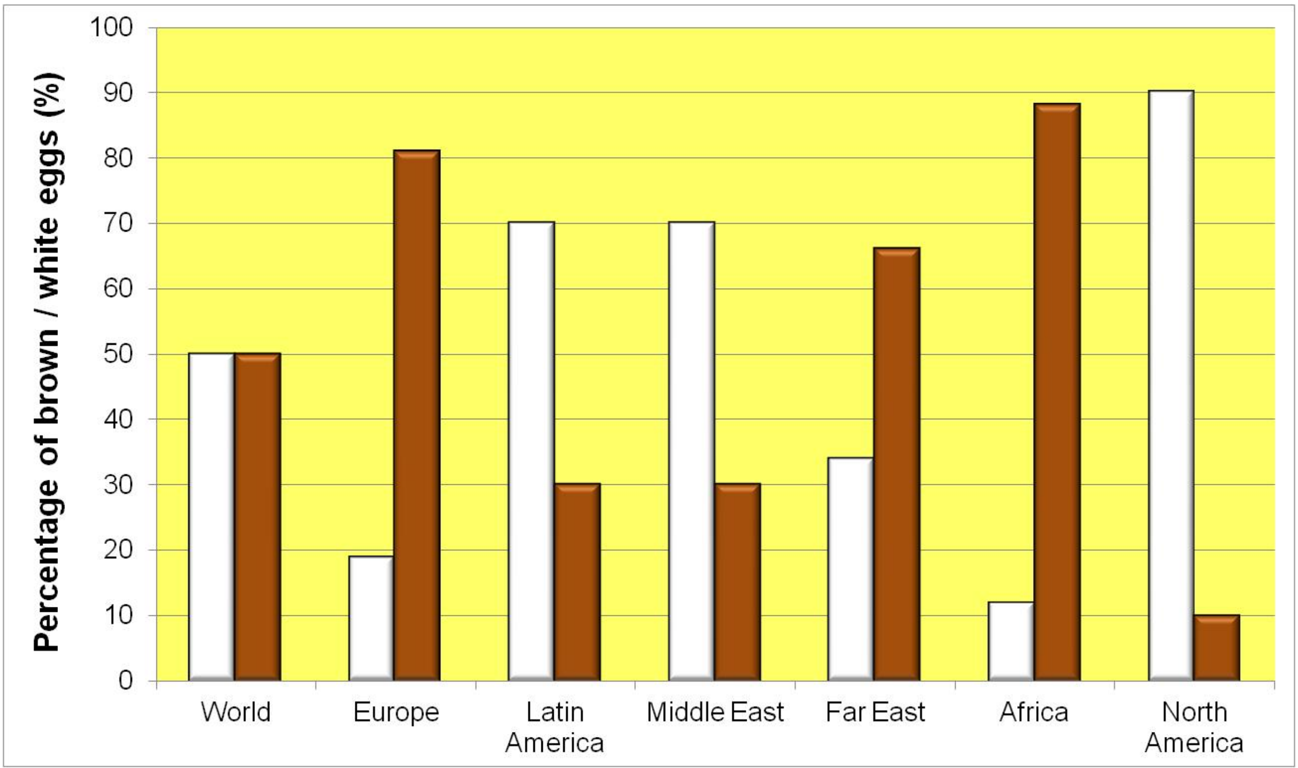
Introduction

First quality eggs must have first quality shells, i.e. they must be clean and have strong shells to withstand handling and transportation. In addition to these primary shell quality criteria and adequate egg weight, a uniform and attractive white or brown shell color is very important to the consumer.

The consumer assesses the quality of an egg according to his specific subjective demands, and one of these demands is clearly eggshell color. The proportion of white and brown eggs consumed in the world is roughly 50:50, with significant differences between continents in preferred shell color (figure 1).

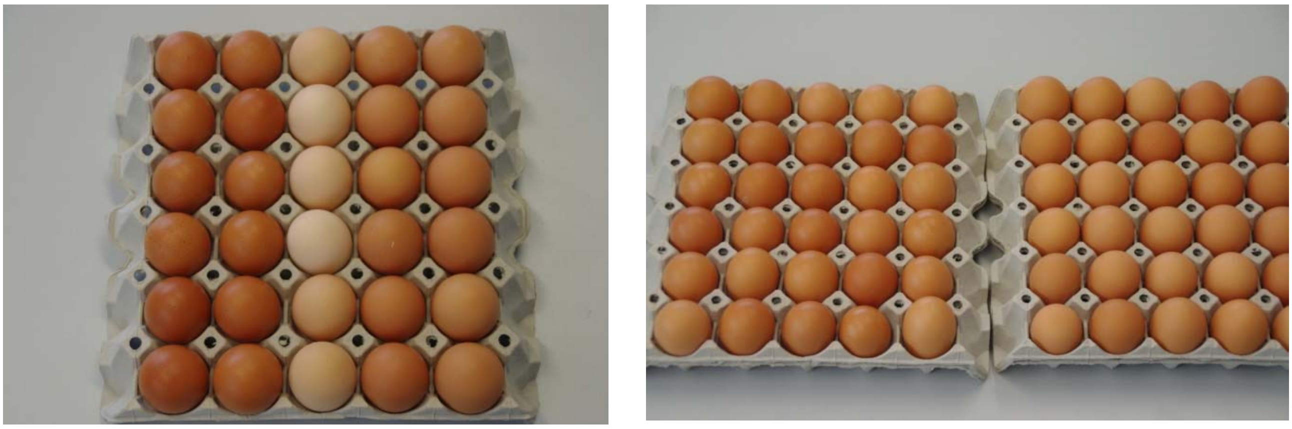
Figure 1: Estimated percentage of brown and white eggs worldwide.



Shell color is not an indication of internal egg quality and says nothing about the nutritive value or the quality of the egg (Flock *et al.*, 2007). However, many consumers who prefer brown eggs, also pay attention to intensity and uniformity of color, and pale or unevenly colored eggs may be rejected. Clearly, reduced variability of eggshell color improves the presentation of eggs at point of sale (Figure 2).

Pigments produced in the uterus at the time of shell formation are responsible for egg shell color. The brown color of eggshells is mainly caused by the pigments protoporphyrin-IX, biliverding-IX and Zinc chelate, which is distributed throughout the entire shell. Pigment is added to the shell quite late in the shell formation process. Therefore, problems with poor pigmentation may occur if the egg is laid prematurely (Nys *et al.*, 1991). Furthermore, the whitening of the shell could be due to an impairment of cut-off mechanisms toward the end of calcification or delays in the oviposition time, rather than changes in the amount of pigment deposited. The final process in shell formation is the deposition of the cuticle. Some authors have argued that eggs with poor shell pigmentation may lack the cuticle layer or parts thereof.

Figure 2. Range of shell color which may be seen in unselected flocks of mixed origin (left) vs. typical variation of shell color in flocks with good uniformity.



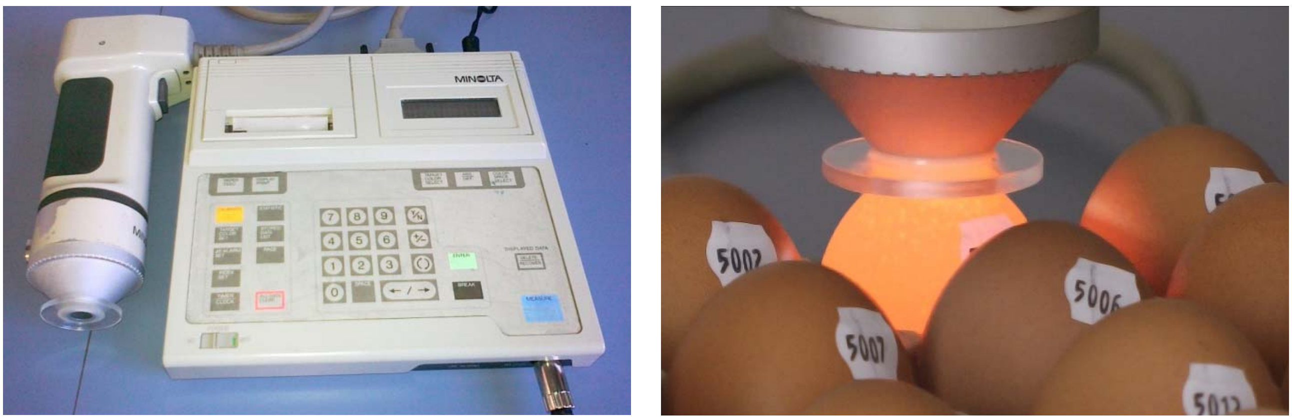
Color determination with the L*a*b* Color System

The color of an object is determined by pigments. These are chemicals which create a given color by subtracting parts of the spectrum of the incident light. The remaining light is reflected and this gives the object its color (Konica Minolta, 2012). Color is a matter of perception and subjective interpretation of the person looking at the object. When colors are classified, they can be expressed in terms of their lightness (brightness), hue (color) and saturation (vividness).

Using the Minolta device (Reflectometer CR 300, figure 3), the color of each individual egg can be objectively determined by the following three parameters:

- L*: lightness (value between 0= black and 100=white)
- a*: hue as a function of the red-green scale (<0 = green, >0 = red)
- b*: hue as a function of the blue-yellow scale (<0 = blue, >0 = yellow)

Figure 3: Reflectometer used to measure eggshell color



The L*a*b* Color System (also known as the CIELab System) was introduced in 1976 and is today one of the most commonly used systems for measuring object colors in many fields. With these three parameters, shell color can be described objectively within the color spectrum. As a* and b* increase (in absolute value) the saturation of the color increases.

In addition to subjective scoring of shell color, Lohmann Tierzucht GmbH started in the early 1990s to measure egg shell color in large numbers of pedigreed brown-egg layers with the Minolta reflectometer to speed up selection for dark shell color. Comparisons of subjective scores with the three reflectometer readings confirmed that the most attractive eggs had low L* values and high positive a* and b* values (Förster *et al.*, 1996). These authors defined "good eggshell color" with the following reference values: L* = 60, a* = 20 and b* = 30.

A shell color index based on the three color parameters is routinely calculated with the formula SCI = L* - a* - b*, lower values indicating darker shell color. While subjective scores depend on light sources in the observation room and preferences of individual graders, the objective parameters are measured on a continuous scale and can be compared across locations and years and between different ages of the same flock. More important from a breeder's point of view is that the variation within a pedigreed flock can be analyzed as a normally distributed quantitative trait and used for systematic selection in the direction of consumer preferences.

Eggshell Color as a breeding goal

Commercial brown-egg lines have been selected for attractive dark brown shells for many years, based on subjective evaluation and quantitative measurement of shell color. Moderate values of heritability for eggshell color reported in the literature range from 0.46 to 0.50 (Förster *et al.*, 1996, Zhang *et al.* 2005; Flock *et al.* 2007). As indicated by the relatively high heritability, there is considerable variation in shell color among families and individual hens within a line. Since the breeding goal is to select for dark brown eggshells, individuals with a breeding value for sub-standard shell color are unlikely to be selected - unless they are outstanding in most other traits. The overall breeding goal is focused on a high number of "saleable" eggs, i.e. to get selected, a candidate must have positive breeding values for both egg number and egg quality, while more eggs with undesirable shell quality are least desired.

Table 1: Eggshell color index of different commercial brown-egg strain crosses (Random Sample Test Ustrasice, average of conventional and enriched cages).

Breed	2006-07*	2007-08⁺	2008-09⁺	2009-10⁺	2010-11ˣ	Mean
Lohmann Brown Classic	14.9	12.9	12.1	11.9	13.8	**13.1**
Lohmann Brown Lite	16.0	15.1	15.8	13.2	15.2	**15.1**
H&N Brown Nick	14.8	12.0	12.1	15.8	16.1	**14.2**
Hy-Line Brown	15.4	16.5	12.8	15.4	14.3	**14.9**
Tetra SL	15.9	12.4	13.7	14.7	18.6	**15.1**
Bovans	19.7	15.8	?	15.9	14.5	**16.5**
ISA Brown	18.3	17.5	18.3	17.4	20.5	**18.4**
Novobrown	-	-	-	17.9	21.3	**19.6**
Average	16.7	14.4	14.4	15.0	17.1	**15.9**

Egg shell color measured in: * period 14; ⁺ period 12; ˣ period 11.

The variation from test to test (shown in table 1) indicates environmental effects, even in a standardized test environment with uniform conditions, and random variation due to small groups of birds.

Effect of hen age on eggshell color

It has been reported that older hens tend to lay larger eggs with lighter shell color. This is because the quantity of pigments deposited on the shell surface does not increase in proportion to egg size. Hence, the pigments of brown eggshells are deposited over a larger surface area as the hen ages and lays larger eggs (Solomon, 1997). Cavero *et al.* (2010) studied the influence of hen age on eggshell color. Data for the analysis were obtained from a flock of 4,400 Rhode Island Red and a flock of 4,743 White Rock pure-line hens in single cages on a breeding farm.

As shown in table 2 the eggshells became significantly lighter with increasing age in the RIR line, whereas the WR line still had excellent shell color at 60 weeks of age. The L* and b* values were relatively constant throughout time, whereas the a* values decreased considerably, especially in the RIR line. The comparison of the two breeds suggests that persistency of eggshell color is also a realistic goal for within-line selection.

Table 2: Change in eggshell color with increasing age (Cavero *et al.*, 2010)

	Rhode Island Red			White Rock		
Age (weeks)	**28**	**45**	**60**	**28**	**45**	**60**
L*	59.7	62.5	63.3	57.3	57.2	57.2
a*	19.0	17.9	13.1	20.8	20.9	18.1
b*	29.0	28.1	27.9	29.3	28.5	29.1
SCI	11.8	16.5	22.3	7.4	8.0	10.0

The genetic parameters were found to be very similar in both lines. Table 3 shows the estimated heritabilities and genetic correlations for the Rhode Island Red line.

Table 3: Estimated heritabilities and genetic correlations at different ages
(Cavero *et al.*, 2010)

	h^2 28 wks	h^2 45 wks	h^2 60 wks	r_g 28:45	r_g 28:60	r_g 45:60
L*	0.46	0.44	0.46	+0.94	+0.83	+0.96
a*	0.43	0.37	0.42	+0.94	+0.82	+0.96
b*	0.33	0.27	0.29	+0.88	+0.86	+0.98
SCI	0.42	0.35	0.40	+0.91	+0.81	+0.97

The heritability estimates of all color parameters were similar at the three ages and ranged from h^2 = 0.27 to h^2 = 0.46. Genetic correlations among the three parameters are not reported in detail here. The correlation between L* (lightness) and a* (red) was consistently highly negative in both lines (r_g = -0.82 to -0.97), whereas the correlations between b* (yellow) and L* and a* varied strongly between the lines and age at measurement (r_g = -0.01 to -0.73 and r_g = +0.02 to +0.71 respectively).

The close genetic correlations between measurements at the different ages suggests that hens which lay eggs with a dark shell color at peak production will also tend to lay dark colored eggs at the end of the cycle, indicating a strong genetic component for general shell pigmentation. If additional measurements at the end of the laying period add little to the accuracy of breeding value estimation, measuring eggshell color at an intermediate age should be sufficient to monitor and further improve lifetime eggshell color.

Relationship between shell color and other important traits

The traits included in this study were egg production in three phases: from 20 to 28 weeks (EP1), from 28 to 48 weeks (EP2) and from 48 to 72 weeks (EP3); egg weight (EW); shell strength (SS); blood and meat spots (BMS); and dark “speckles” on the eggshell (SPE). BMS and SPE are subjective scores (between 1 and 9), higher values indicating lower incidence and smaller size of the spots, i.e. desired direction from a breeding point of view.

Table 4: Genetic correlations between shell color (SCI) and other traits.

	EP1	EP2	EP3	EW	SS	BMS	SPE
Color Index	+ 0.07	- 0.08	- 0.06	+ 0.09	+ 0.19	+ 0.34	+ 0.27

Negative genetic correlations indicate lower SCI and better shell color, i.e. they are desired from a breeding point of view. The genetic correlation between shell color index and egg production is not significantly different from zero, and the slightly positive correlation with egg weight is expected as explained above. The positive genetic correlation with shell strength is small, but needs to be observed while selecting for both strong shells and attractive shell color. The significantly positive correlations with scores for speckles and blood and meat spots are in accordance with Förster *et al.*, (1996), who found that eggs with darker shells tend to have more and/or larger blood and meat spots. In fact, some of the blood or meat spots might result from the deposition of color pigments into the subsequent egg. The positive correlation between shell color and incidence of speckles confirms the expectation that the Minolta device reads the dark spots on brown eggs as "darker" brown. Some consumers actually like speckled eggs, but to avoid an increased incidence of speckles (Arango *et al.*, 2006) and achieve uniform dark brown shell color, we will continue to score the incidence of speckles in addition to taking the objective color measurements, to assure that we are selecting in the desired direction.

New ideas to describe and improve “attractiveness” of eggshell color

Some eggs look more attractive than others, because they have a natural “shine” as if they were washed and oiled. This phenomenon can be observed in both white and brown eggs with different frequency. In Europe and other countries where washing and oiling of eggs is not permitted, it would be interesting to know whether the shine of the eggs is a heritable trait which could be used to improve the attractiveness of shell eggs at point of purchase.

We have tested a new device (Spectrophotometer Minolta CM 600d) along with routine measurements of egg shell color parameters (L*a*b*). Data for shininess of eggshells were collected for two brown-egg pure lines to estimate genetic parameters for this new characteristic. Shininess is measured by comparing the reflection from different angles. An eggshell with a value of 0 has no shine and is completely matt, and the higher the measured value, the shinier is the eggshell. In this study the shininess of the eggs varied between 0 and 14, with an average of 2.6 and standard deviation 2.1. The shininess was lower in the Rhode Island Red line, compared to the White Rock line. As shown in table 5, this trait had a moderate heritability and desirable genetic correlations with all three color parameters: numerically positive with a* and b* and negative with L*.

Table 5: Heritability of the egg shell shininess and its genetic correlation with three color parameters

	$\bar{x}$ Shininess	h^2 Shininess	r_g with L*	r_g with a*	r_g with b*
Rhode Island Red	2.7	0.15	- 0.22	+ 0.25	+ 0.50
White Rock	3.4	0.39	- 0.66	+ 0.60	+ 0.10

Perhaps even more interesting than aesthetic considerations would be to find a positive relation between the shininess of the egg shell and increased protection against pathogen penetration. It seems reasonable to expect that eggs exhibiting a brilliant shine are more likely to have an intact cuticle than eggs with matt appearance.

The cuticle is a proteinaceous layer, which coats the outside of the egg and plays a major role in preventing bacteria from entering the egg. In a recent study using a dye combined with reflectance spectrometry the preliminary results suggest that the cuticle staining is a moderately heritable trait with $h^2 = 0.27$ (Bain *et al.*, 2009). An intact and functioning cuticle could play a key role in selection strategies to support food safety efforts. The measurement cited above is quite costly and time consuming, so it would be interesting to find an indirect measurement which can be recorded with less cost on many eggs. In a preliminary test with a small number of eggs no difference could be found between shiny and dull eggs in relation to the presence of the cuticle (Bain 2011, personal communication).

Conclusions

Improving eggshell quality is a significant objective for breeders to satisfy consumer preferences. The heritability of shell color is moderately high ($h^2 = 0.35$ to 0.45), which allows the breeding companies to achieve further genetic improvement in commercial layers. Shell color in brown eggs tends to deteriorate toward the end of the laying cycle, but a close genetic correlation at different ages assures that early measurements will also improve life time shell color.

There are apparently no serious antagonistic correlations with other traits except speckles on the shells and blood and meat spots in the eggs. Therefore, selection for improved eggshell color in brown-egg layers has to keep these traits in mind to avoid undesirable correlated response.

The natural shine some unwashed and unoiled eggs exhibit appears to be a moderately heritable trait, which could be used in addition to shell strength and shell color to select for attractive shell eggs. Preliminary studies with special equipment have not confirmed the assumption that the shine on eggs also reflects an intact cuticula, which would be highly desirable in the context of food safety.

While eggshell quality is receiving a lot of attention in genetic selection programs, egg producers should be aware of all non-genetic factors which must to be controlled to satisfy high customer expectations in oversupplied markets. In addition to high quality feed and water, effective control of diseases and air quality, monitoring the functioning of all equipment, special attention must be paid to frequent egg collection and egg storage under optimal conditions.

Summary

Although shell color says nothing about the nutritional value of the egg, a uniformly dark brown shell color is considered as one of the important traits for external quality. The heritability of shell color is moderately high (h2 = 0.35 to 0.45), which allows the breeding companies to improve this trait through selection. With the help of a reflectometer the shell color can be measured on a continuous objective scale, which correlates well with a subjective score, and which allows to select for this trait and to compare values across locations and years and between different ages of the same flock.

Shell color tends to become lighter as hens age, but close genetic correlations between measurements at different ages suggests that hens which lay eggs with a dark shell at peak production will also tend to lay dark colored eggs at the end of the cycle. Eggs with darker shells tend to have more and/or larger blood and meat spots, as well as a higher incidence of speckles. Exclusive reliance on the measurements with the Minolta device could therefore lead to undesirable correlated effects, unless they are monitored and compensated by using additional data.

Finally, the natural shine of the egg shell was measured comparing the reflection from different angles with the help of a spectrophotometer. It was found to be a moderately heritable trait (h2 = 0.15 to 0.39), which could be used in addition to shell strength and shell color to select for attractive shell eggs.

Zusammenfassung

Attraktive Schale als Zuchtziel

Obwohl die Schalenfarbe nichts über den Nährwert eines Eies aussagt, ist eine einheitlich dunkelbraune Eischalenfarbe ein wichtiges äußeres Eiqualitätsmerkmal. Eine hohe Heritabilität für die Eischalenfarbe (h^2 = 0,35 bis 0,45) ermöglicht eine züchterische Verbesserung dieses Merkmals durch Selektion. Mit Hilfe eines Reflektometers kann die Farbe der Eischale objektiv, in enger Beziehung zur subjektiven Farbbeurteilung, gemessen werden. Diese erfassten Farbwerte ermöglichen einen objektiven Vergleich von Eiern verschiedener Betriebe und Jahre, sowie unterschiedlicher Altersklassen einer Herde.

Die positive genetische Korrelation zwischen der Eischalenfarbe in unterschiedlichen Altersklassen zeigt, dass die Hennen welche in der Produktionsspitze Eier mit einer dunkleren Eischalenfarbe legen, auch am Produktionsende noch dunklere Eier haben, obwohl die Eischalenfarbe generell mit zunehmendem Alter der Hennen heller wird. Ungünstig sind die genetischen Beziehungen zur Schalenstabilität sowie zur Anzahl/Größe von Blut-und Fleischflecken und dem Auftreten von Sprenkeln. Diese Zusammenhänge müssen bei der Selektion berücksichtigt werden, um unerwünschte Veränderungen bei diesen Merkmalen zu vermeiden.

Weiterhin wurde der natürlich Glanz der Eischale durch einen Vergleich der Reflektion aus verschiedenen Winkeln mit einem Photospektrometer gemessen. Für dieses Merkmal wurde eine moderate Heritabilität von h^2 = 0,15 bis 0,39 geschätzt, und es kann als zusätzliches Kriterium genutzt werden, um auf noch attraktivere Eischalenfarbe zu selektieren.

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U.S. Experiences with Lohmann Selected Leghorn (LSL-Lite) Layers

****Part 3: Livability****

Donald Bell, University of California, Riverside, California, USA

Introduction

"Every flock of chickens has an inherent mortality rate and a pattern of mortality associated with age. Management programs can rarely reduce these basic levels. In some strains, this level may be as low as 0.05% per week and in others as high as 0.20% per week. Superimposed upon this "background" level are additional deaths attributable to many management problems and disease. These problems and disease will elevate this inherent level to the levels we experience in our commercial flocks today – from minor increases to a disease epidemic which may decimate an entire flock." (Bell, 1999)

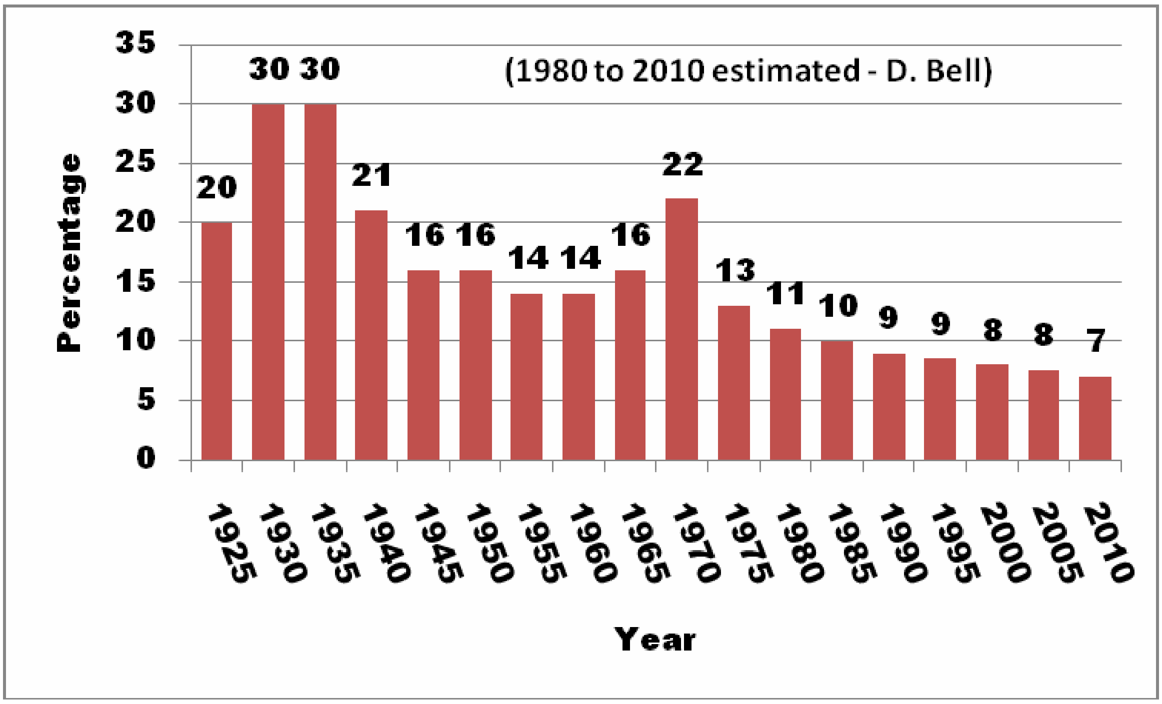
This article has two objectives: (1) to describe the more important factors which have an effect on mortality in commercial layer flocks in general and (2) to discuss in more detail recent experiences in the U.S. with the Lohmann LSL-Lite strain and the subject of mortality and/or livability.

Historical Perspective

Published data on the subject of laying flock mortality are limited before the 1950s in the context of this issue. Since then, management methods used and the performance of laying stock used have evolved into a completely different industry.

University of California studies of mortality trends in laying hen flocks are available back to 1925, but the earlier data refers to very small (<2000 hens) farms. Mortality totals and rates were based upon the entire multi-age farm and various management practices (intensive culling and all-pullet flocks) will have distorted the actual levels of mortality relative to today's rates. Figure 1 illustrates these records for a 100-year California study of layer farm and flock performance and economics.

Figure 1: Annual mortality of laying hens in the U.S. 1925 to 2010



Source: Bell (1995)

More recent studies beginning in the early 1970s have demonstrated a marked reduction in mortality rates from the 0.25%/week level at the beginning of this period to an average 0.05% to 0.10%/week level today. Much of this has come about because of genetic improvements in most strains. Another fraction has been due to changes in the proportions of the various strains being used. And finally, management decisions have been responsible for the remainder of the improvements. The following discussion will discuss many of these factors and place them in their proper context.

Age and Cycle of Production

The relationship of age to mortality rates and total mortality is probably the most predictable of the many factors to be discussed in this paper. However, the increase with age is not the same for all strains and it can be increased or decreased under the conditions described.

In general, most of today's popular strains exhibit an increasing pattern of rate of mortality during the first cycle of production. At the time of molt initiation (depending upon the severity of the molting method), mortality rates will increase for several weeks and then fall back to a lower level for the remainder of the second cycle.

A 1997/98 study of 289 U.S. layer flocks showed the following results for the first and second cycles of egg production and the molting period.

Table 1: Weekly mortality in different egg production periods

Period	Ages in Weeks	No. of flocks at start of period	Weekly mortality (%)
Cycle 1	21 to 70	289	0.144
12 week molt period	71 to 82	242	0.274
Cycle 2	83 to 110	190	0.197

Source: Bell (1999)

Weekly mortality of LSL-Lite flocks from 20 to 60 weeks of age

As shown in the following figure 2, average weekly mortality rates of the 74 LSL Lite flocks during cycle one began at 0.13% to 0.15% levels and then dropped to about 0.10% for 4-5 weeks. From 30 to 60 weeks of age, the mortality rate increased almost linearly along a straight regression line at the rate of +0.0022% per week. Projections of this trend to 80 weeks of age result in a 0.23% estimated rate of mortality at 80 weeks of age (prior to molt).

Cumulative mortality by age to 60 weeks of age

Accumulated mortality rates follow an almost perfect straight line regression. Each additional week increases total mortality by 0.14%, which would project total mortality to about 8.5% by 80 weeks of age (Figure 3). Extrapolation from the rate of increase after 45 weeks of age suggests that total mortality to 80 weeks may be closer to 10%.

Table 2 lists the average weekly and total mortality experienced for the 74-flock sample. These are actual figures and therefore are not "smooth" curves or estimates. (See Figures 2 and 3).

Figure 2: Weekly mortality rates to 60 wks of age for 74 LSL-Lite flocks

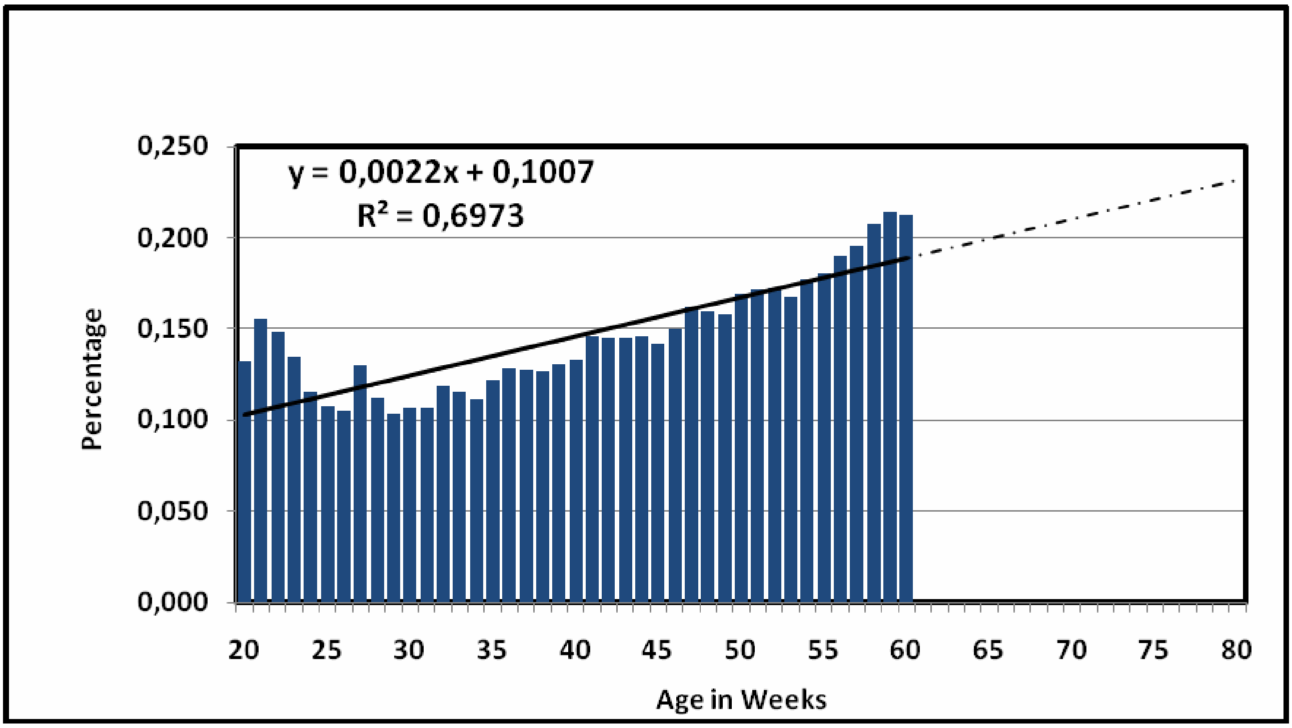


Figure 3: Total mortality to 60 weeks of age of 74 U.S. flocks of LSL-Lite

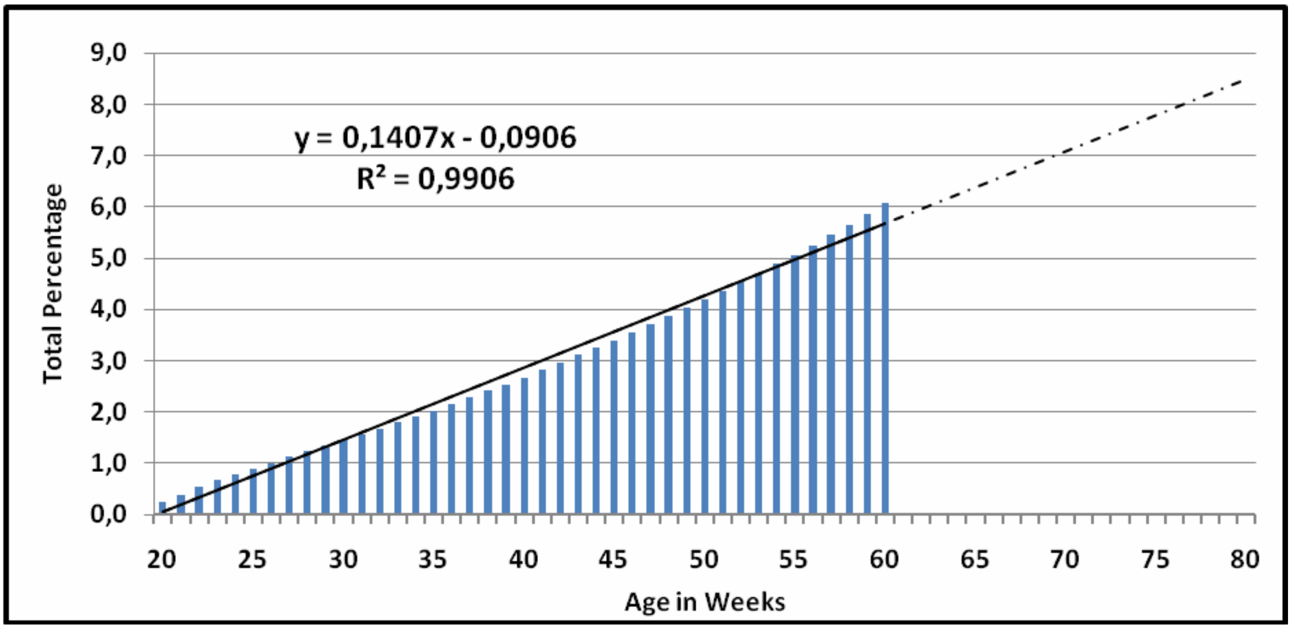


Table 2: Weekly and cumulative mortality to 60 weeks of 74 LSL-Lite flocks age

Week	Mortality (%/week)	Mortality to date (%)	Week	Mortality (%/week)	Mortality to date (%)
19	0.102	0.102	41	0.146	2.818
20	0.132	0.234	42	0.145	2.963
21	0.155	0.389	43	0.145	3.108
22	0.148	0.537	44	0.146	3.254
23	0.135	0.672	45	0.142	3.396
24	0.115	0.787	46	0.150	3.546
25	0.107	0.894	47	0.162	3.707
26	0.105	0.999	48	0.159	3.867
27	0.130	1.129	49	0.158	4.025
28	0.112	1.241	50	0.169	4.194
29	0.104	1.345	51	0.172	4.366
30	0.106	1.451	52	0.173	4.538
31	0.107	1.558	53	0.168	4.706
32	0.119	1.677	54	0.177	4.883
33	0.115	1.792	55	0.180	5.064
34	0.112	1.904	56	0.190	5.254
35	0.122	2.026	57	0.195	5.449
36	0.128	2.154	58	0.208	5.657
37	0.127	2.282	59	0.214	5.871
38	0.126	2.408	60	0.212	6.083
39	0.131	2.539			
40	0.133	2.672			

Best and Poorest Flocks

One of the more important objectives of this report is to demonstrate the full range of results which exist on commercial egg producing farms. Table 3 lists the best and poorest 5 individual flocks and the best and poorest 25% of the 74 flocks, with actual averages and the Lohmann standard for comparison. The average single-age flock consisted of 80 thousand layers at the point of housing, i.e. this study included approximately 6 million layers. Flock size varied between 38,000 for the smallest 25% and 138,000 for the largest 25% of all flocks, with no obvious relation to livability.

It is interesting to note that both the top 5 and top 25% of the flocks had lower rates of mortality than the breeder's standard for this age period. The best 5 flocks had a 97.4% livability result – a remarkable achievement.

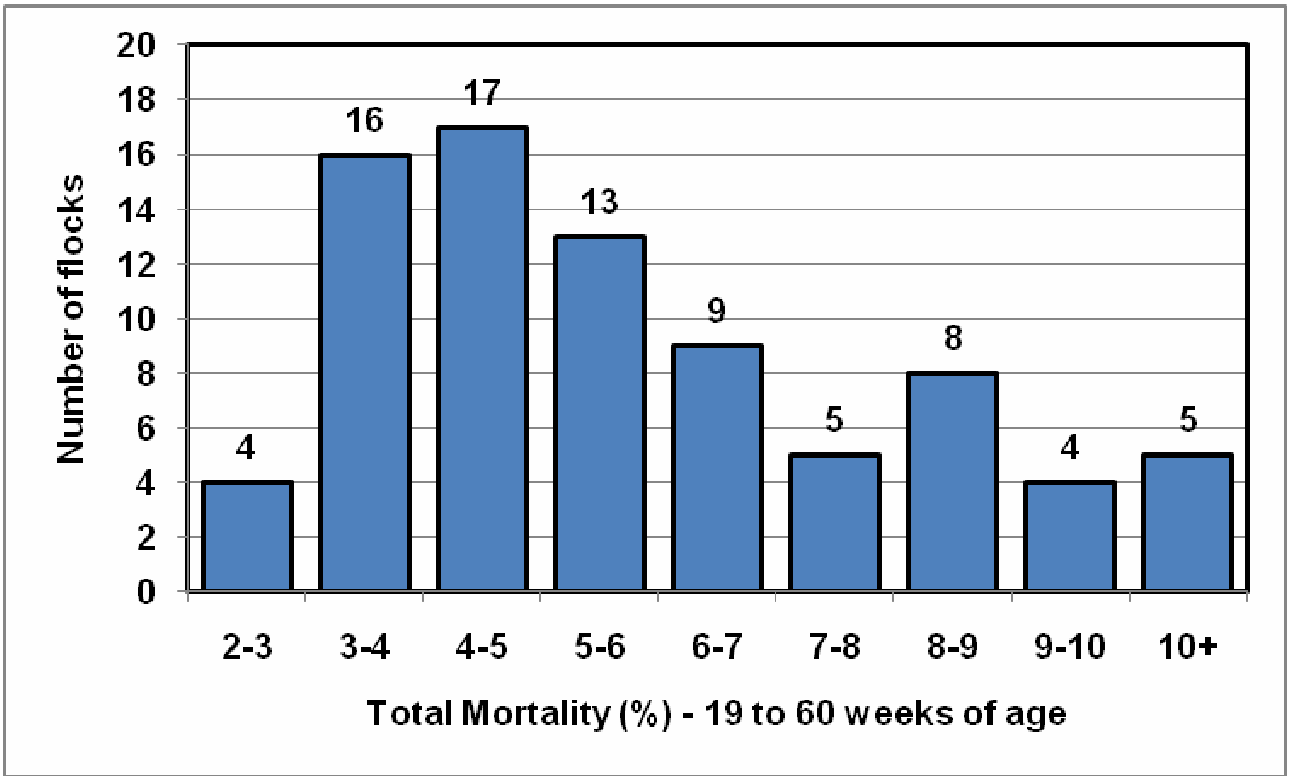
The range of results reported here is not unusual for studies of this kind. It provides us with achievable targets – opportunity for much improvement over the average, especially for the poorer managers.

Table 3: Differences in livability to 60 weeks, weekly and cumulative mortality

Trait	Best 5 flocks	Worst 5 flocks	Best 25%	Worst 25%	All 74 flocks	Lohmann Standard
Livability (%)	97.4	83.6	96.8	89.3	93.8	95.0
Weekly Mortality (%)	.08	.38	.08	.25	.14	.13
Total Mortality (%)	2.6	16.4	3.2	10.7	6.2	5.0

Figure 4 demonstrates the different mortality totals for the 74 flocks in this study. Twenty flocks (27%) had less than 4% morality to 60 wks of age.

Figure 4: Distribution of cumulative mortality from 19 to 60 weeks of age for 74 U.S. flocks of LSL Lite



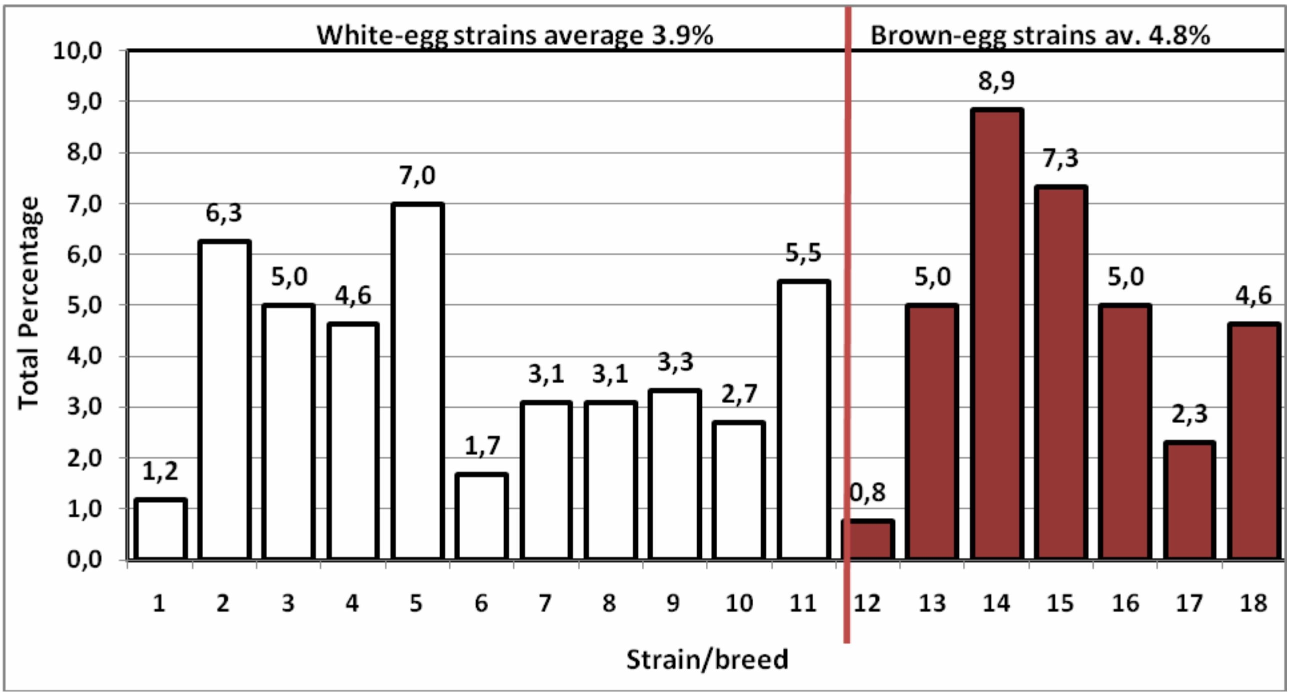
Strain Differences

Although strains and breeds perform differently relative to mortality, the author does not have sufficient data from enough commercial flocks to make satisfactory comparisons. Therefore, this discussion will be based on the recently (2011) published results from the 38th North Carolina Layer Performance and Management Test authored by Dr. Ken Anderson at NC State University.

Hatching eggs for this study were received from all major breeders, the pullets were raised in common rearing facilities and maintained as adults for two cycles of egg production. Management for all groups is comparable so that performance differences are attributable to strain or breed.

Figure 5 illustrates the differences in total mortality for each of the 11 white-egg and 7 brown-egg strains. Individual strains experienced two and three times the amount of mortality as others. White-egg strains lost 3.9% of their birds by 60 weeks of age compared to 4.8% for the brown-egg strains. Obviously, strain selection is based upon multiple performance factors, and mortality is only one of many.

Figure 5: Strain mortality totals to 60 wks. of age (all strains) in NC Test



Mortality Patterns in Various Strains

Most discussions of mortality in chicken flocks refer to hen-day or hen-housed data. Current weekly mortality should be based upon the current count of chickens. Farm managers have to focus on current flock performance to identify and solve acute problems as early as possible. Hen-housed mortality, on the other hand, is a better measure to compare total losses in subsequent flocks. The problem with total mortality is that this measure ignores **when** the birds died – an important piece of information. A 5% total loss means two different things if they die early in their productive cycle or just before sale. Birds that die at earlier ages will obviously lose more on hen-housed production. Some authors have suggested the average number of days alive during the production period as a more meaningful measure of livability.

Figure 6 compares the pattern of mortality for the two flocks with the highest and lowest total mortality in the 38th North Carolina Performance Test, **based upon 4-week periods**.

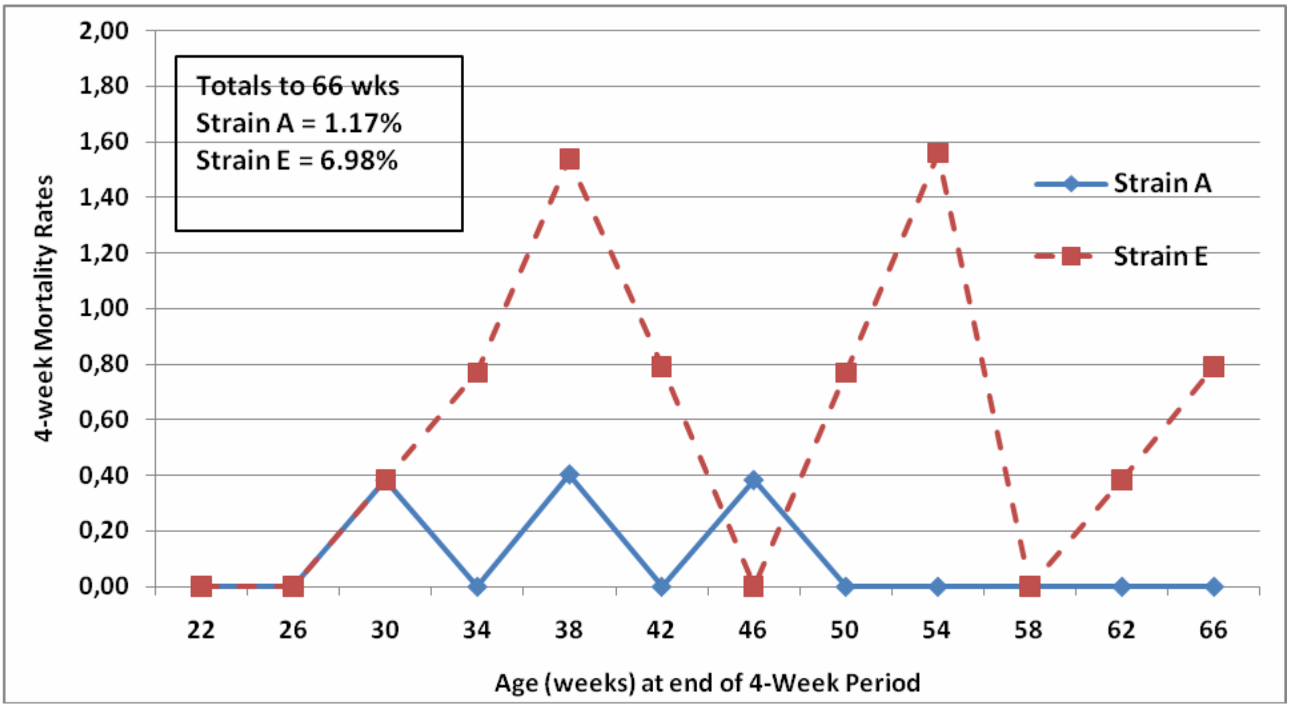
Environmental Effects – Temperature and Season

Studies relating temperature to mortality are rare because of the small numbers of birds involved in controlled experiments. Climate chambers are few in number and their capacity is usually limited to less than 100 birds each – too few to analyze the relationship of mortality to temperature. For this reason, observations of mortality records from multiple commercial flocks are a better way of determining this relationship.

Field observations from different production farms, however, are subject to many uncontrolled sources of variation and may raise a number a questions, e.g.: was the recorded temperature representative for the whole poultry house, to what extent were air quality and ventilation rates affected, and what temperature patterns were being used?

U.S. studies of hundreds of flocks housed in controlled environment buildings show only slight effects of normal temperatures or season on mortality, probably because the differences in average housing temperature observed between months were very small. As shown in Table 4, this temperature difference amounted to only 5 degrees F or 3 °C. This illustrates the excellent temperature control systems

Figure 6: Different mortality patterns in 4-week periods for two White Leghorn strains in the 38th North Carolina test 2011



5 hens per cage @ 72 square inches

being used on commercial farms today, but it says nothing about the accuracy of the measurements or the quality or the uniformity of the air. The house temperature in this study averaged 76.1 degrees F (24.5 °C) with a monthly range from 74.2 to 79.5 F (23.4 to 26.4 °C).

Seasonal and Temperature Effects on Mortality

Table 4: Weekly mortality (%) by month of lay for 368 first cycle white-egg flocks; U.S. data for two time periods (1993-94 and 2002-05).

Years	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
93-94	0.164	0.172	0.169	0.167	0.168	0.170	0.174	0.158	0.153	0.149	0.153	0.155
02-05	0.136	0.149	0.146	0.144	0.132	0.128	0.113	0.110	0.114	0.116	0.119	0.127
Av.	0.150	0.161	0.158	0.156	0.150	0.149	0.144	0.134	0.134	0.133	0.136	0.141
Av. Temp.												
°F	74.2	74.3	75.0	75.8	76.5	78.6	79.5	78.3	77.1	75.5	74.4	75.0
°C	23.4	23.5	23.9	24.3	24.9	25.9	26.4	25.7	25.1	24.2	23.6	23.9

Average 76.1 degrees F (24.5 °C)

Table 5: Weekly mortality by month of housing (at 18-20 weeks of age)

Years	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
93/94	0.164	0.195	0.145	0.156	0.163	0.164	0.178	0.169	0.155	0.145	0.167	0.163
02/05	0.120	0.141	0.110	0.101	0.122	0.125	0.194	0.119	0.173	0.123	0.114	0.113
Av.	0.142	0.168	0.128	.0129	0.143	0.145	0.186	1.144	.0164	0.134	0.141	0.138

Management Effects – Cage and Housing Density

One of the more documented factors which affect mortality is cage or housing type and density. Very large differences in mortality are associated with different housing types and, within cage systems, the addition of a single bird. Dozens of well-designed experiments have repeatedly shown from 2.6% to 6.5% increases in annual mortality when a 4th hen is added to a three-hen cage or a 7th hen to a six-hen cage (and other combinations as well).

Tables 6 and 7 summarize 52 experiments from the University of California from 1960 to 1994 using four different cage sizes.

Table 6: Higher mortality due to increased bird density per cage

Cage Size in sq. in.	Description	No. of experiments	Floor space per hen A (sq. in.)	Floor space per hen B (sq.in.)	Total Mortality (%) A	Total Mortality (%) B	Advantage A-B
<200	Small	14	85	56	9.7	15.8	+6.1
200-300	Medium	27	84	60	8.3	14.8	+6.5
300-400	Large	3	61	51	8.9	11.5	+2.6
400+	X-Large	8	60	52	16.3	19.8	+3.5
Weighted average	All	52	79	57	9.9	15.6	5.7

Source: Bell, (2002)

Table 7: Summary of Regression Analyses

X axis	Y axis	Degrees of freedom	X Coefficient	Constant	R squared
Floor space/bird (square inches)	Total Mortality (%)	87	-0.142	22.46	.301
Feeder space/bird (inches			-2.377	22.54	.285
Colony Size (birds/cage)			+1.87	5.46	.304

Source: Bell, (2002) – all regressions were at the 0.001 level of statistical significance.

Table 8 documents the effects of increasing bird density in a popular cage size (24 x 18 inches, 60 cm wide x 45 cm deep).

Table 8: Total Mortality with increasing cage density: 6, 8, 10 and 12 hens per cage

Colony Size	6	8	10	12
Floor Space/hen (square inches)	72 (465 cm²)	54 (348 cm²)	43 (277 cm²)	36 (232 cm²)
Feeder Space/hen (in.)	4.0 (10 cm)	3.0 7.5 cm)	2.4 (6 cm)	2.0 (5 cm)
Mortality Rate (%)	10.0	16.3	24.0	34.2

Source: Bell, (1983)

As more and more alternative housing types are being used in the U.S., egg producers must be careful in applying their selection criteria. Table 9 shows statistics for total mortality in five housing types, summarized in a CEAS report (2004).

Table 9: Total mortality in various housing systems (EU 2001-2003)

Item	Traditional cage	Barn/aviary/ perchery	Free-range	Organic	U.S. cages (est.)
Mortality per year (%)	6.0	9.1	10.4	13.8	7.2

Source: CEAS report (2004)

Agra CEAS (2004) summarized results from studies in three EU countries with enriched or furnished cages. Details about the different designs were not described in this report, but total mortality was low and very similar in these countries: 5.4% in Sweden (without beak trimming), 4% in Belgium and the UK (with beak treatment).

Management – Effects of Beak Trimming

Beak trimming to control cannibalism has been shown to reduce mortality in laying flocks. Different methods of trimming result in more or less control of mortality due to cannibalism. In Experiment (1), University of California research in the early 1960's compared two different beak trimming methods (7 days vs. 18 weeks) at three different cage densities (2, 3, 4 hens per 12" x 18" cage). Losses were separated into three categories: cannibalism, other causes, and culling (less than 1% were culled).

Table 10 lists the mortalities due to cannibalism; the differences were statistically significant. The differences in mortality, in turn, resulted in significantly different hen-housed egg production. Mortality was higher with precision beak trimming at 7-days, and the disadvantage of early beak trimming in terms of cannibalism became more pronounced if combined with increased cage density.

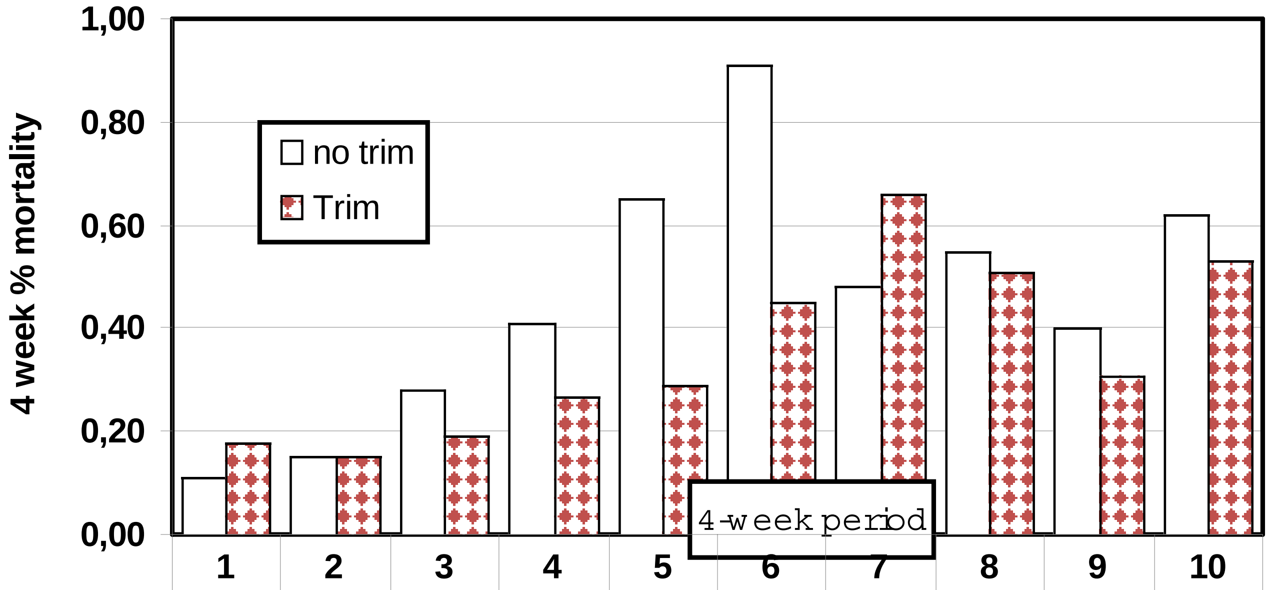
Table 10: Effects of beak trimming method and cage density on % cannibalism

Beak trimming method	Hens per cage	% cannibalism
18-week conventional	2	1.6
7-day precision	2	2.1
18-week conventional	3	4.6
7-day precision	3	12.0
18-week conventional	4	13.8
7-day precision	4	23.2

Source: Bell and Little (1966)

In a second experiment, Bell (1996) compared no beak trimming with traditional beak trimming at 7-weeks, using a strain of birds known for low mortality rates. Overall mortality averaged only 0.10% per week in this experiment, but the non-trimmed birds exhibited a 40% higher rate of mortality than their trimmed sisters within the same house (4.73% vs. 3.39%). As shown in Figure 7, the non-trimmed birds had higher mortality rates in seven of the ten 4-week periods.

Figure 7: Long-term mortality benefits from beak trimming



	1	2	3	4	5	6	7	8	9	10
no trim	0,11	0,15	0,28	0,41	0,65	0,91	0,48	0,55	0,40	0,62
Trim	0,18	0,15	0,19	0,27	0,29	0,45	0,66	0,51	0,31	0,53

Source: Bell (1996)

Summary

In this paper, possible causes of elevated mortality rates between egg production farms are discussed in general, based on published literature and personal observations. Data from 74 U.S. flocks of a single strain (LSL Lite) were used to illustrate the range of mortality which may be encountered in practice. Average results per farm for 9 farms with at least three flocks each are shown in Table 11. The remaining 19 flocks were kept on farms with only one or two flocks of LSL Lite during the years covered in this study.

Table 11: Farm to farm comparisons – only LSL-Lite flocks

Farm I.D.	Av. Flock Size (000)	No of flocks	Weekly Mortality (%)
J	100	5	0.099
A	128	4	0.104
G	68	3	0.105
E	91	8	0.109
L	38	4	0.132
H	55	17	0.144
M	77	5	0.146
D	148	4	0.174
K	53	5	0.272
Other	About 80	19	0.143

Table 11 shows the wide range of mortality between farms attributable to many of the factors discussed throughout this article. Within this fairly small group of egg producers annual mortality ranged from 0.099% to a high of 0.272% per week – a 2.7 times higher rate, without strain being a factor. It is noted that livability in the best 25% of the 74 flocks analyzed exceeds the Lohmann standard (Table 7).

Mortality is only one of several important performance traits. Egg production rates and egg size were discussed in the first article in this series, feed consumption and conversion in the second article. The following fourth article (in this issue of Lohmann Information) will focus on the economic interpretation of these multiple factors.

Zusammenfassung

**Praxisergebnisse mit LSL LITE Legehennen in den USA,
Teil 3: Verluste und Verlustursachen**

Im dritten Teil einer Serie von Untersuchungen zu Leistungsdifferenzen zwischen Praxisbetrieben geht es vorwiegend um Verlustraten und wichtige Einflussfaktoren, die einen Teil der Varianz erklären können. Anhand der Ergebnisse von 74 Herden einer einzigen Herkunft (LSL LITE) wird die Varianz zwischen Betrieben dokumentiert und interpretiert.

Verluste können bei allen Herkünften in unterschiedlicher Höhe auftreten und/oder im Laufe der Legeperiode steigen. Außergewöhnliche Verluste haben häufig Ursachen, die in wenigen Wochen abklingen. Z.B. können grobe Fehler in Futtermischungen erhöhte Verluste bringen, Feldinfektionen mit virulenten Erregern können zu Verlusten von 25 bis 50% und mehr in ungeschützten Herden führen, ganze Herde können Feuer oder extremen Temperaturen zum Opfer fallen.

Betriebsvergleiche sind ein unverzichtbares Mittel für die Beratung und sollten genutzt werden, um das genetische Leistungspotenzial in der Praxis möglichst auszuschöpfen.

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U.S. Experiences with Lohmann Selected Leghorn (LSL-Lite) Layers

**** Part 4: Economic Evaluation of Flock Performance****

Donald Bell, University of California, Riverside, California, USA

Introduction

"Flock indexing (or profiling) is a system for evaluating multiple traits of performance in table egg laying flocks. Oftentimes, flocks will experience good results in several traits with poor results in others. Flock indexing allows multiple traits to be evaluated simultaneously in relation to their economic importance. Egg production, egg size, feed consumption and mortality effects are considered along with typical feed and egg prices to come up with an index of profitability. The use of standardized egg prices and feed costs allow flock or production system comparisons over different time periods. An index is really a measure of biological performance stated in economic terms" (Bell, 1991).

This article has two objectives: (1) To describe the more important factors which have an effect on the economics of production in commercial layer flocks in general and (2) to discuss in more detail recent U.S. experiences with the LSL-Lite layer and the subject of flock evaluations.

Background

Individual flock performance monitoring became common in the 1960s when flock separation by age became prevalent. Prior to then, individual houses often contained different ages, sources and strains. The one-age house allowed improved records and more effective management.

In the early 1990s, a multi-trait record system was developed by Extension personnel of the University of California to economically evaluate flocks, programs and products. The system was field-tested on a dozen commercial farms with several hundred large flocks totaling approximately 28 million White Leghorn laying hens. Cooperating farms provided us with detailed lifetime records representing weekly performance. These records were then analyzed and reports were provided back to each cooperator.

Flock Results for 1991 and 2003 hatch dates

Results improved dramatically between flocks included in the first two studies which were 12 years apart. Egg production increased by an additional egg per hen-housed each year. The number of weeks over 90% production doubled (see Table 1).

Table 1: Changes in Performances and Economic Results between flocks hatched in 1991 vs. 2003

Measurement	1991 hatch	2003 hatch
No. Eggs/HH to 60 wks.	225	237
Weeks of 90+% HD EP	8.8	17.5
Mortality (%/wk.)	.163	.133
Egg weight (g)	60.1	59.9
Feed (lbs./dozen)	3.23	3.03
Feed (g/egg)	122	114
Total egg mass (kg/HH)	13.35	13.98
Flock Index ($/HH)	5.26	5.75

(Bell, 2012a)

Flock Index variation between flocks representing major strains of White Leghorn chickens

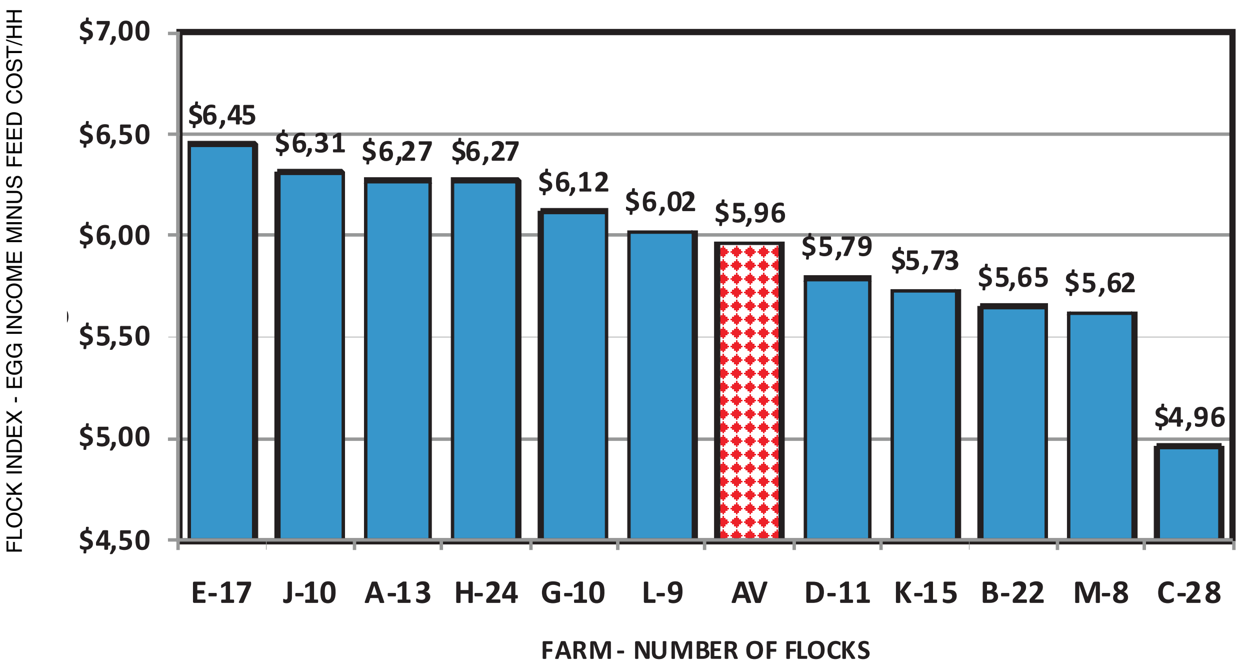
Table 2 lists the flock to flock variation in index results for an earlier study. Since nine White Leghorn strains were used, differences in performance could be attributed to many factors **including** strain selection. Arbitrary grouping into five income classes identified major index differences. A total flock index difference of approximately $1.50/HH was observed among the 165 flocks in the study.

Table 2: Frequency of Flock Indexes – 2010 U.S. study*

Classification	Egg Income minus Feed Cost Range	Number of Flocks	Percentage of Flocks
Exceptional	$6.50+	4	2.4
Excellent	$6.00 to $6.49	48	29.1
Good	$5.50 to 5.99	68	41.2
Fair	$5.00 to $5.49	33	20.0
Poor	< $5.00	12	7.3

*165 flocks (all white-egg strains) – January, 2010
Egg prices standardized at 55 cents per dozen for large eggs
Feed prices standardized at $7.50/100 pounds (16.5 cents/kg)

Figure 1: Flock Indexes U.S. study of 74 LSL-Lite flocks – Eleven Farms -



Flock variation within a single strain

Figure 1 illustrates the individual company flock indexes for the 74 LSL-Lite flocks in the most recent study. Even within this fairly short period, the total value of the differences observed was almost $1.50 per hen housed. A comparison of the results in the flock index report (see Table 4A and 4B) within or between farms reveal the traits leading to significant index differences. This example excluded “strain” as a contributor to the observed differences, because all flocks were of the same strain.

Variation between companies and flocks for each performance trait has been discussed in previous reports (Bell, 2011, 2012a, 2012b). Table 3 illustrates the range in results for the eleven farms studied in the current report.

Table 3: Range in performance and economic results between farms 2012 U.S. study – 74 LSL-Lite flocks – 20 to 60 wks of age

Measurement	Low Farm*	High Farm*	Average (11)
No. Eggs/HH	220	247	239
Mortality (%/wk.)	.075	.198	.121
Egg wt. (g/egg)	57.0	59.9	58.8
Feed (lbs./dozen)	3.00	3.19	3.07
Feed (g/egg)	113	120	116
Total egg mass (kg/HH)	12.06	14.18	14.06
Flock index ($/HH)	4.98	6.45	5.00

*Each row within a column may represent different flocks

Input Data for the Major Performance Traits

Calculation of the index requires the user to enter flock profiles in terms of records for egg production, mortality, feed consumption and egg weight. These profiles can be for a one-use-only application or may be used to represent "typical" results. We recommend to start with representative curves for each trait based upon at least five actual farm records. As flock performance changes over time, these curves should be modified.

We are now using a series of egg price data sets which are associated with different ages and case weights (360 eggs). These are developed to be used for a multi-year period. Prices can be changed over time or between flocks IF justified by major changes in the economy. The egg price/value tables can relate to actual on-going weights or to standard age relationships. Five years ago, we used a 55 cent price for one-dozen large eggs in the U.S.

Tables 4A and 4B list weekly performance traits based upon a U.S. sample of 74 LSL-Lite flocks. The spreadsheet calculates the flock index value based upon the unique data in the input and the standardized values for eggs and feed. The columns with these input values are shaded to reflect sample input.

Why are standard values used?

The only estimated values used in these projections are for egg prices and feed prices. Since these values change almost weekly, they must be standardized in order to be able to measure the real effect of performance changes – and not those caused by different prices. This allows us to make meaningful comparisons over time, between regions and countries, and between flocks hatched in different seasons.

Egg value standards

Egg values vary by the size and proportions of eggs of different weights as well as with changes in value associated with the season and market place.

Eggs may be valued based upon their average weight, by the piece or by their category (large, medium, small). Software is available to estimate the "all egg" average price based upon standard weight/category definitions and different price levels. Since these are estimates for the future, we suggest that you continue using the same standards unless there are major changes in costs or prices.

The original prices used twenty years ago were 55 cents per dozen for large eggs and $7.50 per 100 pounds of feed (16.5 cents per kg). In recent years both of these figures have become outdated. Today we use 85 cents for large eggs and $15.00 for feed. These are the values used in Figure 1 and Tables 4A and 4B. Interestingly these two combinations of egg and feed prices result in almost equal flock indexes - $5.00 to $6.00 per hen-housed to 60 weeks of age.

Sample data input and output forms

Tables 4A and 4B represent the completed input and output spreadsheets used in calculating the flock indexes for the average results from the 74 LSL-Lite flocks. The shaded areas are used for inputting new data. All the other columns are automatically calculated and represent the output. The reader can substitute his/her own figures for starting hen counts, weekly mortality, hen-day egg production, case weight for eggs (360 eggs), daily feed consumption, and egg and feed price estimates. Formulas are written in U.S. units, but can be altered to systems used in other countries.

The spread sheet calculates performance for the 20 to 60 week period of a flock's life. This period was chosen to allow for the comparisons of similar periods of time – it can be extended to 80 weeks, but care must be taken to not include variable molting ages. This would make comparisons between flocks less meaningful.

The flock indexes listed in columns 24 and 25 are the egg income minus feed costs for each hen housed at 20 weeks of age. Since laying periods and prices and costs have been standardized, the index represents the economic value of performance per se. This allows for meaningful comparisons of two or more flocks with their associated management systems. In other words: two strains may be compared or two feeding programs or any other factor of interest to the egg producer and researcher which yields different performance profiles. Positive and negative factors can be evaluated in terms of additive trait results and net worth.

Multiple Uses for Flock Indexing Software

The flock indexing software is a multi-use system for recording current flock performance and a modeling system for projecting events into the future.
Modeling allows a manager to simulate situations in a "what if" format.

Seven principle uses of this software are listed below:

1. Current actual flock results compared with various standards
2. Placing each item of performance and costs in proper perspective
3. Forecasting company results with different cost/income assumptions
4. Determining optimum replacement policies
5. Long-range planning for new investments
6. Developing marketing strategies based on accurate production forecasting
7. Testing a concept on paper before investing in the product or project

Much of the success of an egg enterprise is associated with how well it is planned from the beginning. Input comes from many individuals from within a company as well as from outside sources. In the planning stages, it is important to "try out" various ideas before they become an integral part of a company's plans for the future. Modeling is the most efficient and least expensive way to evaluate new ideas.

Profiling (flock indexing) software is presented to give the reader ideas and to stimulate their thinking about new technologies. Broad categories are listed above. The general concepts presented in this article are illustrated with actual field results for a single strain of layers. The existing software can be used by researchers or individual companies to evaluate various alternatives, and they can be modified to include many other items and relationships. With a little study, practically any output can be produced in tabular or graphic formats.

Table 4A: Flock Performance Index – Input data – 74 LSL-Lite flocks

FLOCK PERFORMANCE INDEXING				(enter)						
20 WEEK HEN COUNT:				10.000						
PERFORMANCE FACTORS										
1	2	3	4	5	6	7	8	9	10	11
		(enter)	(enter)	WKLY	(enter)		WT OF	(enter)	FEED	
AGE	AVG	%	H.D.	EGGS	EW	EW	EGGS	FD	USED	EGGS/HH
WKS	HENS	DIED	%	DOZEN	LB/CS	G/EGG	(CWT)	LBS/100	(CWT)	TO DATE
20	9.993	0,132	24,5	1.428	35,4	44,6	16,84	16,70	116,8	1,7
21	9.978	0,155	50,1	2.916	37,8	47,6	36,71	17,71	123,7	5,2
22	9.963	0,148	71,8	4.173	39,6	49,9	55,11	18,85	131,5	10,2
23	9.950	0,135	83,9	4.870	41,2	51,9	66,87	20,10	140,0	16,1
24	9.938	0,115	90,3	5.235	42,6	53,7	74,40	21,00	146,1	22,3
25	9.928	0,107	92,1	5.334	43,7	55,0	77,66	21,43	148,9	28,7
26	9.917	0,105	93,2	5.392	44,4	56,0	79,87	21,65	150,3	35,2
27	9.904	0,130	93,2	5.385	45,0	56,7	80,72	21,98	152,4	41,7
28	9.893	0,112	93,6	5.402	45,6	57,4	82,04	22,31	154,5	48,2
29	9.883	0,104	93,8	5.408	45,9	57,9	82,82	22,32	154,4	54,6
30	9.872	0,106	93,7	5.396	46,4	58,4	83,41	22,38	154,6	61,1
31	9.862	0,107	93,8	5.396	46,6	58,7	83,87	22,40	154,6	67,6
32	9.850	0,119	93,8	5.390	46,9	59,1	84,24	22,56	155,5	74,1
33	9.839	0,115	93,8	5.383	47,1	59,3	84,47	22,71	156,4	80,5
34	9.828	0,112	93,7	5.372	47,2	59,5	84,55	22,59	155,4	87,0
35	9.816	0,122	93,5	5.354	47,5	59,8	84,75	22,87	157,2	93,4
36	9.803	0,128	93,2	5.330	47,8	60,2	84,83	22,62	155,2	99,8
37	9.791	0,127	93,1	5.317	47,9	60,3	84,85	22,54	154,5	106,2
38	9.778	0,126	92,8	5.293	47,9	60,4	84,56	23,00	157,5	112,5
39	9.766	0,131	92,8	5.286	47,9	60,4	84,47	22,52	153,9	118,9
40	9.753	0,133	92,4	5.257	48,1	60,6	84,31	22,64	154,6	125,2
41	9.738	0,146	92,2	5.238	48,2	60,8	84,22	22,86	155,8	131,5
42	9.724	0,145	92,2	5.230	48,3	60,8	84,19	22,92	156,0	137,7
43	9.710	0,145	92,0	5.211	48,4	61,0	84,10	22,89	155,6	144,0
44	9.696	0,146	91,6	5.181	48,4	60,9	83,52	22,85	155,1	150,2
45	9.682	0,142	91,3	5.157	48,5	61,1	83,37	22,90	155,2	156,4
46	9.668	0,150	91,1	5.138	48,6	61,2	83,17	22,91	155,0	162,6
47	9.652	0,162	90,9	5.118	48,7	61,3	83,02	22,89	154,6	168,7
48	9.637	0,159	90,6	5.093	48,6	61,3	82,56	22,95	154,8	174,8
49	9.621	0,158	90,2	5.062	48,6	61,3	82,08	23,17	156,1	180,9
50	9.605	0,169	90,2	5.054	48,8	61,5	82,20	22,99	154,6	187,0
51	9.589	0,172	89,6	5.012	48,7	61,4	81,43	23,24	156,0	193,0
52	9.572	0,173	89,2	4.981	48,8	61,5	81,08	23,09	154,7	198,9
53	9.556	0,168	89,0	4.961	48,9	61,7	80,93	23,22	155,3	204,9
54	9.539	0,177	88,6	4.930	49,0	61,7	80,46	23,17	154,7	210,8
55	9.522	0,180	87,9	4.882	49,1	61,9	79,98	23,07	153,7	216,7
56	9.504	0,190	87,6	4.856	49,3	62,1	79,74	23,20	154,4	222,5
57	9.485	0,195	87,3	4.830	49,3	62,1	79,38	23,17	153,8	228,3
58	9.466	0,208	86,9	4.798	49,4	62,2	79,01	23,15	153,4	234,1
59	9.445	0,214	86,2	4.749	49,5	62,4	78,39	23,20	153,4	239,8
60	9.425	0,212	86,1	4.734	49,6	62,5	78,31	23,10	152,4	245,4
						Total lbs.	321.248			
			Summary of Performance (20 to 60 weeks of age)					74 flocks		
	Hen day %				87,8		Av egg wt/case (lbs)		47,12	
	Eggs/hen housed				245,4		Av egg wt/egg (g)		59,37	
	Feed/day (lbs)				0,223		Av Mortality/week (%)		0,144	
	Feed/dozen (lbs)				3,04		Total egg mass (kg/hh		14,57	
	Feed:Egg ratio				1,94		Av daily egg mass (g)		52,2	

Table 4B: Flock Performance Index – Output data – 74 LSL-Lite flocks

											0				
	ECONOMIC FACTORS				price adj + 30 = 85 cts for large eggs										
(1)	12	13		14	15	16	17	18	19	20	21	22	23	24	25
				AV EGG		EGG		EGG INCOME MINUS				EGG INCOME MINUS FEED COST/HH			
	FEED	FEED	CASE	VALUE		INCOME		FEED COST ($)							
AGE	COST	COST	WT	CTS/DOZ		$	($)	CURRENT		TO DATE		Current		TO DATE	
WKS	($)	$/DOZ	LBS	(no prem.)	(premium)	No prem.	Premium	No prem.	Premium	No prem.	Premium	No prem.	(prem.)	No prem.	(prem.)
20	1752	1,227	35,4	38,0	38,0	543	543	-1.210	-1.210	-1.210	-1.210	-0,121	-0,121	-0,121	-0,121
21	1856	0,636	37,8	36,7	36,7	1.070	1.070	-786	-786	-1.995	-1.995	-0,079	-0,079	-0,200	-0,200
22	1972	0,473	39,6	55,0	55,1	2.295	2.299	323	327	-1.673	-1.668	0,323	0,327	-0,167	-0,167
23	2100	0,431	41,2	62,5	63,0	3.043	3.068	943	968	-729	-701	0,943	0,968	-0,073	-0,070
24	2191	0,419	42,6	68,0	68,2	3.560	3.570	1.369	1.379	640	679	1,369	1,379	0,064	0,068
25	2233	0,419	43,7	72,0	72,5	3.840	3.867	1.607	1.633	2.246	2.312	1,607	1,633	0,225	0,231
26	2255	0,418	44,4	74,5	75,0	4.017	4.044	1.762	1.789	4.009	4.101	1,762	1,789	0,401	0,410
27	2286	0,424	45,0	76,0	76,4	4.092	4.114	1.807	1.828	5.815	5.929	1,807	1,828	0,582	0,593
28	2317	0,429	45,6	77,0	77,6	4.159	4.192	1.842	1.874	7.657	7.804	1,842	1,874	0,766	0,780
29	2316	0,428	45,9	77,5	78,1	4.191	4.223	1.875	1.908	9.532	9.711	1,875	1,908	0,953	0,971
30	2320	0,430	46,4	78,0	78,8	4.209	4.252	1.889	1.932	11.421	11.644	1,889	1,932	1,142	1,164
31	2320	0,430	46,6	78,4	79,1	4.231	4.268	1.911	1.949	13.332	13.592	1,911	1,949	1,333	1,359
32	2333	0,433	46,9	78,7	79,5	4.242	4.285	1.909	1.952	15.241	15.544	1,909	1,952	1,524	1,554
33	2346	0,436	47,1	78,8	79,6	4.242	4.285	1.896	1.939	17.137	17.483	1,896	1,939	1,714	1,748
34	2331	0,434	47,2	78,8	79,6	4.233	4.276	1.902	1.945	19.039	19.428	1,902	1,945	1,904	1,943
35	2357	0,440	47,5	79,0	80,0	4.229	4.283	1.872	1.926	20.911	21.354	1,872	1,926	2,091	2,135
36	2328	0,437	47,8	79,0	80,1	4.210	4.269	1.882	1.941	22.793	23.295	1,882	1,941	2,279	2,329
37	2318	0,436	47,9	79,0	80,0	4.201	4.254	1.883	1.936	24.676	25.231	1,883	1,936	2,468	2,523
38	2362	0,446	47,9	79,0	80,0	4.182	4.235	1.820	1.873	26.496	27.104	1,820	1,873	2,650	2,710
39	2309	0,437	47,9	79,0	80,0	4.176	4.229	1.867	1.920	28.364	29.024	1,867	1,920	2,836	2,902
40	2319	0,441	48,1	79,0	80,2	4.153	4.216	1.834	1.897	30.198	30.921	1,834	1,897	3,020	3,092
41	2337	0,446	48,2	79,0	80,3	4.138	4.206	1.801	1.869	31.998	32.790	1,801	1,869	3,200	3,279
42	2340	0,447	48,3	79,1	80,4	4.137	4.205	1.797	1.865	33.795	34.654	1,797	1,865	3,379	3,465
43	2334	0,448	48,4	79,1	80,4	4.122	4.190	1.788	1.856	35.583	36.510	1,788	1,856	3,558	3,651
44	2326	0,449	48,4	79,1	80,4	4.098	4.165	1.772	1.839	37.354	38.349	1,772	1,839	3,735	3,835
45	2328	0,451	48,5	79,1	80,5	4.079	4.151	1.751	1.823	39.105	40.172	1,751	1,823	3,911	4,017
46	2325	0,453	48,6	79,1	80,5	4.064	4.136	1.738	1.810	40.844	41.982	1,738	1,810	4,084	4,198
47	2320	0,453	48,7	79,2	80,7	4.053	4.130	1.734	1.811	42.577	43.793	1,734	1,811	4,258	4,379
48	2322	0,456	48,6	79,1	80,6	4.029	4.105	1.706	1.783	44.284	45.575	1,706	1,783	4,428	4,558
49	2341	0,462	48,6	79,1	80,6	4.004	4.080	1.664	1.739	45.947	47.315	1,664	1,739	4,595	4,731
50	2318	0,459	48,8	79,3	80,9	4.008	4.089	1.689	1.770	47.637	49.085	1,689	1,770	4,764	4,909
51	2340	0,467	48,7	79,2	80,9	3.969	4.054	1.629	1.714	49.266	50.800	1,629	1,714	4,927	5,080
52	2320	0,466	48,8	79,3	80,9	3.950	4.029	1.629	1.709	50.895	52.509	1,629	1,709	5,090	5,251
53	2329	0,470	48,9	79,5	81,0	3.944	4.019	1.615	1.689	52.510	54.198	1,615	1,689	5,251	5,420
54	2320	0,471	49,0	79,5	81,5	3.919	4.018	1.599	1.698	54.109	55.896	1,599	1,698	5,411	5,590
55	2306	0,472	49,1	79,5	81,5	3.881	3.979	1.575	1.673	55.685	57.569	1,575	1,673	5,568	5,757
56	2315	0,477	49,3	79,6	81,5	3.866	3.958	1.550	1.643	57.235	59.211	1,550	1,643	5,723	5,921
57	2307	0,478	49,3	79,6	81,5	3.845	3.937	1.538	1.629	58.772	60.841	1,538	1,629	5,877	6,084
58	2301	0,479	49,4	79,7	81,5	3.824	3.911	1.524	1.610	60.296	62.451	1,524	1,610	6,030	6,245
59	2301	0,485	49,5	79,7	81,6	3.785	3.876	1.484	1.574	61.780	64.025	1,484	1,574	6,178	6,402
60	2286	0,483	49,6	79,7	81,7	3.773	3.868	1.487	1.581	63.267	65.606	1,487	1,581	6,327	6,561
					Total $	156.607									
								No premiu	Premium			Price assumptions:			Premium
		Average egg value (cts/dozen)						0,766	0,777			Jumbo eggs @ $.85/dozen			$0,91
		Average feed cost/dozen (cts)						0,456	0,456			Extra large eggs @ $.85			$0,88
		Egg income/hen housed ($)						15,66	15,89			Large eggs @ $.85			
		Feed cost/hen housed ($)						9,33	9,33			Medium eggs @ $.65			
		Egg income minus feed cost/hh ($)						6,33	6,56			Small eggs @ $.35			
												Feed @ $15.00/cwt			
		Average egg value ($/lb)				0,487									
		Average egg value ($/kg)				1,075									

Summary and conclusion

Traditional approaches for analyzing flock performance, one trait at a time, must make way for more complex techniques which bring the economics of the issue into proper focus. Researchers as well as egg producers must evaluate multiple traits and this can be done only with representative economic values. Over-emphasis on one performance trait over others can and does lead to erroneous conclusions regarding strain selection, programs used and products purchased. Egg producers in today's low margin industry cannot live with errors of interpretation of this nature.

Important relationships relative to products and management practices should be re-examined from time to time under new price and cost conditions to assure that good technology is not lost to the industry because "at one time, it was not considered a sound economic practice". Likewise, the economic circumstances widely accepted in certain regions or countries may not justify the use of certain technology which may be commonly used by others. Sound economic analyses using attainable performance results from local flocks and representative cost/income standards will give the final answers to these important decisions. The industry and scientific communities must review the many factors involved in the decision-making process continuously.

Zusammenfassung

Wirtschaftliche Bewertung der Leistung von Legehennen und Praxisergebnisse von LSL Lite in den USA

In der Vergangenheit wurden Herden häufig nur anhand einzelner Merkmale verglichen. Stattdessen sollten vorhandene Programme genutzt werden, um die gesamtwirtschaftlichen Auswirkungen von Maßnahmen zur Steigerung der Leistung zu bewerten. Falsche Entscheidungen kann sich die Geflügelwirtschaft angesichts der geringen Margen nicht leisten.

Teilergebnisse umfangreicher Auswertungen von Praxisdaten aus 74 LSL Lite Herden in den USA wurden bereits in drei vorangegangenen Beiträgen berichtet. In diesem vierten Beitrag werden die Ergebnisse genutzt, um die Indexberechnung zu illustrieren.

Hauptanliegen der Beratung bleibt es, durch Herden- und Betriebsvergleiche deutlich zu machen, welches genetische Potenzial heute in den besten Betrieben realisiert wird und durch Problemanalysen auf konkrete Verbesserungsmöglichkeiten aufmerksam zu machen.

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Airborne moulds, dust and endotoxins in four alternative housing systems for laying hens

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Summary

Airborne moulds and endotoxins as well as inhalable dusts were monthly measured during the course of one year using impingement (AGI 30) and filtration-elution-method in four different housing systems: a floor keeping system, a usual aviary, a floor keeping system with outdoor-access (free range) and the german 'Kleingruppenhaltung' (a small group system). Highest concentrations of endotoxins were regularly found in the floor keeping system (about 4000 EU/m³), followed by the aviary, free range and 'Kleingruppenhaltung' (about 1000 EU/m³). The concentrations of inhalable dusts ranged from below 1mg/m³ to 9 mg/m³ with the highest levels in the systems with integrated litter space. The impact of the housing type on the concentration of airborne moulds seems lower than the seasonal influence. The results indicate an urgent need for improving the work environment of farm workers e.g. by breathing masks in order to prevent negative health effects.

Introduction

Airborne particles like mould spores, dust and endotoxins in and from the animal husbandry are associated with a multiplicity of health effects on the human and animal organism. Comparatively high concentrations can be found in the poultry keeping units, especially in broiler barns [5, 4]. With the move to alternative housing systems for laying hens in the EU (1999/74/EC), in order to improve animal welfare, new systems have been introduced which allow the birds more free movement than in the former battery cages. However, little is known about the air pollution in these systems and the possible health effects on the people working in these atmospheres. For this reason a study, funded by the German Ministry of Food, Agriculture and Consumer Protection (BMELV) through the German Federal Agency for Agriculture and Food (BLE), was carried out in four different alternative keeping systems for laying hens to learn more about the concentrations of airborne bacteria in these environments.

Materials and Methods

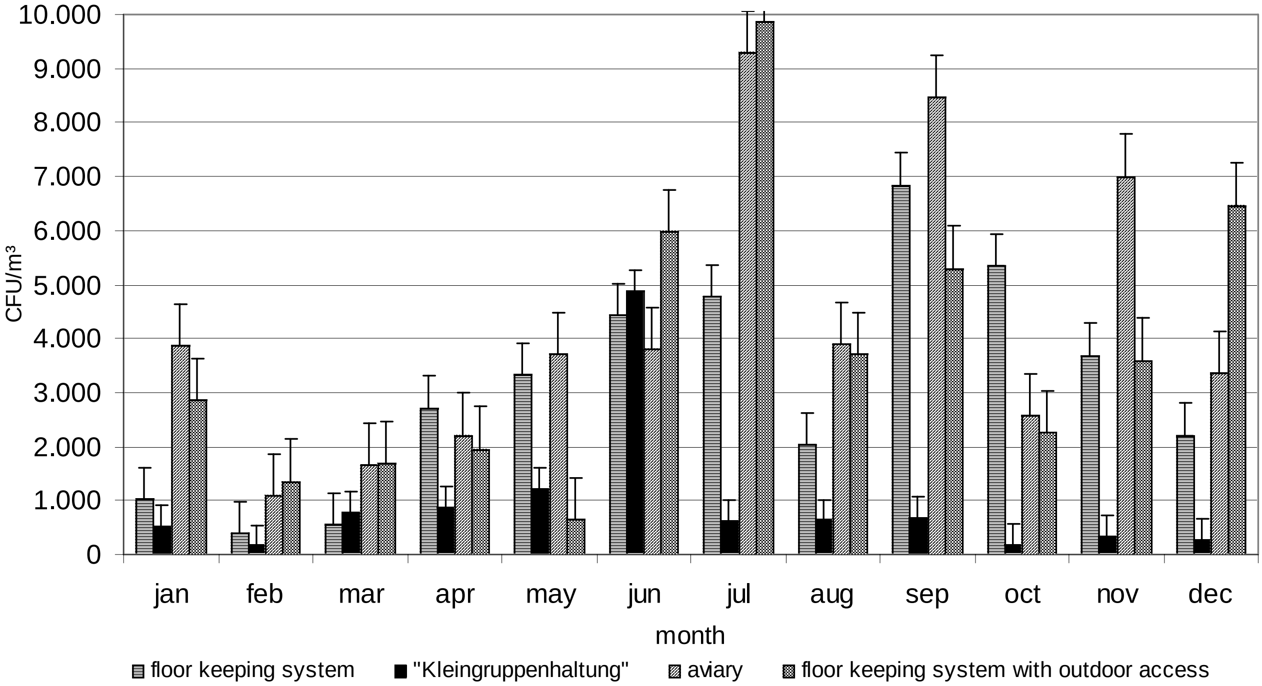
The collection of mould spores was conducted by impingement (All-Glass-Impinger type AGI 30). This method is known to show the highest yield of micro-organisms in stables under regular conditions [2, 1]. For each measurement there were six samples collected in three turns with two impingers running parallel. The impingers were charged with phosphate buffer (after Soerensen) to avoid a change in pH-value due to a drag-in of ammonia. Collecting of air samples took place in 150 cm height in the centre of the barn and middle of the daily maintenance patrol. During sampling impingers were kept in temperated and isolated aluminium tubes to allow for constant sampling conditions over the year. After sampling the impingers were stored and transported to the laboratory at 4' C. Estimation of airborne moulds was done by aerobic plate count method (APC) on DG18-Agar (Oxoid, Wesel, Germany). Colony forming units (CFU) were counted after incubation at 25' C and 36' C for 72 hours. Dust was collected on glass fibre filter in I.O.M. filter heads on SKC-pumps with an airflow of 2.5 l/min. The amount of airborne total inhalable dust was estimated by calculating the weight gain of the filter. After weighing the glass fibre filter were further processed to assess the concentrations of airborne endotoxins by LAL-Test (Kinetic QCL, BioWhittaker, East Rutherford, USA).

Results and Discussion

Figure 1 shows the concentration of airborne moulds during the course of the year. There is a clear seasonal course with highest concentrations in the late summer and autumn month for all investigated housing systems. Mould spore concentrations in ambient air show a similar course during the year [3], indicating that introduced moulds from outside have a great effect on the burden of airborne mould spores in the air of the housing systems. The highest concentrations of mould spores can be found for the floor keeping system with outdoor access presumably due to a higher exchange with the ambient air and dragged-in mould-bearing floor coverings. Lowest values were found for the german ‘Kleingruppenhaltung’.

This is the same for the airborne inhalable dust (figure 2). Whereas the values of dust concentrations exceed the threshold limit value of 4 mg/m³ (MAC, maximum allowable concentration) in the air of the aviary and the floor keeping system regularly - especially in the winter months when air exchange is lowered to reduce heat losses -, the dust concentrations in the air of the ‘Kleingruppenhaltung’ do not exceed 2 mg/m³.

Figure 1: The mean concentrations (n=18) of airborne moulds in the air of four different housing systems for laying hens during the course of one year



Ventilation dependent concentrations can also be found for the airborne endotoxins (figure 3). Again the highest values can be found for the floor keeping system, followed by the floor keeping system with outdoor access and the aviary. Lowest concentrations of airborne endotoxins among the four housing systems for laying hens were detected in the ‘Kleingruppenhaltung’. In contrast to the three other housing systems the concentrations of endotoxins in the air of ‘Kleingruppenhaltung’ show an adverse seasonal course with slightly higher values in the ‘warm’ (summer) month whereas aviary, floor keeping system and floor keeping system with outdoor access have a higher burden of airborne endotoxins in the ‘cold’ (winter) month. This is again - as for inhalable dusts – presumably due to a reduced ventilation in cold weather.

Figure 2: The mean concentrations (n=3) of airborne inhalable dust in the air of four different housing systems for laying hens during the course of one year

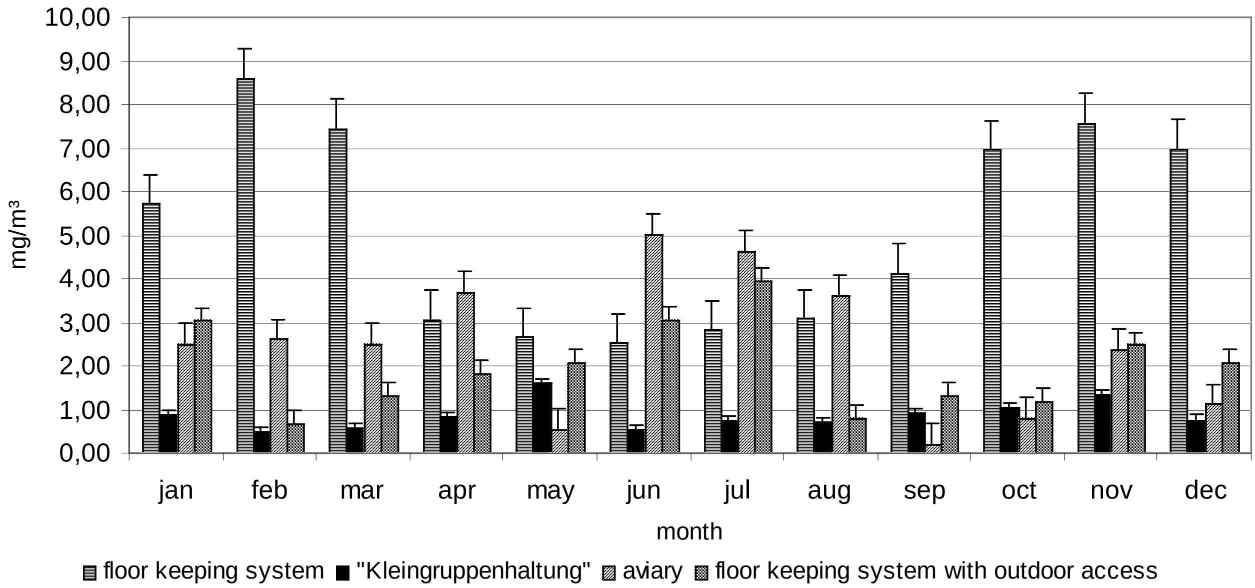
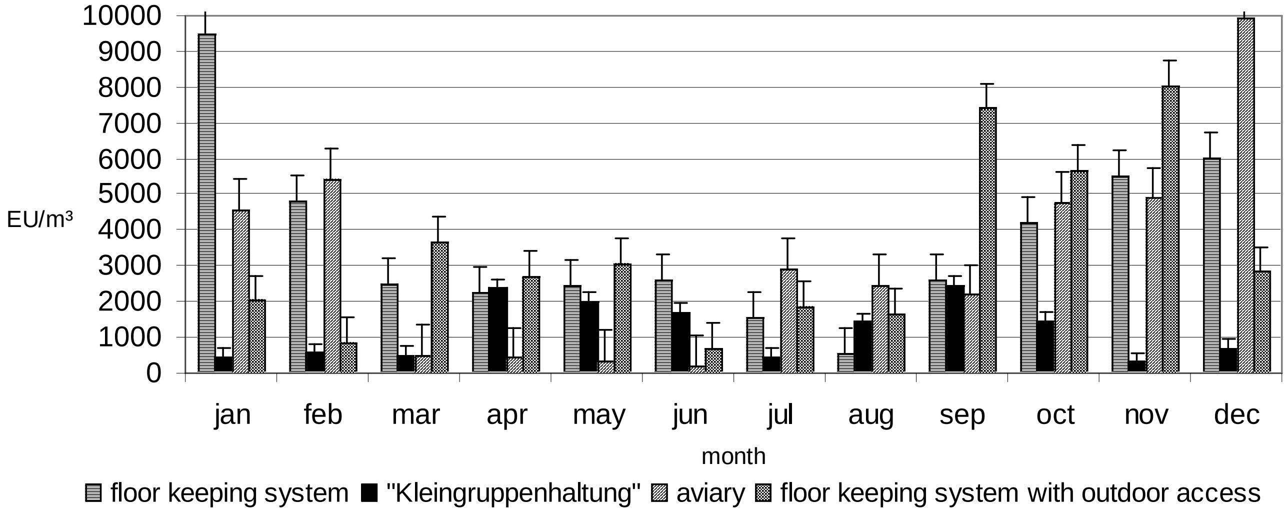


Figure 3: The mean concentrations (n=3) of airborne endotoxins (EU= Endotoxin Units) in four different housing systems for laying hens during the course of one year



Conclusions

Endotoxin respectively dust concentrations in the air of alternative housing systems for laying hens exceed the natural concentrations in ambient air by a factor of up to 100 respectively 10. There is a strong influence of housing type and season on endotoxin and dust particle counts.

The results indicate an urgent need to protect the respiratory health of farm workers also in alternative laying hen houses e.g. by breathing masks in order to prevent negative health effects.

Zusammenfassung

Schimmelpilzsporen, Staub und Endotoxine in der Luft von vier alternativen Haltungsformen für Legehennen

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Die Konzentrationen luftgetragener Schimmelpilzsporen und Endotoxine sowie der Gehalt an einatembarem Staub wurden monatlich im Verlauf eines Jahres mit Impingement (AGI30) und Filtration (IOM-Sammelköpfe mit Glasfaserfilter) im wöchentlichen Wechsel in vier verschiedenen Legehennenhaltungen erhoben: ein Bodenhaltungssystem mit zentraler Kotgrube, eine Volierenhaltung mit mehreren Ebenen und Kotband, eine Freilandhaltung mit Kotgrube und Kaltscharrraum und eine Kleingruppenhaltung. Die höchsten Konzentrationen an Endotoxinen konnten regelmäßig in der Bodenhaltung (durchschnittlich etwa 4000 EU/m³) gefunden werden, gefolgt von der Volieren-, der Freiland- und der Kleingruppenhaltung. (etwa 1000 EU/m³). Die Staubkonzentrationen variierten zwischen unter 1 mg/m³ und bis zu 9 mg/m³ mit den höchsten Werten in den beiden Systemen mit innenliegendem Scharrraum. Der Einfluss der Haltungsform auf die Konzentrationen luftgetragener Schimmelpilze ist weniger stark ausgeprägt als der Einfluss der Jahreszeit. Zur Vorbeugung von Atemwegserkrankungen und anderer negativer Effekte auf die Gesundheit der Arbeiter sollte der Arbeitsschutz an diesen Arbeitsplätzen durch geeignete Maßnahmen wie zum Beispiel das konsequente Tragen von Atemschutz verbessert werden.

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Detoxification of aflatoxin in poultry feed: a review from experimental trials

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Introduction

Aflatoxins (AF) are a major concern in poultry production and public health because of serious economic losses and health problems. AF contamination causes reduced feed quality and reduced animal efficiency either through poor conversion of nutrients or problems such as reproductive abnormalities. Aflatoxicosis in poultry also causes listlessness, anorexia with lowered growth rate, poor feed utilization, decreased egg production and increased mortality. Additionally, anemia, reduction of immune function, hepatotoxicosis, hemorrhage, teratogenesis, carcinogenesis and mutagenesis are associated with aflatoxicosis. The toxicity of AF in poultry has been widely investigated by determining their teratogenic, carcinogenic, mutagenic and growth inhibitory effects. The biochemical-hematological, immunological, gross and histopathological toxic effects of AF have also been well described.

Preventing of mould growth and AF contamination in feed and feedstuffs is very important but when contamination cannot be prevented, decontamination of AF is needed before using these materials. Producers, researchers and governments aim to develop effective prevention management and decontamination technologies to minimize toxic effects of AF.

Practical and cost-effective methods of detoxifying AF-contaminated (AF-CT) feed are in great demand. Besides preventive management, approaches have been employed including physical, chemical and biological treatments to detoxify AF in contaminated feeds and feedstuffs. An approach to the problem has been to use non-nutritive and inert adsorbents in the diet to bind AF and reduce the absorption of AF from the gastrointestinal tract. Since the early 1990s, experiments with adsorbents such zeolites and aluminosilicates have proven successful, but high inclusion rates and possible potential interactions with feed nutrients are causes for concern. Also, possible dioxin contamination may be a risk factor for using natural clays in case of forest and trash fire near their source.

Possible solutions

Some studies suggested that the best approach for decontamination would be biological degradation such as yeast and yeast components which could allow removal of AF under mild conditions, without using harmful chemicals or causing appreciable losses in nutritive value and palatability. A successful detoxication process must be economical and capable of eliminating all traces of toxin without leaving harmful residues without impairing the nutritional quality of the commodity. As a result, researchers have directed efforts towards finding effective means of biological degradation of AF. Most studies have used greater concentrations of AF than are likely to be found under field conditions. The AF concentrations in these experiments ranged from 2 to 5 ppm, because these high concentrations were expected to elicit the toxic effects of AF and also any effects of the feed additive would be easily seen in a shorter experimental period.
The *in vivo* experimental trials performed by using adsorbents and biological products as a feed additive in poultry are briefly given below. A total of 155 studies (*in vivo* and in poultry species only) were examined and are listed for 35 countries according to the first author's institute.

The present review is based on an invited paper, written and published at the beginning of 2011 (Oguz, H., 2011). Since then, 20 new articles related to detoxification of AF in poultry feed were published and are included here.

Countries and researches

Argentina

- Miazzo *et al.* (2000) added synthetic zeolite (1%) to AF-CT (2.5 ppm) broiler diet and zeolite significantly diminished the adve of AF on performance and reduced the incidence and/or severity of hepatic histopathology lesions caused by AF.
- Miazzo *et al.* (2005) supplemented sodium bentonite (SB; 0.3%) to AF-CT (2.5 ppm) broiler diet and SB provided significant improvements in liver histopatholgy and biochemistry.
- Magnoli *et al.* (2008) incorporated natural bentonite (0.3%) to AF-CT (30-135 ppb) broiler diet and bentonite reduced severity of hepatic histopathology changes associated with aflatoxicosis.
- Magnoli *et al.* (2011) added SB (0.3%) and monensin (55 ppm) into AF-CT (100 ppb) broiler diet. Histopathology indicated that SB was effective in reducing the severity of hepatic changes associated with aflatoxicosis. Also the decrease of its capacity in the presence of monensin was observed.
- Mosca and Marichal (2011) supplemented hydrated sodium calcium aluminosilicate (HSCAS), esterified glucomannan (EGM) and multi modular additive (MM) to AF-CT (4.5 ppm) broiler diet and MM appeared to be the most effective to counteract the adverse effect produced by these mycotoxin combinations (AF plus fumonisin).

Australia

- Bryden (2012) recently reviewed mycotoxin contamination in the feed supply chain, with implications for animal productivity and feed security; numerous (260) related references.

Belgium

- Schwarzer and Baecke (2009) reviewed inactivators for mycotoxins (based on botanicals, yeast and clay-minerals) on animal performance.

Brazil

- Santurio *et al.* (1999) supplemented SB (0.25 and 0.5%) to AF-CT (3 ppm) broiler diet and SB partially neutralized the effects AF on broiler chickens when included at 0.5% in the diet.
- Rosa *et al.* (2001) added SB (0.3%) to AF-CT (5 ppm) broiler diet and SB in the diets significantly improved the adverse effects of AF on performance, biochemistry and gross and histopathology of liver.
- Santin *et al.* (2003) added Saccharomyces cerevisiae (SCE; 0.2%) to the broiler diet and SCE did not improve the suppressive effects of AF on performance and immunity.
- Batina *et al.* (2005) added sodic montmorillonite (MNT; 0.25 and 0.5%) to AF-CT (5 ppm) broiler diet and addition of 0.5% level MNT provided partial improvements in biochemical changes associated with AF.
- Franciscato *et al.* (2006) added sodic MNT (0.25 and 0.5%) to AF-CT (3 ppm) broiler diet, addition of 0.5% sodic MNT provided significant improvements in biochemistry.
- Santin *et al.* (2006) incorporated yeast cell wall (0.1%) into AF-CT (250 and 500 ppb) broiler diet, and yeast cell wall was found to be effective in preventing the detrimental effects of AF on performance.
- Siloto *et al.* (2011) incorporated glucan derived from yeast cell wall (0.2%) into AF-CT (1 ppm) layer hen's diet, and yeast cell wall partially ameliorated the detrimental effects of AF on performance and egg quality.
- Uttpatel *et al.* (2011) supplemented EGM (0.1%) into AF-CT (500 and 750 ppb) broiler breeders diet. Body weight of the breeders, egg weight, specific weight of eggs, hatchability and chick quality were not affected by the levels of AF and adsorbent present in the diet.

- Rosa *et al.* (2012) added EGM (0.1%) to AF-CT (500, 750 and 1000 ppb) broiler diet; the addition of up to 750 ppb AF and adsorbent in the breeder diets during eight weeks did not affect the performance or blood parameters of their progeny.

Cameroon

- Kana *et al.* (2009) added plant charcoal from Canarium schweinfurthii (charcoal A) and maize cob (charcoal B) at doses of 0.2; 0.4 and 0.6 % to AF-CT (22 ppb) broiler diet. The addition of 0.20% of charcoal A and 0.60% of maize charcoal was effective in absorbing AF and promoting growth performance of broilers.

China

- Shi *et al.* (2009) added MNT (0.3%) and MNT nanocomposite (0.3%) to AF-CT (110 ppb) broiler diet; MNT nanocomposite significantly diminished the effects of AF on performance and biochemistry.
- Juan-juan *et al.* (2010) incorporated yeast cell extracts, HSCAS and a mixture of yeast product; HSCAS at the levels of 1.5% into AF-CT (100 ppb) broiler diet and HSCAS effectively prevented the toxic effects of AF on performance and biochemistry.
- Che *et al.* (2011) added EGM (0.05%), HSCAS (0.2%) and a kind of adsorbent (CMA) into AF-CT broiler. Addition of 0.05% EGM and 0.2% HSCAS partially alleviated the adverse effects of AF; 0.1% CMA ameliorated the adverse effects.
- Guan *et al.* (2011) reviewed the microbial strategies to control AF in food and feed with 111 related references.
- Liu *et al.* (2011) supplemented EGM (0.05%), HSCAS (0.2%) and compound mycotoxin adsorbent (CMA; 0.1%) to AF-CT (450 ppb) broiler diet. the addition of EGM, HSCAS or CMA prevented some adverse effects of mycotoxins to varying extents, with CMA being the most effective adsorbent treatment.
- Liu *et al.* (2012) recently reviewed the advanced research on the mycotoxin removing with related references.

Colombia

- Diaz *et al.* (2009) added some feed additives (containing aluminosilicate and phytogenic substances) to AF-CT (250 and 500 ppb) turkey diet and used feed supplements partially diminished the negative effects of AF on performance and immunology by the supplements.

Croatia

- Peraica *et al.* (2002) reviewed prevention of mycotoxin production and methods of decontamination including adsorbents, with related 68 references.

Cuba

- Rivera and Farias (2005) reviewed clinoptilolite (CLI)-surfactant composites as a drug support and their mechanism, with related 52 references.

Czech Republic

- Trckova *et al.* (2004) reviewed kaolin, bentonite and zeolites, their binding properties and their usage as feed supplements for animals, with related 108 references.

Denmark

- Shetty and Jespersen (2006) reviewed SCE and lactic acid bacteria for decontamination of mycotoxins. The authors also noted the binding mechanism of the them, with related 84 references.

Egypt

- Matari (2001) incorporated SB (0.5 and 1%) into AF-CT broiler diet and SB significantly restored the adverse effects of AF.
- Eshak *et al.* (2010) added SCE (0.5, 1, 2, 2.5%) to AF-CT (0.5 ppm) quail diet and addition of SCE to quail diets suppressed the aflatoxicosis in quail tissues leading to improvement of growth performances and enhancement of expression levels of neural and gonadal genes.
- Ellakany *et al.* (2011) supplemented HSCAS (0.50%), SCE (0.25%) and EGM (0.25%) into AF-CT broiler diet. While HSCAS significantly improved performance, biochemical and immunological parameters when compared with AF group; EGM significantly improved performance, but there was no effect on other parameters. SCE had no effect on any of the parameters tested when compared with broilers fed AF.

France

- Guerre (2000) reviewed the physical and chemical methods used for inactivation of mycotoxins. The adsorbents including aluminosilicates were also explained in detail, with the results of related 128 references.
- Jouany (2007) reviewed the methods for preventing, decontaminating and minimizing the toxicity of mycotoxins including aluminosilicates and yeast derivatives, with related 165 references.

Germany

- Dänicke (2002) reviewed prevention and/or control of mycotoxins in poultry feed; results of the researches in detail, with related 128 references.

Hungary

- Bata and Laztity (1999) reviewed physical and chemical methods and biolgical adsorbents recommended for detoxification of mycotoxin-contaminated feed. The present state of research in this field and the perspectives of such procedures were also discussed, with 42 related references.

India

- Jindal *et al.* (1994) added activated charcoal (200 ppm) to AF-CT (0.5 ppm) broiler diet; the results showed that activated charcoal provided protection of broilers against harmful effects of AF on performance and biocemistry.
- Raju and Devegowda (2000) incorporated EGM (0.1%) into AF-CT (300 ppb) broiler diet; addition of EGM significantly decreased the detrimental effects of AF on performance parameters, biochemistry and organ morphology.
- Girish and Devegowda (2004) added EGM (0.1%) and HSCAS(1%) to AF-CT (2 ppm) broiler diet and both adsorbents provided significant improvements in performance and relative organ weights associated with aflatoxicosis.
- Gowda *et al.* (2008) added turmeric powder (0.5%) and HSCAS (0.5%) to AF-CT (1 ppm) broiler diet and the adsorbents demonstrated protective action in the deleterious effect of AF on performance, biochemistry, antioxidant functions and histopathology.
- Sawarkar *et al.* (2011) supplemented Toxiroak Gold (0.1%) to AF-CT (100 ppb) broiler diet; herbomineral toxin binder feed supplement provided amelioration of aflatoxicosis in broilers.
- Srikanth *et al.* (2011) added activated charcoal (0.4%) and yeast culture (0.1%) into AF-CT (1 ppm) broiler diet; the combination of activated charcoal and yeast culture was more effective in counteracting the combined toxicity of AF and T-2 toxin compared to the activated charcoal alone.

Indonesia

- Sjamsul *et al.* (1990) supplemented activated charcoal (1.5 and 3%) to AF-CT (150 ppb) duck diet and addition of charcoal alleviated the detrimental effects of AF on gross and histopathology of the livers of ducks. 3% activated charcoal was found to be more effective.

Iran

- Modirsanei *et al.* (2004) added SCE (0.5%) and natural zeolite (0.75%) to AF-CT (1 ppm) broiler diet; addition of 0.75% zeolite did not reduce any of the adverse effects, whereas supplemention of SC moderately ameliorated the effects in respect of performance and biochemistry.
- Safameher *et al.* (2004) administrated ammonia to AF-CT (1 ppm) broiler diet and they provided significant improvements in performance and hematology by treating ammonia in contaminated feed.
- Abousadi *et al.* (2007) incorporated SB (0.5%), SCE (0.2%), HSCAS (0.5%), ammonia (0.5%), formycine (0.1%), and toxiban (0.1%) into AF-CT (125 ppb) broiler diet. Generally addition of the compounds made an improvement against negative effects of AFB1 on performance and biochemistry in broiler chickens. Formycine was recognized to be the best additive in this respect.
- Modirsanei *et al.* (2008) added diatomaceous earth (30 ppm) to AF-CT (1 ppm) broiler diet; the added adsorbent alleviated the negative effects of AF in performance and biochemistry associated with aflatoxicosis.
- Safameher (2008) supplemented CLI (2%) to AF-CT broiler diet to ameliorate the toxic effect of AF (0.5 ppm) and CLI provided significant improvements against AF toxicity in performance, biochemistry and liver histopathology.
- Ghahri *et al.* (2009) added EGM (0.1%), SB (0.5%) and humic acid (0.2-1%) to AF-CT broiler diet to ameliorate the toxic effect of AF (254 ppb) against humoral immunity. The addition of EGM, SB and humic acid to the AF-CT diet ameliorated the negative effects of AF on ND antibody titers, but humic acid proved to be more effective in the amelioration of the detrimental effect of AF on humoral immunity against ND.
- Kamalzadeh *et al.* (2009) added yeast glucomannan (0.5, 1 and 1.5%) to AF-CT (184 ppb) broiler diet and yeast glucomannan significantly decreased the negative effects of AF on performance. 1% glucomannan was found more effective than other concentrations.
- Kermanshahi *et al.* (2009) supplemented SB (0.5 and 1%) to AF-CT (0.5 and 1 ppm) broiler diet and SB significantly improved the effects of AF on performance and biochemistry.
- Manafi *et al.* (2009) added high-grade SB (1%) to AF-CT (500 ppb) broiler diet and SB reduced the toxicity of AF on some parameters.
- Shabani *et al.* (2010) incorporated nanozeolite (0.25-1%) into AF-CT (500 ppb) broiler diet; nanozeolite significantly reduced the toxic effects of AF in performance and biochemistry.
- Manafi (2011; 2012) added bentonite (0.5; 0.75 and 1%), Spirulina platensis (0.1%) and EG (0.2%) to AF-CT (300, 400 and 500 ppb) broiler breeders diet. Among the binders, EG showed better protection against AF in terms of biochemical and immunological parameters, fertility and hatchability.
- Mogadam and Azizpour (2011) added yeast glucomannan (0.05 and 0.1%) and SB (1.5 and 3%) to AF-CT (250 ppb) broiler diet. The addition of yeast glucomannan and SB, individually and in combination to the AF-containing diet, ameliorated the adverse effects of AF. But 0.1% yeast glucomannan supplementation to the contaminated diet with AF proved to be much more effective in the amelioration of the adverse effect of AF on performance and humeral immunity against ND.
- Rangsaz and Ahangaran (2011) incorporated ethanolic turmeric extract (0.05%) to AF-CT (3 ppm) broiler diet. The results suggested that turmeric extract (Curcuma longa) provided protection against the negative effects of AF on performance of broiler chickens.

- Khadem *et al.* (2012) supplemented yeast (0.5%), zeolite (1.5%) and active charcoal (1.5%), alone or in combination into AF-CT (200 ppb) broiler diet. Results indicated that the mixtures of the tested absorbents were more effective in reducing symptoms of AF toxicity in growing broilers.

Iraq

- Ibrahim *et al.* (2000) added SB (0.2, 0.4 and 0.6%) to AF-CT (2.5 ppm) broiler diet and the addition of SB was significantly effective in ameliorating deleterious effect of AF on humoral immunity. SB also improved the adverse effects of AF on performance and hematology (Ibrahim et al. 1998) and carry-over of AF from feed to eggs (Ibrahim and Al-Jubory 2001).

Italy

- Rizzi *et al.* (1998) supplemented EGM (0.11%) to the layer diet and EGM provided significant improvements in the detrimental effects of AF.
- Galvano *et al.* (2001) reviewed dietary strategies to counteract the toxic effects of mycotoxins; feed additives and binding agents were discussed in detail, with the results of 113 related references.
- Rizzi *et al.* (2003) added CLI (2%) to AF-CT (2.5 ppm) layer diet and CLI provided no improvements in egg quality.
- Tedesco *et al.* (2005) added silymarin-phospholipid complex (600 mg/kg BW) to AF-CT (800 ppb) broiler diet; they provided significant improvements in performance parameters by adding feed additive.
- Zaghini *et al.* (2005) added mannanoligosaccharide (MOS; 0.11%) to AF-CT (2.5 pmm) layer diet and MOS decreased the gastrointestinal absorption of AF and its level in tissues.

Korea

- Kim *et al.* (2003) incorporated soybean paste (doen-jang; 0.5, 1 and 5%) into AF-CT (500 ppb) layer diet and the addition of 5% soybean paste significantly reduced the effects of AF on performance, biochemistry, gross and histopathology of liver, egg production and accumulation of AF in hens' eggs.

Mexico

- Mendez-Albores *et al.* (2007) treated AF-CT (110 ppb) duck feed with citric acid (1N for 15 min, 3 ml/g feed) and citric acid significantly ameliorated negative effects of AF on mutagenity, carcinogenity and toxicity in respect of performance, biochemistry and pathology.

Pakistan

- Musaddeq *et al.* (2000) added Myco-Ad, Sorbatox and Mycofix-Plus to AF-CT (8 and 60 ppb) broiler diet and the adsorbents recovered the negative effects of AF on performance of chicks.
- Hashmi *et al.* (2006) supplemented yeast sludge (1%; 0.26% mannan oligosaccharide) to AF-CT (100, 200 and 300 ppb) broiler diet and 1% yeast sludge act as toxin binder effectively at 100 and 200 ppb AF, but its efficiency was reduced at 300 ppb AF level; higher levels of yeast sludge effectively improved the aflatoxicosis condition.
- Pasha *et al.* (2007) added SB (0.5 and 1%), SB+gention violet, SB+acetic acid, Sorbatox and Klinofeed to AF-CT (100 ppb) broiler diet. Addition of indigenous 0.5% SB gave overall better results than the market products and provided significant improvements in performance, organ weight and immunology.

Poland

- Kolacz *et al.* (2004) reviewed the use of synthetic aluminosilicates in decontamination of mycotoxins including AF. They also noted the characteristics of aluminosilicate and its decontaminating effect, with 43 related references.

Saudi Arabia

- Teleb *et al.* (2004) added kaolin and activated charcoal (0.5%) to AF-CT (30 ppb) broiler diet and two adsorbents ameliorated the toxic effects of AF on performance but did not reduce the histopathological changes associated with aflatoxicosis.

Serbia

- Zekovic *et al.* (2005) reviewed the use of natural and modified glucans to promote health and control diseases including their immunomodulator effects and mycotoxin adsorption ability, with 245 related references.

Slovak Republic

- Iveta *et al.* (2000) added CLI and cephalite (0.5%) to AF-treated (0.5 mg/kg BW) broilers; long term oral administration of two sorbents caused an increase in CD3+ cells in lamina of duodenum. AF did not change the number of CD3+ lymphocytes significantly.

South Africa

- Rensburg (2005) incorporated humic acid (0.35%) into AF-CT (1 and 2 ppm) broiler diet; partial improvements in performance, hematology and biochemistry were found.
- Rensburg *et al.* (2006) also added humic acid (0.35%) and dried brewer yeast (0.35%) to AF-CT (1 and 2 ppm) broiler diet; they provided significant improvements by humic acid in performance, biochemistry and hematology. Humic acid was found to be much more effective than brewer yeast.

Spain

- Marquez and Hernandez (1995) added two Mexican aluminosilicates (Atapulgita and Füller earth) at the levels of 0.5 and 1% to AF-CT (200 ppb) broiler diet and the results showed that both aluminosilicates were as efficient as the commercial material in protecting chicks against AF toxicity on performance and gross and histopathology.
- Ramos *et al.* (1997) reviewed nonnutritive adsorbent compounds used for prevention of toxic effects of mycotoxins, with 111 related references.
- Denli *et al.* (2009) added AflaDetox (1, 2 and 5%) AF-CT (1 ppm) broiler diet; the addition of AflaDetox prevented all toxic effects on performance and serum biochemistry and reduced the accumulation of AFB1 residues in the livers.

Switzerland

- Huwig *et al.* (2001) reviewed nonnutritive clay-based adsorbents used in poultry feed and their respective mechanism of adsorption. They also listed the adsorption capacity of compounds commonly used, with 73 related references.

Thailand

- Banlunara *et al.* (2005) supplemented EGM (0.05 and 0.1%) to AF-CT (100 ppb) duck diet; supplementation of EGM effectively reduced AFB1-induced hepatic injury in ducklings.
- Bintvihok and Kositcharoenkul (2006) added Ca propionate (0.25 and 0.5%) to AF-CT (100 ppb) broiler diet; addition of Ca propionate appeared to be effective in reducing toxicity of AF on performance and hepatic enzyme activities in broilers.
- Bintvihok (2010) reported that using EGM (0.05% and 0.1%) to AF-CT (60 and 120 ppb) duck diet and EGM provided significant improvements in performance, histopathology and leg deformity caused by AF. The addition of 0.05% EGM also recovered the adverse effects of AF (100 ppb) on serum biochemistry and in ducklings.

Turkey

- Oguz (1994,1997) produced AF on rice for feeding trials by using Aspergillus parasiticus culture with minor modification of Shotwell's method (1966). After production of AF, fermented rice was then steamed to kill the fungus, dried and ground to a fine powder. The rice powder was then analyzed for AF content. Then it became useful rice powder which was possible to be incorporated into the basal diet to provide desired amounts of AF levels in animal experiments.
- Kececi *et al.* (1998) incorporated synthetic zeolite (0.5%) into AF-CT (2.5 ppm) broiler diet and synthetic zeolite provided significant improvements in the adverse effects of AF on performance, hematology and biochemistry.
- Oguz and Kurtoglu (2000) added CLI (1.5 and 2.5%) to AF-CT (2.5 ppm) broiler diet and CLI provided significant improvements in performance. Addition of 1.5% CLI also ameliorated the toxic effects of AF (2.5 ppm) on hematology-biochemistry (Oguz et al. 2000a) and reduced the number of affected broilers and the severity of gross and histopathological lesions caused by AF (Ortatatli and Oguz 2001).
- Oguz *et al.* (2000b) also incorporated CLI (1.5%) into lower levels AF-CT (50 and 100 ppb) broiler diet and CLI significantly recovered the negative effect of AF on performance of broilers. Adding 1.5% CLI also improved the changes in gross and histopathology of target organs (Ortatatli et al. 2005) and humoral immunity (Oguz et al. 2003) associated with aflatoxicosis.
- Parlat *et al.* (2001) added SCE (0.1%) to AF-CT (2 ppm) quail diet and SCE provided significant improvements the effect of AF on performance. SCE (0.2%) was also added to AF-CT (5 ppb) quail diet and the negative changes in the performance, egg production and egg quality were significantly ameliorated by adding of SCE (Acay 2006).
- Celik *et al.* (2001) added SCE (0.1%) to AF-CT (100 ppb) quail diet and SCE partially neutralized some toxic effects of AF.
- Denli *et al.* (2003) supplemented vitamin A (15.000 IU) to AF-CT (100 ppb) quail diet and vitamin A partially decreased the negative effects of AF on performance, biochemistry and pathology.
- Denli *et al.* (2004, 2005) added conjugated linoleic acid (CLA; 0.2 and 0.4%) to AF-CT (200 and 300 ppb) broiler diet and CLA provided a partial improvement in performance and biochemistry parameters. CLA also decreased the detrimental effects of AF on liver pathology.
- Eraslan *et al.* (2004a) incorporated SB (0.25 and 0.5%) into AF-CT (1 ppm) broiler diet and SB provided a partial improvement in lipid peroxidation in the liver and kidneys of broilers.
- Eraslan *et al.* (2004b) also added HSCAS (0.5 and 1%) to AF-CT (2.5 ppm) quail diet and HSCAS provided a moderate amelioration the negative effects of AF on performance and biochemistry.
- Oguz and Parlat (2004) added MOS (0.1%) to AF-CT (2 ppm) quail diet and MOS significantly improved the adverse effects of AF on performance of quail.
- Yildiz *et al.* (2004) added SCE (0.2%) to AF-CT (2 ppm) quail diet and the addition of SCE significantly recovered the deleterious effects of AF on performance, egg production and egg weight. The addition of 0.2% SCE also provided significant improvements in hatchability and fertility of quails (Yildirim and Parlat 2003).
- Basmacioglu *et al.* (2005) supplemented EGM (0.1%) to AF-CT (2 ppm) broiler diet and EGM significantly ameliorated the toxic effects of AF on hematology and biochemistry. Addition of 0.1% EGM also reduced the rate of affected broilers and the severity of lesions in the target organs caused by AF (Karaman et al. 2005).
- Celik *et al.* (2005) added tribasic copper chloride (200 ppm) to AF-CT (1 ppm) broiler diet and tribasic copper chloride significantly improved the effects of AF on performance and biochemistry.
- Sehu *et al.* (2005) incorporated Mycotox (0.5%) into AF-CT (2.5 ppm) quail diet; the adsorbent did not reduce the toxic effects of AF.

- Denli and Okan (2006) added HSCAS, diatomite and activated charcoal (0.25%) to the AF-CT (40 and 80 ppb) broiler diet. HSCAS was the most effective adsorbents among them to ameliorate the toxic effects of AF in performance and biochemistry.
- Essiz *et al.* (2006) supplemented HSCAS (0.5%) and yeast wall (0.5%) and to AF-CT (2.5 ppm) quail diet and they restored plasma malondialdehyde levels altered by AF. The addition of 0.5% HSCAS also moderately decreased the toxic effects of AF (2.5 ppm) in quail in terms of performance, histopathology and immunology parameters (Sehu et al. 2007).
- Kabak *et al.* (2006) reviewed strategies to prevent contamination of animal feed and listed all detoxification methods which have been studied in vivo and in vitro and used for mycotoxin decontamination; results with 276 related references.
- Cinar *et al.* (2008) added yeast glucomannan (0.075%) to AF-CT (2 ppm) broiler diet; yeast glucomannan at this level was not sufficient to ameliorate the oxidative damage caused by AF in broilers.
- Keser and Kutay (2009) reviewed chemical methods including adsorbents and biological methods for preventing of mycotoxins, with 40 related references.
- Ozen *et al.* (2009) added melatonin (10 mg/kg/bwt) to AF-CT (150 and 300 ppb) broiler diet; melatonin supplementation greatly reduced the nitrosative tissue degeneration caused by AF.
- Demirel *et al.* (2010) reviewed the usage of natural zeolites in animal production including poultry, with 49 related references.
- Karaman *et al.* (2010) added lipoic acid (60 mg/kg/bw) to AF-CT (150-300 ppb) broiler diet they; lipoic acid provided moderate improvements in lipid peroxidation and histopathology of target organs.
- Matur *et al.* (2010) supplemented SCE extract (0.1%) to AF-CT (100 ppb) hen diet; addition of SCE extract reduced the toxic effects of AF on pancreatic lipase and chymotrypsin activity.
- Yildirim *et al.* (2011) added yeast glucomannan (0.075%) to AF-CT (2 ppm) broiler diet; the deleterious effects were partially alleviated, but the treatment did not prevent tissue damage.

United States

- AF was produced on rice by using Aspergillus flavus culture (Shotwell et al. 1966) for using in feeding trials with poultry and other animals. This method has become a preferential method in the experiments for investigating AF toxicity and/or evaluation of preventive efficacy of feed additives against AF.
- Kubena *et al.* (1990) supplemented HSCAS (0.2%) and activated charcoal (0.5%) to AF-CT (5 and 7.5 ppm) Leghorn chicks' diet and HSCAS significantly diminished the adverse effects of AF on performance, organ weights and biochemistry, whereas adding activated charcoal had no effect.
- Araba and Wyatt (1991) added SB, HSCAS and ethacal (0.5 and 1%) to AF-CT (5 ppm) broiler diet. Addition of 0.5% SB and HSCAS significantly reduced the deleterious effects of AF on performance, liver weights and liver lipids.
- Kubena et al. (1991) added HSCAS (0.5%) to AF-CT (0.5 and 1 ppm) turkey diet and HSCAS neutralized the effects of AF performance, relative organ weights, hematological and biochemical values associated with 0.5 ppm AF.
- Huff *et al.* (1992) incorporated HSCAS (0.5%) into AF-CT (3.5 ppm) broiler diet and HSCAS effectively recovered the detrimental effects of AF on serum biochemistry.
- Harvey *et al.* (1993) added zeolites (CLI, zeomite and mordenite) (0.5%) to AF-CT (3.5 ppm) broiler diet; zeomite and mordenite decreased the toxicity of AF to growing chicks as indicated by weight gains, liver weight, and serum biochemical values.
- Kubena *et al.* (1993) added HSCAS (0.5%) to AF-CT (2.5 and 5 ppm) broiler diet. The addition of 0.5% of the HSCAS compounds significantly recovered the growth inhibitory effects caused by AF. The increases in relative organ weights and the decreases in serum biochemical values caused

by AF were significantly alleviated to differing degrees by HSCAS compounds and HSCAS was found to be protective against the effects of AF in young growing broilers.

- Scheideler (1993) incorporated Ethacal, Novasil, zeobrite and perlite (1%) into AF-CT (2.5 ppm) broiler diet. Initial three adsorbents provided significant improvements in performance and liver lipid, and partial improvements in mineral status.
- Abo-Norag *et al.* (1995) added HSCAS (0.5%) to AF-CT (3.5 ppm) broiler diet; HSCAS effectively restored the negative effects of AF on performance and serum biochemistry.
- Edrington *et al.* (1997) supplemented super activated charcoal (0.5%) to AF-CT (4 ppm) broiler diet; active charcoal moderately alleviated the toxic effects of AF on performance, hematology and biochemistry.
- Bailey *et al.* (1998) added three different adsorbents (0.5%) to AF-CT (5 ppm) broiler diet; the adsorbents offered some protection against AF toxicity in chickens.
- Kubena *et al.* (1998) added HSCAS (0.25%) to AF-CT (5 ppm) broiler diet and significantly reduced negative effects of AF on performance and serum biochemistry.
- Ledoux *et al.* (1999) added HSCAS (Milbond-TX; 1%) to AF-CT (4 ppm) broiler diet and HSCAS completely improved in AF-dependent changes in organ weights, serum chemistry changes, and gross pathology observed in chicks fed AF. HSCAS also effectively reduced the incidence and severity of the hepatic and renal histopathology changes associated with aflatoxicosis.
- Phillips (1999) reviewed dietary clay used in the prevention of aflatoxicosis. In this review AF prevention strategies, chemoprevention, HSCAS and possible nutrient interaction with adsorbents were expressed, with 70 related references.
- Stanley *et al.* (2003) added SCE (0.05 and 0.1%) to AF-CT (5 ppm) broiler diet and the addition of 0.1% SCE significantly improved the changes in performance, relative organ weights and serum biochemistry associated with aflatoxicosis.
- Stanley *et al.* (2004) also added yeast culture residue (2 lb/ton) to AF-CT (3 ppm) breeder hen diet; the inclusion of yeast culture in the AF-treated diet improved hatchability and egg production, and lowered embryonic mortality significantly. Serum globulin and albumin were partially restored with the addition of yeast.
- Bailey *et al.* (2006) incorporated MNT clay (0.5%) into AF-CT (4 ppm) broiler; they reported that MNT clay in broiler diets provided significant protection on growth performance, serum biochemistry, and relative organ weight associated with aflatoxicosis.
- Fairchild *et al.* (2008) added bentonite based Astra-Ben (1 and 2%) to AF-CT (4 ppm) broiler diet; the adsorbent provided significant improvements in performance and liver lipid content.
- Rawal *et al.* (2010) reviewed toxicology, metabolism and prevention of AF; clay-based inorganic adsorbents and their effects were also discussed, with 121 related references.
- Zhao *et al.* (2010) supplemented HSCAS and yeast cell wall component with two doses (0.1 and 0.2%) to AF-CT (1 and 2 ppm) broiler diet and they provided significant improvements by adding of HSCAS and less improvements by yeast cell wall components in performance, biochemistry and histopathology changes associated with aflatoxicosis.
- Jaynes and Zartman (2011) reviewed the AF toxicity reduction in feed by enhanced binding to surface-modified clay additives, with 45 related references.

Venezuela

- Marin *et al.* (2003) added SCE (0.1%) and selenium (2.5 ppm) to AF-CT (70 ppb) broiler diet; no improvements in biochemistry and hematology by adding the supplements were found.
- Arrieta *et al.* (2006) incorporated SCE (0.1%) and selenium (2 ppm) into AF-CT (70 ppb) broiler diet; no improvements were seen in biochemical parameters. Also no significant changes were seen by adding low levels of AF in parameters.

- Gomez *et al.* (2009) supplemented SCE (0.1%) and Se (2 ppm) to AF-CT (70 ppb) broiler diet and the results suggested that the ingestion during 42 days period with 70 ppb AFB1 on diet of broiler may have some effects on production parameters.

Vietnam

- Kinh et al. (2010) added Mtox (0.25%) to AF-CT (31-44 ppb) broiler diet; Mtox improved growth rate and feed efficiency of broiler chickens significantly.

Conclusion

The evaluation of the preventive efficacy of protective agents is possible by determining significant statistical differences between parameters of AF and AF plus additive groups in the target organs and key parameters in favor of AF plus feed additive groups. In my opinion, the best way to assess the performance of feed supplements against AF toxication for producers and scientists is to evaluate the results "as total" in terms of performance, biochemical-hematological, immunological and gross pathologic and histopathological parameters by comparing the AF groups with AF plus feed additive groups.

Evaluation of experiments "as total" is not always easy, because authors from different departments sharing responsibility for designing the experiment and interpreting the results tend to publish special aspects of experimental results in different scientific journals, with focus on their own special field of interest. To assess the "total" preventive efficacy and practical benefit of toxin binders used in experiments, nutritionists in the feed industry may invest some of their time following the titles of articles and/or associate authors and/or materials and methods of articles – unless they rely on recent reviews.

As the present review shows, experiments to reduce negative effects of AF in poultry feed have been mainly performed with zeolites and bentonites such as HSCAS, CLI and SB or biological matters such as yeast (SCE) and yeast derivates (EGM). Nutritionists in the feed industry and scientists can examine the results and decide which protective agent to use, taking into account the AF dose in feed, levels of protective agent, the experimental period and the species/variety of poultry species. Feed supplements must be inert and non-toxic and have no pharmacological and toxicological effects themselves in the organisms of animals. Possible nutrient interaction and dioxin contamination should also be regarded for using of natural clays.

Summary

In this meta-analytic review in vivo experimental trials on inactivation of aflatoxins by using adsorbents and biological products as a feed additive in poultry feed are briefly summarized. For this purpose, 155 researches performed in 35 different countries were examined and listed by country of first author, with main results presented in their summary. The aim of this review is to present the results of the experiments for nutritionists in the feed industry and scientists and to provide a basis for total evaluation on the basis of regional results.

For research on AF in poultry feed, it is preferable to evaluate the preventive efficacy of feed additives "as total" in terms of performance, biochemical-hematological, immunological and gross and histopathologic parameters, comparing AF treated control diets with AF plus feed additive diets. Scientists can assess the preventive efficacy and practical usability of feed additives in more detail by following the titles of articles, associate authors and/or materials and methods of related articles. For application in practice, focus on limiting AF contamination by optimizing harvesting and storage conditions should be stressed instead of expecting miracles from feed additives which have shown positive effects under experimental conditions.

Zusammenfassung

Entgiftung von Aflatoxin im Geflügelfutter: eine aktuelle Literaturübersicht

In dieser kurzen Übersicht werden Ergebnisse von Fütterungsversuchen zur Inaktivierung von Aflatoxinen durch Futterzusätze mit Adsorbentien und biologischen Produkten aus 155 Veröffentlichungen zusammengestellt Die zitierten Arbeiten sind mit den wichtigsten Ergebnissen nach Ländern des Erstautors aufgeführt, um Lesern einen schnellen Zugang zu regionalen Lösungsversuchen zu geben.

Leistungsmerkmale, biochemisch-hämatologische, immunologische und histopathologische Parameter sollten im Zusammenhang betrachtet werden, um die Effizienz spezifischer Futteradditiva in der jeweiligen Dosierung zu bewerten.

References

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