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Prof. Dietmar Flock, Editor

Editorial

Three years after changing to the online format of Lohmann Information, we are encouraged by the growing number of recipients: after deleting all incomplete addresses with unidentified country of residence, this issue will be mailed to 2247 readers in 124 countries. The cumulative number of visits on the website for specific papers confirms our expectation that many people also appreciate access to earlier publications when certain questions come up. We have therefore expanded the archive to include a list of all publications in "Lohmann Information International" 1/1979 to 25/2005; the complete papers may still be found in libraries.

Included in this issue are seven papers and one special reference as "food for thought":

1. Many of our readers will be directly or indirectly affected by consequences of the international financial crisis. Patterns of trade and terms of credit for investments in the global food industry are affected. The paper **"Effects of the financial crisis on the international meat industry"** by **Vito Martielli, Nan-Dirk Mulder** and **Albert Vernooij**, experts of Rabobank in The Netherlands, is reproduced from a recent publication few of our readers may have access to.

2. April is not the time when poultry producers have to worry about heat stress, but as good as any time to plan ahead for the hottest time of the year. **Prof. Nuhad J. Daghir** of the American University of Beirut, Lebanon, has worked extensively on nutrition under high temperature conditions and recently published a revised edition of his book "Poultry Production in Hot Climates". His paper **"Nutritional Strategies to Reduce Heat Stress in Broilers and Broiler Breeders"** is focused on minimizing heat stress by adapting feed composition and feeding to the needs during hot weather periods.

3. The general problem of heat stress in many regions of the world is similar for all types of poultry, but the solutions to minimize heat stress may differ. Based on extensive experience in her service area of Africa, **Viola Holik**, Tanzania, reviews the principles of heat management in her paper **"Management of laying hens to minimize heat stress"**. As for broilers, optimum nutrition is important for layers, and relatively simple strategies to reduce the effects of extreme temperatures can help to maintain good production.

4. Most people involved in animal production are aware of the importance of "feed conversion", but our knowledge is limited as to what happens in the gut between "input" of feed and "output" of edible meat, milk or eggs. In his paper **"The desired ideal: healthy gut and microbiota stability", Dr. David Taras** points out the importance of developing a quantitative definition of "gut health" in terms of microbiota composition.

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5. The EU has set ambitious targets for reducing Salmonella contamination in different species of farm animals. **Dr. Ilka Schröder** and **Dr. Ina Bräunig** review the complexities of Salmonella infections in their paper **"Holistic measures on combating Salmonella in broiler farms"** and propose how Salmonella reduction can best be achieved.

6. In connection with attempts to minimize losses due to aggressive behaviour in poultry and different species of farm animals, it is of interest to know to what extent differences between and within populations exist and may be used for genetic selection. **Dr. Georg Heil** and **Dr. Leo Dempfle** studied this question in experiments with male rabbits of different breeds and crosses. In their paper **"Genetic differences in the development of aggressive behaviour of male domestic rabbits"**, the statistical models used are described in detail. Injuries due to aggressive behaviour were shown to be age-dependent and related to sexual maturity. Heritability estimates indicate that aggressive behaviour can be successfully reduced by selection if the males are kept in groups beyond the usual killing age.

7. The German egg industry is currently changing from conventional cage management to floor systems or enriched cages ("Kleingruppenhaltung") which conform to German animal protection laws. As reported by **Prof. D.K. Flock** in his note **"WPSA support for Germany's exit from conventional cages"**, the German Branch of the World Poultry Science Association is cooperating with the poultry industry in an attempt to provide information on different management systems to producers who make their results available and to the general public.

8. Copyrights prevented us from reprinting a recent publication by **J. Gray** and **B. Griffin "Eggs and dietary cholesterol - dispelling the myth"**. You can access this article on the website of the British Nutrition Foundation under http://www.nutrition.org.uk/home.asp?siteId=43&sectionId =1308&subSectionId=344&parentSection=303&which=6.

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

With kind regards,

Prof. Dietmar Flock,
Editor

Effects of the financial crisis on the international meat industry[1]

Vito Martielli, Nan-Dirk Mulder and Albert Vernooij

The entire international Food and Agribusiness industry (F&A) is suffering the effects of the ongoing financial crisis. The global meat industry has been feeling the impact as consumers are cutting back on their food spending, financial institutions have tightened their credit lines, market confidence is lower and cross border F&A trade has declined. Players in the meat industry must overcome this temporarily negative medium-term outlook by focussing on their core business with clear cost control and processing efficiency. Since long-term demand drivers are not affected by the financial crisis, future winners will be those companies that take advantage of opportunities provided by the medium-term market dynamics, improving their starting position when markets normalise.

The global financial crisis and its implications

Financial crisis deteriorating meat demand growth

Meat consumption has been affected in many countries worldwide and global per capita meat consumption in 2009 will decline compared to 2008. However, due to continuing population growth, meat demand in absolute volume terms will grow, although at a slower pace.

In developed countries, where income represents the main driver of consumption growth, demand elasticity is generally low because meat is a basic good. However, as incomes come under pressure in 2009 due to the economic slowdown and consumer confidence reaches historically low levels, meat consumption is expected to decrease slightly. The value of the meat market in developed countries will decline even more as consumers will switch to lower-cost alternatives: from beef to pork and poultry, from steaks to sausages and from out-of-home to at-home consumption. For many developing countries positive GDP projections and population growth will result in further growth in meat demand albeit at a slower pace.

Declining meat demand is having a negative impact on sales and margins of meat companies. Many of these companies are already under pressure to recover from negative margins which were a result of the effects of the high feed costs during the second half of 2007 and the first half of 2008.

Investment in the industry reduced by decreased credit availability and market confidence

The financial crisis has decreased access to credit and capital markets. Credit from banks is still available but banks have become more selective in lending or increasing credit facilities. The reduction in available credit impacts the cost of borrowing and is leading to stricter terms. This increases the risk profile of many F&A players, including the meat industry. The overall situation has resulted in a reduction of production and trade, as well as difficulties in running or expanding existing operations.

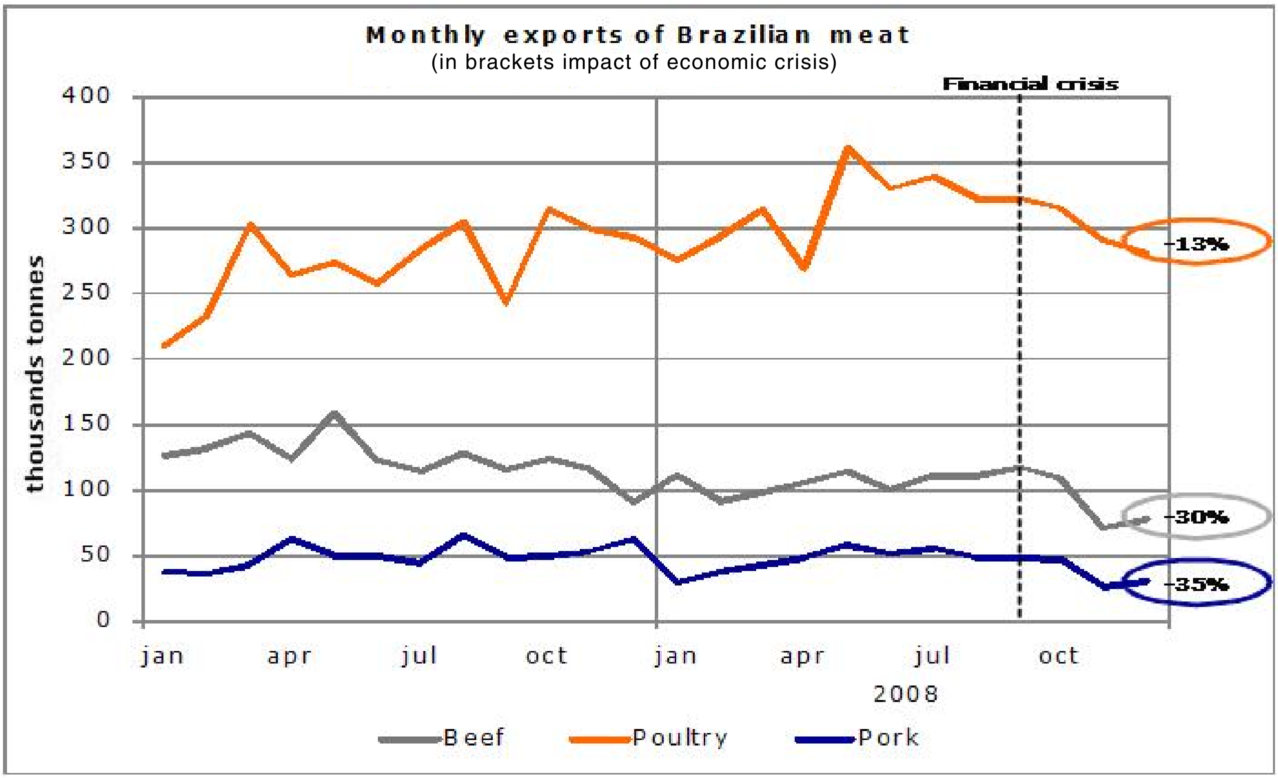
Low confidence in the market makes companies reluctant to take major strategic steps, although there are opportunities available. The reduced availability of capital, both equity and debt, has made it difficult for any one company to acquire another. This has resulted in a drop in M&A activity or new investments financed with external capital or by private equity houses. Low expectations for the meat industry in 2009 in combination with less available capital and credit has resulted in a sharp decline in new projects. For many years, investments for new projects in Russia were facilitated by government policies and the availability of capital from outside the F&A sectors. This resulted in a rapid modernisation and expansion of the domestic pork and poultry industries in Russia. However, today the meat industry is not able to invest in expected further growth of Russian supply, due to the country's quickly increasing interest rates and lack of financial sponsors. In other emerging markets such as India, Indonesia and China, a limited number of new projects have been announced in the last few months.

[1] Repinted from IMS Newsletter No. 423, March 2nd 2009 with slight modifications.

Declining cross-border trade further impacted by exchange rate volatility

The reduced availability of trade financing together with slowing meat demand has had a strong impact on global trade. A very clear example is the development of exports from Brazil, the global powerhouse in meat trade (see Figure 1). While Brazil had been able to expand its total meat exports for many years, they have now dropped an average of 20 percent on a monthly basis (August vs. December 2008) compared to the pre-crisis months. The beef and pork industries have been hit hardest, with total export drops of 30 percent and 35 percent respectively, while the poultry industry has been facing a 13 percent drop in export demand. The impact of these figures is even bigger considering that Brazil's competitive position has increased significantly compared to that of the USA, its main competitor, due to the appreciation of the US dollar.

Figure 1: Monthly Exports of Brazilian Meat, Jan – Oct 2008



Source: ABIPEX, ABIEC, ABEF, Secex, 2009

Competitive positions have been impacted by volatile exchange rates since the start of the financial crisis. The US dollar strengthened considerably vis-à-vis other currencies in the last months of 2008 but returned to 2008 lows in the first weeks of 2009, reviving the positive competitive position for US meat exporters. Australian producers in particular have seen a strong increase in world market prices, due to the weakening of the Australian dollar. The flip side of weakening currencies and the relative competitive position is that the price of inputs imported from the world market rise by the same percentage, thus undoing part of the competitive advantage.

The feed variable: refocus of attention on sourcing

Prior to the agricultural commodity boom, sourcing was not a major concern as commodity prices seemed fairly predictable and availability was hardly an issue. However, higher feed costs over the last one-and-half years have pressured working capital needs and severely reduced profit margins. The decline in commodity prices in the second half of 2008 relieved pressure on the working capital needs of companies; however, this did not improve margins. The expected rise in meat prices, which usually follows feed prices with some delay, did not occur due to the sudden drop in meat demand and declining cross-border trade. Some producers have forward contracts for feed purchases at the still higher price level. This will continue to reduce their margins for the coming months.

Commodity prices will continue to be very volatile in the coming years. Commodity stock levels are still relatively low which implies that prices of agricultural commodities could rise again if the coming harvests do not fully meet the growing demand. This situation could occur faster than expected because farmers are forecasted to apply less fertiliser in the current crop and/or take less land into production.

The continuing high volatility will have a huge impact on the future position of the meat industry. Sourcing has re-entered the meat industry chain at full speed due to its strategic impact on profitability. Companies are shifting focus to the upstream and midstream segments of the value chain.

Outlook and key success factors of the winning players

The financial crisis has deteriorated market confidence, decreased credit availability, increased exchange rate volatility and lowered cross-border trade. All of this is having a negative effect on per capita meat consumption and deteriorating the investment climate for the short to medium term.

However, due to continuing population growth in developing countries meat demand in absolute volume will continue to grow, albeit at a slower pace during the next few years. Moreover, long-term meat demand in volume will keep growing as other demand drivers, such as income growth and urbanization, are still in place resulting in a positive, long-term outlook for the global meat industry.

The deteriorating investment climate will challenge the meat value chain in the coming few years. Firstly, to attract direct capital in order to continue operations including possible restructurings in the current uncertain environment in which capital costs are higher than before; secondly, to have sufficient indirect working capital access when meat demand and/or commodity prices, begin to rise. This situation will be even worse if these two things happen simultaneously.

Winning companies will be those which perform well in the following three areas: good financials, operational excellence and demand focus. Companies with good financials have a strong balance sheet, positive cash flow and efficient cost control, which gives them possible access to direct and indirect capital and therefore the ability to face the difficulties of the financial crisis. Operational excellence is characterized by a lean-and-mean business model with optimal processing efficiency and flexible sourcing which is able to overcome commodity price volatility. The key aspect of demand focus is the company's ability to react quickly to changes in demand. A broad customer portfolio and few preferred relationships with select customers will allow them to react quickly when meat demand recovers. Furthermore, even in the current difficult circumstances, restructuring, M&A and investment opportunities are available for such companies to strengthen their strategic position. These companies will be able to overcome the temporarily negative market developments, grasp the opportunities provided by the medium-term market dynamics and position themselves to be in the driver's seat when markets normalize.

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Nutritional Strategies to Reduce Heat Stress in Broilers and Broiler Breeders

N.J. Daghir, Beirut, Lebanon

Introduction

The poultry industry has for some time occupied a leading role among agricultural industries in many parts of the world. Poultry meat production has shown much higher growth than any other type of meat during the past decade. The potential for growth is obvious in view of the value of this kind of meat in modern day human diets. Chicken meat production has been on the increase in all continents with the highest increases in Asia and South America. The rate of increase in chicken meat has averaged 5.7% per year since 1990 (Daghir, 2008). The hot regions of the world have probably the greatest potential for further growth since the level of consumption is still very low. Asia now leads the world in poultry meat production, followed by North and Central America which had the lead until 1990. In 2005 Asia and South America contributed 50% to global poultry meat production (Daghir, 2008). The rapid expansion of the industry in these regions is very evident in countries like Brazil in South America, Morocco and Nigeria in Africa, and Saudi Arabia in the Middle East. Shane (2006) presented data indicating that there will be an increase of 12.5% in consumption of poultry meat during the present decade. According to this author, the highest increase will be in Asia, Africa and South America, the main warm regions of the world.

There are several constraints to the future development of the poultry meat industry in the hot regions of the world. The first and foremost is the availability of capital. With the exception of the oil-rich countries, these regions are in general poor and have low per capita income. The availability of adequate supplies of grain and protein supplements necessary for the production of feeds is another major constraint for development. A third constraint on future development in these areas is the need to develop the various supporting industries for commercial production such as equipment, pharmaceuticals, packaging materials, housing materials, etc.. The lack of poultry-skilled people for middle management positions in these areas is a real hindrance to further growth in the industry as well as lack of adequate disease diagnosis and control facilities. Finally, the most obvious constraint to high production in these regions is climate. High temperature, especially when coupled with high humidity, imposes severe stress on birds and leads to reduced performance. During the past two decades there has been a great deal of research and development on ways and means of reducing heat stress of birds subjected to high temperature. By far the most effective have been developments in housing practices for hot climates. This paper will deal mainly with certain nutritional manipulations and feeding practices that have been found to be helpful in reducing heat stress in broilers and broiler breeders.

General Temperature Effects

There is considerable disagreement as to what is the ideal temperature range for different classes and age groups of poultry. This is probably due to the fact that many factors influence the reaction of poultry to temperature changes. The most important are humidity of the atmosphere, wind velocity, and previous acclimatization of the birds. Birds perform well within a relatively wide range of temperatures. Whether they are broilers, layers or turkeys, this range extends between 10 and 27° C. Kampen (1984) found that the highest growth rate of broilers occurs in the range of 10-22° C while maximum feed efficiency is at about 27° C. Charles (2002) reviewed the literature on the optimum temperature for performance and concluded that for growing broilers it is 18-22° C. It is known, however, that what is ideal for growth is not ideal for feed efficiency. The overall optimum range mainly depends on the market value of the product produced, relative to feed cost. As the price ratio widens, the best temperature falls, and vice versa.

The most important factor affecting performance in broilers subjected to high temperature is reduced feed intake. However, only part of the reduced performance of broilers is due to reduced feed intake and the rest is due to high temperature per se. Dale and Fuller (1979) showed that 63% of the reduction in broiler growth is due to reduced feed intake. More recently, we conducted some paired-feeding as well as forced-feeding studies on broilers raised at high temperature and found that 67% of the reduction in growth rate in these birds is due to reduced feed intake (Daghir and Hussein, unpublished data).

The response of broilers at high temperatures differs with different relative humidity. High temperature accompanied by high humidity is more detrimental to broiler growth than high temperature with low humidity. At the same time, constant high temperature of 30-32° C is more deleterious to broilers than cyclic or alternating temperatures of 30-32° C by day and 25° C by night. Feed conversion in broilers is subject to marked fluctuations because of seasonal as well as ambient temperature changes. All studies indicate that high temperatures reduce the efficiency of utilizing feed energy for productive purposes. Broilers not only eat less at high temperature, but also gain less per unit of intake, especially at temperatures above 30° C. Feed conversion in broilers is subject to marked fluctuations because of seasonal as well as ambient temperature changes. Poultry producers in the state of Florida found that 0.09 kg more feed was required to produce a unit of gain in broilers during the hot months June to August compared to the period November to April.

It has been known for some time that chickens can adapt to climatic changes. Attempts have therefore been made at reducing heat-stress mortality in broilers by acclimatization. Raising house temperature prior to the onset of a heat wave has been shown to reduce mortality. This is partly due to the reduction in feed intake in response to the stress. Arjona *et al.* (1990) observed that exposure to 35-38° C for 24 hours at 5 days of age reduced mortality when these birds were heat stressed for 8 hours at 44 days of age. It has been suggested that a temperature of 36-37.5° C at three days of age is optimum for early conditioning of broilers (Yahav and McMurty, 2001). Incubating eggs at high temperature has also shown to improve the tolerance of fast-growing broilers to heat stress (Yalcin *et al.,* 2008). Although this practice of acclimatization is still in the experimental stage, it has strong potential for the broiler industry.

Broiler Nutrition in Hot Climates

Environmental temperature is the most important variable affecting feed intake and thus weight gain of broilers. Several authors have shown that increasing the energy content of the diet can partially overcome this growth depression. It is common practice now in formulating broiler feeds for hot regions to boost the energy level of these diets by adding fat. This practice not only increases the energy intake but also reduces the specific dynamic effect of the diet, which helps birds to cope better with heat stress. Ghazalah *et al.* (2008) showed that high fat diets (5%) helped in reducing the detrimental effect of heat stress in broilers raised at 29-36° C. High fat content of the diet helps to reduce heat production, since fat has a lower heat increment than either protein or carbohydrate. The addition of fat to the diet also appears to increase the energy value of other feed constituents (Mateos and Sell, 1981) and has been shown to decrease the rate of food passage in the GI tract and thus increase nutrient utilization (Mateos *et al.,* 1982).

Besides energy, consideration must be given to the amino acid balance of the diet during heat stress. If the energy content of the diet is increased, all other nutrients must be increased proportionally. Minimizing excess amino acids usually improves feed intake. During hot periods, lower protein diets supplemented with limiting amino acids (mainly methionine and lysine) give better results than high-protein diets. Several workers have tested low protein diets supplemented with the most critical amino acids or simply protein levels higher than what is recommended by NRC (1994) for broilers raised at high temperatures. Filho *et al.* (2006) found that at 32° C, low protein diets (18-16.6-15%) for broilers impair performance. These protein levels were obviously too low for our modern broiler strains. Cheng *et al.* (1997) reported that feeding low protein diets to broilers partially ameliorates the negative effects of high temperature. Rahman *et al.* (2002) evaluated different levels of protein on broilers raised in a hot and humid environment and found that there were no significant differences in performance between groups receiving 23 vs. 21% protein. Temim *et al.* (2000) studied the effect of chronic heat exposure (32° C) on broilers fed different levels of protein and concluded that raising the protein level above 20% is not helpful to broilers to withstand high temperature conditions.

Most research has shown that temperature changes neither increase nor decrease the protein requirement of birds per unit gain. Some work shows that there is decreased protein synthesis and increased breakdown under heat stress (Lin *et al.,* 2006) and that this decreased protein synthesis can not be restored by increasing the dietary protein level. Part of this decreased performance is due to the increased heat production, since protein has a high heat increment. Therefore heat increment is lowered by decreasing dietary protein. Gonzalez-Esquera and Leeson (2005) found that the length of exposure to heat stress may affect the response of birds to dietary protein. Short term exposure has a different effect from long-term exposure. Reduction in crude protein levels in heat-stressed birds as a means to reduce heat production may not always be justified. Amino acid requirements as affected by temperature have been studied for many years and the response to amino acid supplementation at high temperature has varied a great deal.

Several factors therefore may be involved in differing responses to amino acid supplementation at high temperature. Chen *et al.* (2005) reported that the response to crystalline amino acid supplementation is affected by dietary electrolytes such as sodium chloride. Brake *et al.* (1998) confirmed this and reported that increasing the Arg:Lys ratio in Australian diets fed to broilers raised at 31° C improved weight gain and feed conversion when the diets contained low levels of NaCl. Balnave and Brake (2001) found that sodium bicarbonate improved broiler performance with high Arg:Lys ratio. Gonzalez-Esquera and Leeson (2006) concluded that the Arg:Lys ratio, methionine source and time of exposure to heat stress all altered protein utilization in hyperthermic birds. This brings us to the conclusion that the ideal amino acid balance for broilers raised at high temperature may vary with different dietary conditions.

The supplementation of essential amino acids to a diet with poor quality protein or unbalanced amino acid profile helps performance by reducing heat increment and the harmful effects of high temperature. The industry therefore has followed the practice of adjusting the dietary levels of protein and amino acids in order to assure an adequate intake of these essential nutrients as house temperature and thus feed intake vary. This is based on the assumption that temperature does not affect the efficiency with which amino acids are utilized for growth. Some nutritionists recommend to increase amino acid levels as a percentage of the diet up to 30° C, but beyond that temperature further increases are not justified because growth will be depressed.

Several acid-base imbalances occur in heat-stressed broilers. The occurrence of alkalosis in heat-stressed birds has been known for a long time and the addition of ammonium chloride, potassium chloride and/or sodium bicarbonate have improved performance of broilers by improving water and feed intake (Ahmad *et al.,* 2008). Mineral therapy and manipulation appear to be effective means of reducing detrimental effects of heat stress in broilers. The dietary electrolyte balance (DEB) also known as acid-base balance is probably more critical at high temperature than at normal temperature, and different results have been reported on the most appropriate DEB for birds under high temperature conditions. Ahmad and Sarwar (2006) reviewed the literature on this subject and concluded that differences in response depend on ambient temperature, age of bird, and length of exposure to high temperature. Very high (360 mEq/kg) and very low (0mEq/Kg) DEB can result in metabolic alkalosis and acidosis, respectively. In diet formulation very high and low DEB should be avoided. These authors concluded that birds under heat stress perform best at a DEB of 250 mEq /Kg. At the same time, excesses or deficiencies of any specific mineral should be avoided. Based on their recent study, Mushlag *et al.* (2007) concluded that the dietary requirements are 0.20-0.25 % Na and 0.30 % Cl during the finishing period (29-42 days) at temperatures ranging from 32 to 40° C.

Since heat stress always depresses appetite and therefore reduces nutrient intake, the use of a vitamin and electrolyte pack in the drinking water for 3-5 days during a heat wave has been shown to be helpful in most cases. Vitamin C supplementation is probably the most beneficial among vitamins, and several nutritionists recommend the administration of 1 g ascorbic acid / liter drinking water throughout heat periods. In addition, a vitamin pack of A, D, E and B complex supplementation of drinking water is beneficial for both performance and immune function of heat–stressed broilers.

Since many countries in hot regions import their vitamin and trace mineral mixes, and since there are often delays in transport of ingredients, the problem of vitamin stability is of primary concern. Temperature, moisture, and oxidation by polyunsaturated fatty acids, peroxides and trace minerals are the most critical factors affecting vitamin stability in both complete feeds and vitamin-trace mineral premixes. Therefore, vitamin activity in feeds should be preserved by the incorporation of antioxidants, selecting gelatin-encapsulated vitamins, appropriate storage conditions, adding choline separate from the vitamin and trace mineral premix, delaying the addition of fats until just before the use of the feed and using feeds as soon as possible after mixing.

Temperature and Body Composition of Broilers

Today's broilers are selected and managed with the aim of increasing meat yield and decreasing fat deposition. Several studies have shown that environmental temperature has an effect on carcass composition and meat yield. At high temperature, meat yield, particularly breast meat yield, is reduced (Yalcin *et al.,* 1997, 2001). Akit *et al.* (2005) studied the effect of temperature on meat quality and found that high temperature had an adverse effect on meat quality.

Cahaner and Leenstra (1992) found that males were more affected by high temperature than females.

Lu *et al.* (2007) found that abdominal fat deposition of Beijing You (BYJ) chickens was enhanced by heat exposure, while fat deposition in Arbor Acres broilers was decreased in heat-exposed and pair-fed chickens. They concluded that the impact of heat stress was breed dependent and that the BYJ chickens showed higher resistance to high temperature, which could be related to their increased feed efficiency and deposition of abdominal fat under heat exposure. Although there is a lot of research on breed and strain differences in resistance to heat stress, very little has been done in relation to breed and strain responses to different nutritional states at high temperatures. Havenstein (2007) reported in a study on turkeys that strains and sexes reacted very differently to an old (1966) vs. a modern (2003) dietary regime in response to high temperature and high humidity. Birds on the 1966 diet (high protein, low energy) performed better during the summer than those on the modern high energy diet (see figures 1 through 4). Birds on the modern high energy diet reduced their intake as an adaptive measure to minimize heat stress. This author agreed with Veldkamp *et al.* (2002) who concluded that turkeys modulate feed intake when exposed to high ambient temperature in relation to the caloric density of the diet.

Fig. 1: Body Weight Males

(G1 = generation 1966, G2 = generation 2003; F1 = feed 1966, F2 = feed 2003)

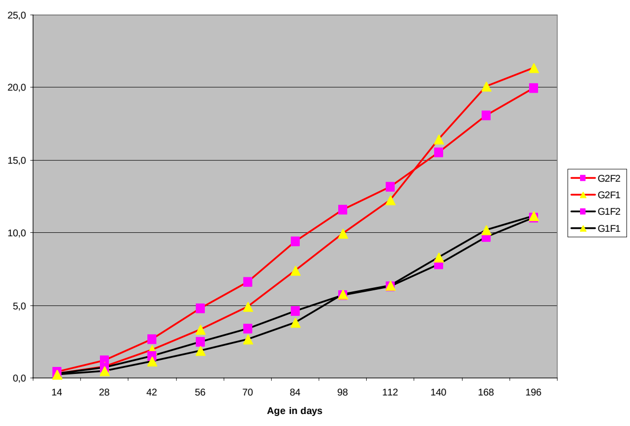


Fig. 2: Body Weight Females

(G1 = generation 1966, G2 = generation 2003; F1 = feed 1966, F2 = feed 2003)

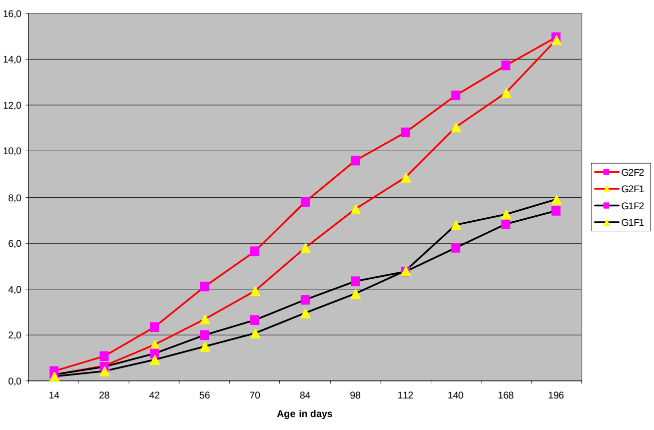


Fig. 4: FCR Males

(G1 = generation 1966, G2 = generation 2003;
F1 = feed 1966, F2 = feed 2003)

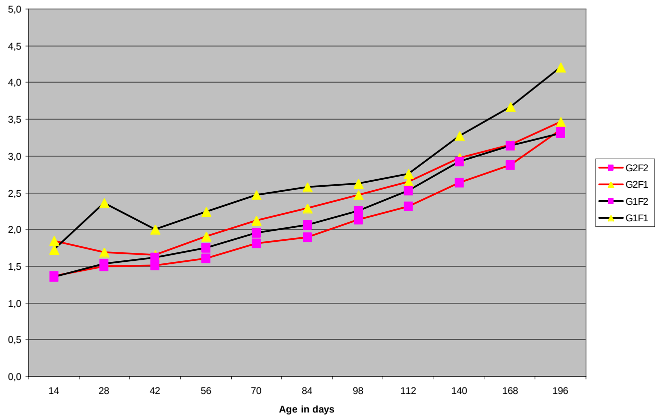
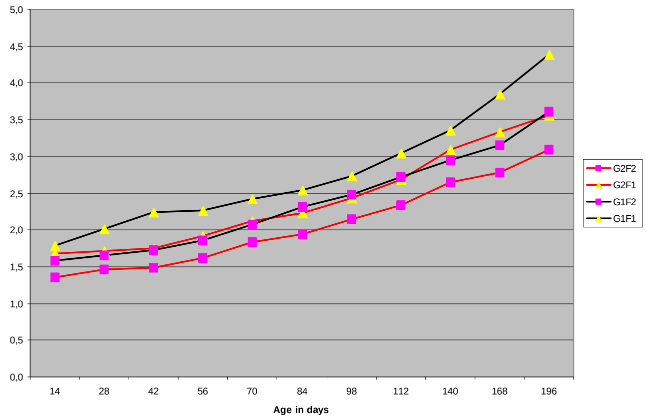


Fig. 3: FCR Females

(G1 = generation 1966, G2 = generation 2003;
F1 = feed 1966, F2 = feed 2003)



Broiler Feeding Recommendations

For hot climates, the author recommends that protein levels be about 1-2 % lower than usually recommended for temperate regions because of what has been presented above. Energy levels should be adjusted to protein levels, but kept higher than currently used in many hot regions. The potassium level should be increased to 0.6 % in contrast to 0.4% normally recommended in cool climates. Levels of critical amino acids should be about 5-10% higher than normally used at the same protein level.

In many cases, straight-run broilers are fed a starter diet for the first three weeks of age; a grower diet from three to 6 weeks of age; and a finisher diet from 6 weeks to market weight. If the growth rate is depressed due to hot climate, it may be necessary to feed the grower to 7 weeks. In hot and humid climates, slight increases in dietary protein late in the broiler cycle may be beneficial for growth and feed efficiency. These increases in dietary protein are also helpful in reducing abdominal fat content.

Broilers are usually fed either crumbles or pellets. In hot climates, broilers prefer feed with larger particle size and therefore it may be beneficial to start pellet feeding earlier than usual. Intermittent feeding programs have been used in some broiler operations. This method could have possible applications in hot climates since the hours of darkness provide minimum activity on the part of the birds and therefore reduced heat production.

Fasted animals produce less heat than fed animals. Feed withdrawal has been shown to reduce heat production, leading to a decrease in body temperature and mortality of broilers (Francis *et al.,* 1991; Yalcin *et al.,* 2001). Feed withdrawal during the hottest hours of the day has therefore become a common practice in many broiler-producing areas. One suggested practice during a heat wave is not to feed between 8:00 a.m. and 8:00 p.m. Fasting will probably result in reduced weight gain, a longer growing period and thus a delay in marketing age, but also reduced mortality. Therefore the producer has to weigh the benefits of a faster growth rate vs. a greater mortality risk. Another concern about feed withdrawal is that alterations in intestinal morphology and depletion of intestinal mucosa due to fasting may reduce the integrity of the intestine (Thompson and Applegate, 2006).

Water plays an important role in cooling broilers. The cooler the drinking water, the better the birds can tolerate high environmental temperature. Growers usually provide broilers with approximately 25% more drinker space than the standard cool climate recommendation. Where possible, wide and deep drinkers, permitting not only the beak but all the face to be immersed, should be used. In case chlorinated water is being used on the farm, it is recommended to discontinue chlorination on extremely hot days.

Nutritional manipulations, such as the addition of fat and the reduction of excess protein and amino acids as described above are recommended. Birds should be fed during the cool hours of the day. Maintenance of both carbon dioxide and blood pH is critical to the heat-stressed broiler and the addition of ammonium chloride and potassium chloride to the drinking water to maintain this balance is advised. The addition of extra vitamins and electrolytes to the drinking water is helpful under most situations and the use of ascorbic acid in the feed or in the drinking water is a common practice in many hot regions of the world.

Broiler Breeder Nutrition in Hot Climates

Nutrition for meat-type breeders differs from egg-type chickens because the former tend to become obese and decline in egg production. Boren (1993) presented some basic rules on broiler breeder nutrition and pointed out that nutritional strategies in use today are to help balance the lower potential for egg production against the economic necessity of maximizing viable hatching egg production and minimizing costs. There are very few studies on the feeding of broiler breeders in hot climates. We know that males are more susceptible to heat stress than females, and that younger females experience a more severe drop in egg production when heat stressed.

Broiler breeder pullets are placed under feed restriction starting at about 14 days of age. Two methods of quantitative restriction are used for pullets. Birds can be fed either restricted amounts daily or on a skip-a-day program. For hot climates, the heat production of birds on every-day feeding is about 10% lower than those on a skip-a-day feeding (Leeson and Summers, 1991).

In cool climates, the effect of using high-protein pre-breeder rations has been studied on reproductive performance of the broiler breeder hen and the results have not always been positive. This practice, however, may be useful in certain warm regions where poor-quality protein is used and where breeder pullets may be underweight at onset of production.

The energy requirement of the broiler breeder hen is considered to be the most limiting nutrient. Rostagno and Sakamoura (1992) studied the effects of environmental temperature on feed and ME intake of broiler breeder hens. Daily feed intake, nitrogen corrected ME, and nitrogen corrected true ME decreased linearly as environmental temperature increased. Hen body weight and rectal temperature were not affected. A rise in temperature by 1° C resulted in a decrease of feed intake by 2.43 g per hen, 2.10 kcal MEn/kg body weight and 2.20 kcal TMEn/ kg body weight. Egg production, egg weight, egg mass and feed conversion were not affected by environmental temperature.

The use of vitamin supplements to improve performance of breeder flocks in hot climates has been studied by few workers. It is fairly well established that fertility in hot climates can be improved in breeder flocks by the addition of extra amounts of vitamin E if breeder rations contain the usual level of 15-20 mg/kg of diet. The addition of ascorbic acid to breeder rations of both chickens and turkeys has yielded positive responses in many cases. Supplementation of broiler breeder feeds with 300 ppm ascorbic acid during hot summers in the Eastern Mediterranean region improved performance (Cier *et al.,* 1992).

The calcium requirement of the breeder hen increases with age. Birds require slightly more phosphorous at high than at moderate or low temperatures. Breeders need a minimum daily intake of about 700 mg of total phosphorous. For breeder hens maintained in cages, the requirements of both calcium and phosphorous are significantly higher than for those kept on litter floors. The daily sodium requirement of broiler breeders has been estimated to be about 170 mg per hen (Harms, 1987).

Feed allowances for breeder hens are usually determined by egg mass output, body weight and changes in time to consume feed by the breeder. Egg mass output usually continues to increase after peak egg production has been reached. Therefore, peak feed, which is usually started from about 40 to 50 % of production, should be maintained for 3-4 weeks after maximum egg production has been reached. Changes in consumption time are good indicators of over- or underfeeding. Several stressors have been shown to affect the time required to eat the daily allowance, high environmental temperature being one of the most important. McLeod and Hocking (1993) compared two lines of breeder hens divergently selected for fatness and leanness for susceptibility to heat stress. Their results showed that fat line birds were more susceptible to heat stress; this susceptibility was not related to increased heat production, but to a decreased ability to lose heat.

Feeding broiler breeders once vs. twice daily was studied by Samara *et al.* (1996) to determine the effect of feeding time and environmental temperature on performance. High temperature caused a significant reduction in egg weight, specific gravity and shell thickness as expected. Changing the feeding time from 7:00 a.m. to 6:00 p.m. did not improve eggshell quality in heat-stressed hens.

Broiler Breeder Feeding Recommendations

The nutrition of meat-type breeders is critical in hot climates because of the feed restriction used and differences in maintenance requirements as well as quality of feeds available in many hot regions. The use of a high-protein pre-breeder ration may be useful in those areas where breeder pullets are underweight at onset of production. Broiler breeder pullets should not be severely restricted early in their life cycle in hot climates since a moderate restriction at that age is less stressful. This allows for better uniformity and proper fleshing, both of which contribute to good hatching egg production. Feed allowances for growing meat breeders should be determined on the basis of ME requirements per bird per day and these should be adjusted in relation to body weight and condition and uniformity of the pullets. Lack of uniformity may be due to insufficient feeder space and/or inadequate feed quality.

The daily energy requirement of the meat breeder hen increases from about 300 kcal ME at 20 weeks to about 400 kcal ME per bird at 28 weeks of age. This early part of the production cycle is critical, and calculations based on flock averages ignore the fact that individual needs differ between hens before and after onset of lay. Therefore, feed allowances during this period should exceed the average requirements to provide a safety margin for hens already producing. The daily protein requirement of the meat breeder has been estimated to be about 20 g per bird and less protein intake of individual birds will reduce egg weight and body weight.

A feeding program is recommended which consists of an 18% protein chick starter with 2850 kcal/kg, a 15% protein grower with 2750 kcal/kg, a 16% protein female breeder with 2750 kcal/kg and a 12% protein male breeder with 2750 kcal/kg. When it is difficult to use a specific male diet, the grower diet can be used for feeding males separately throughout the breeding period, provided that it is supplemented with the breeder vitamin and trace mineral premix rather than the grower premix.

Nutritional manipulations stated above for both broilers and broiler breeders can reduce detrimental effects of heat stress but can not fully eliminate them.

Summary

One of the most important constraints for the development of the poultry meat industry in the hot regions of the world is climate. This paper deals with certain nutritional manipulations and feeding practices that have been found to be helpful in reducing heat stress in broilers and broiler breeders. The most important factor affecting performance in broilers subjected to high temperature is reduced feed intake. High temperature accompanied by high humidity is more detrimental to broiler performance than high temperature with low humidity. Nutritional manipulations, such as the addition of fat and the reduction of excess protein are recommended. During hot periods, lower protein diets supplemented with limiting amino acids give better results than high protein diets. Responses to amino acid supplements differ with different dietary factors at high temperature; dietary electrolytes being one of them. Maintenance of both carbon dioxide and blood pH is critical to heat-stressed broilers and the addition of ammonium chloride and potassium chloride to the drinking water to maintain this balance is advised. The dietary electrolyte balance (DEB) is more critical at high temperature than at normal temperature. The addition of extra vitamins and electrolytes to the drinking water is also helpful and the use of ascorbic acid in the feed or in the drinking water has become a common practice in hot regions. Environmental temperature has an effect on carcass composition and at high temperature, meat yield, particularly breast meat is reduced.

The nutrition of meat-type breeders is critical in hot climates because of the feed restriction used and the differences in maintenance requirements and in the quality of feeds used. Broiler breeder pullets should not be severely restricted early in their life cycle in hot climates. The use of a high-protein pre-breeder ration is useful in those areas where breeder pullets are underweight at onset of production. Specific energy and protein requirements are presented in the paper for both female and male breeders in hot regions.

Nutritional manipulations used for broilers and broiler breeders are useful in reducing the detrimental effects of high environmental temperatures, but what is more effective is controlling house temperature such as the use of environment controlled housing.

Zusammenfassung

Richtige Ernährung von Broilern und Broilerelterntieren als Beitrag zur Minimierung von Hitzestress

Der wirtschaftliche Erfolg der Haltung von Broilern und Broilerelterntieren hängt in vielen Regionen vom Klima bzw. der Effektivität von Maßnahmen zur Optimierung der Stalltemperatur ab. Diese Arbeit gibt einen Überblick über bewährte Praktiken der Futteroptimierung und Fütterungstechnik an heißen Standorten bzw. bei saisonal erhöhten Temperaturen.

Broiler reagieren auf hohe Stalltemperatur vor allem durch reduzierte Futteraufnahme, vor allem bei gleichzeitig hoher Luftfeuchtigkeit. Um die dadurch verringerte Nährstoffaufnahme auszugleichen, sollte man das Futter durch Fettzusatz energiereicher machen, den Proteingehalt absenken und limitierende Aminosäuren entsprechend erhöhen.

Die Wirkung erhöhter Aminosäurengehalte hängt von verschiedenen Faktoren ab, u.a. von den Elektrolyten im Futter. Der Zusatz von NH4Cl und KCl zum Trinkwasser ist zu empfehlen, um einen ausgeglichenen CO_2 Gehalt und pH-Wert im Blut der Broiler bei Hitze zu unterstützen. Ausgewogene Elektrolyten sind bei hohen Stalltemperaturen wichtiger als im optimalen Temperaturbereich. Erhöhte Vitaminzusätze im Futter und Elektrolyten im Trinkwasser sind zu empfehlen, Ascorbinsäure wird üblicherweise in heißen Regionen im Futter oder Wasser zugesetzt.

Erhöhte Temperaturen wirken sich auf die Schlachtkörperzusammensetzung aus: unter Hitze leidet der Ausschlachtungsgrad, und vor allem der Anteil Brustfleisch ist niedriger als bei optimaler Stalltemperatur.

Die richtige Fütterung von Broilerelterntieren ist eine besondere Herausforderung im heißen Klima wegen der notwendigen und üblichen Mengenbegrenzung. Während der Aufzucht sollten Mastelterntiere nicht zu scharf im Futterverzehr begrenzt werden. Wenn die Junghennen bei Legebeginn untergewichtig sind, sollte eine proteinreiche Prestarter Ration gefüttert werden. Detaillierte Empfehlungen für den Energie- und Proteingehalt im Futter für Hennen und Hähne in heißen Regionen werden gegeben.

Angepasste Ernährung von Broilern und Mastelterntieren ist eine sinnvolle Maßnahme, um den Hitzestress zu mildern, es ist jedoch kein Ersatz für die noch wichtigeren Maßnahmen zur Kontrolle der Stalltemperatur.

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Management of laying hens to minimize heat stress

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Introduction

Animal production constitutes an important component of the agricultural economy of developing countries, a contribution that goes beyond direct food production and includes multipurpose products and uses, such as skins, feathers, fibre, manure for fertilizer and fuel, power and transportation, as well as a means of capital accumulation and as a barter product in societies without circulation of currency. Poultry production has emerged as a substitute for beef and mutton, with spectacular growth rates throughout the world during the last decade: 23 percent in developed and 76 percent in developing countries, respectively. This increase is due to the introduction of commercial production and has been most notable in the Far East where growth averaged 90 percent. In India, for example, production has increased sixfold in ten years.

People in industrial countries eat about twice as many eggs as people in developing countries-approximately 226 eggs per person per year. Yet only 30 countries are seeing any growth in per capita egg consumption. Among these nations are China, Libya, Mexico, Colombia, Turkey, and India. Elsewhere, egg consumption is either stable or falling. FAO predicts that most future growth in egg consumption will occur in the developing world in places like China, where income and population patterns are still shifting

Table 1: Changing contribution of continents to global hen egg production
(World Poultry Vol 23, No 6, 2007)

Continent	1970	1990	2005
Africa	3.0	4.4	3.7
Asia	23.7	39.2	60.4
Europe	30.9	20.1	16.8
USSR	11.5	13.0	-
NC America	25.3	16.4	13.6
S America	4.3	6.3	5.1
Oceania	1.2	0.7	0.4

In many developing countries poultry production is based mainly on traditional extensive poultry production systems. For example, it has been estimated that 80 percent of the poultry population is found in traditional family-based poultry production systems, contributing up to 90 percent of poultry products in low income countries like Ethiopia.

In order to supply the rising demand of a growing and increasingly urban population, intensive commercial projects are being introduced. An obvious example for this development is Asia. Poultry production has rapidly changed in Asian countries like China, India, Thailand, Vietnam, Indonesia, Japan and Korea. Following the introduction of modern breeds and Western technologies, countries such as Thailand and China have become major poultry exporters, supported by cheap labour and cheap power, inclusion of non-conventional feeds and substantial government support. Poultry entrepreneurs in Asia make use of the high production potential of modern egg and meat strains, follow similar management practices and bio-security as Western countries, compete with one another on the global market and often face the same challenges.

Heat stress is a common problem world wide in poultry production. High ambient temperatures can be devastating to commercial broilers and layers; coupled with high humidity they can have even

Table 2: Productivity of scavenging chickens relative to modern breeds

Parameter	Scavenging village chickens	Commercial chickens
Age at marketable weight (weeks) Age at sexual maturity (weeks)	>24	<8 for broilers <20 for layers
Egg production (eggs/hen/year)	40-60	>250
Egg weight (g)	30-50	>60
Mature weight (kg)	1-1.7	>2
Mortality rate (%)	Chicks >60 Adults 45-100	<20

André Mayer 1997

Table 3: Estimated population of rural poultry in developing countries

Country	Number of rural poultry ('000)	Village poultry as a percentage of national flock
Africa	1 500 000	70
China	2 000 000	50
Côte d'Ivoire	-	53
Ethiopia	53 200	99
Indonesia	187 000	60
Kenya	16 000	70
Lesotho	1 600	-
Malaysia	6 500	13
Myanmar	23 200	85
Nepal	-	90
Nigeria	120 000	80
Pakistan	55 500	42
Philippines	43 000	72
Sri Lanka	2 500	25
Tanzania	-	86
Thailand	120 000	80
Uganda	16 000	80
Viet Nam	196 000	98
Malaysia (West)	6 600	15
Zimbabwe	-	30

Source: Awan (1993)

more harmful effects. Heat stress interferes with the birds comfort and suppresses productive efficiency. During periods of heat stress the hens have to make major thermo-regulatory adaptations to prevent death from heat exhaustion. The result is that the full genetic potential of the layer is often not achieved.

The purpose of this article is to review some of the effects of heat stress on layers and methods which can be used by the poultry producer to partially alleviate some of the detrimental effects of heat stress on the birds' productivity.

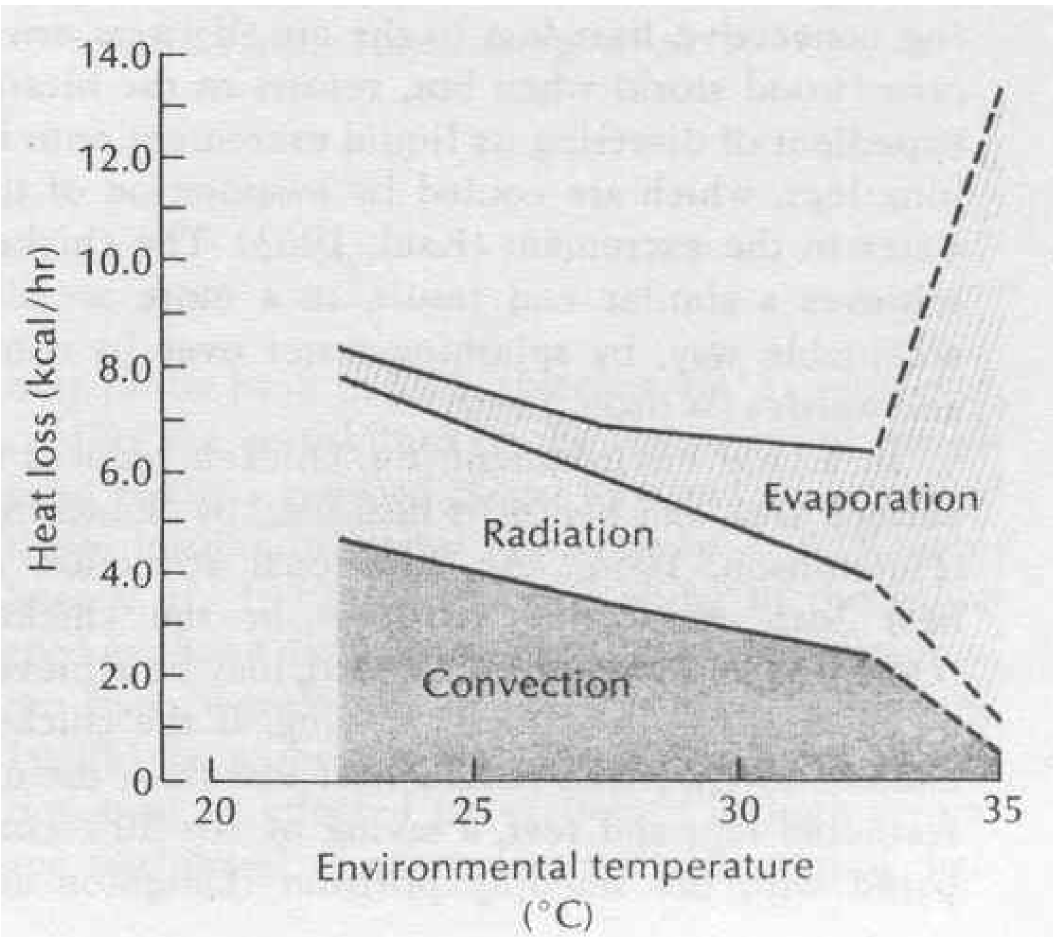
General

The body temperature of a hen varies between 40 and 42°C (Anderson 1997. North 1998). depending on day time (before and after feeding. night time). feather cover in connection with moulting, brooding and environmental temperature – on which we will focus here.

The ideal environmental temperature for chickens is 18-24°C. Above 24°C the bird has a number of possibilities to remove the excessive body heat:

- **Radiation** – heat loss is proportional to the temperature difference between the body surface and the surrounding air. Poorly insulated, hot roofs will increase house temperature and heat stress on sunny days - similar to direct sun on free range birds without shade.
- **Convection** - heat loss will occur due to increasing air temperature around the hot body. This process can be assisted by providing moving air fast enough to break down the layer of still air surrounding the body.
- **Conduction** - is relatively unimportant. but heat may flow surface to surface e.g. if the birds stand or sit on cool litter or cool water pipes. Usually the litter has a similar temperature as the house and water pipes are insulated.
- **Evaporation** - since the bird's skin has no sweat glands, evaporation takes place through panting and this is only effective if the humidity is not too high. Hot and humid conditions are therefore much more stressful than hot and dry conditions. In order to lose 1 ml of water, the chicken uses 540 Cal, and this energy loss may result in significant drop of production.

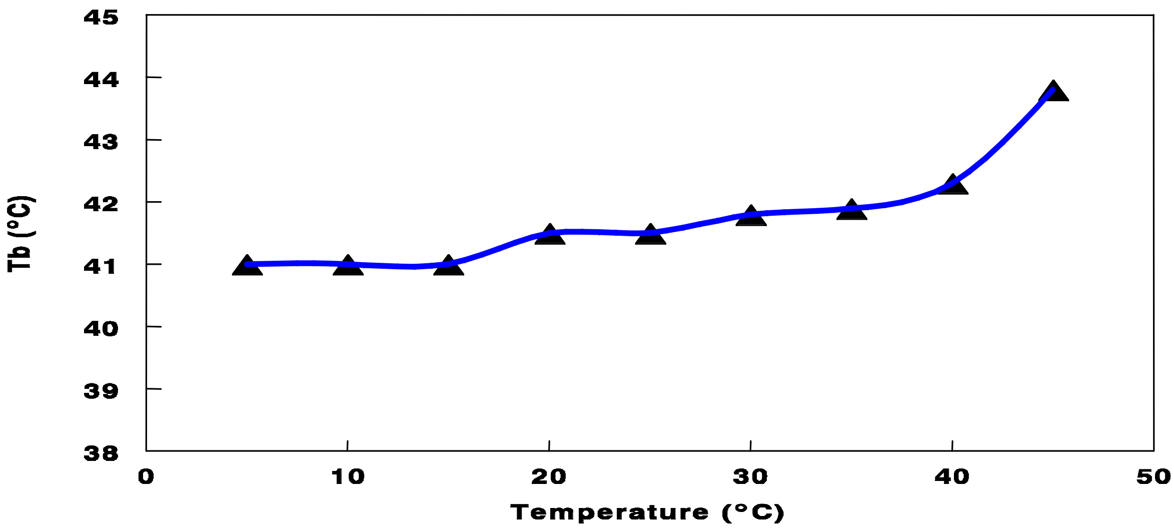
Fig. 1: Radiation, convection and evaporation with increasing house temperature
(Source: Whittow, 1976)



Source: Roller & Dale (1962); Deshazer (1967)

As illustrated in Figure 1, the rate of losing body heat through radiation and convection decreases with increasing temperature, and the bird has to rely mainly on temperature regulation via evaporation.

Fig. 2:



As mentioned above, 18 - 24°C is the ideal environmental temperature for a hen. Up to a temperature of about 30°C the hen can still regulate the body temperature, but when the house temperature reaches 40°C the body temperature will increase dramatically.

Exposed to 30°C the hen reacts with reduced feed intake, resulting in smaller egg size and eventually lower egg production.

When the temperature increases from 30 to 38°C, shell quality is likely to deteriorate as indicated by increasing percentage of cracked eggs. Above 38°C the bird can only get rid of body heat through severe panting which produces respiratory alkalosis. This physiological response is characterised by an increase in blood pH (more basic) along with a decrease in blood CO_2 concentration. It upsets the acid-base balance and produces a decrease in blood calcium and bicarbonate which are necessary for the production of strong egg shells. As a result, more thin-shelled eggs will be produced.

From 41°C the risk of death is high and emergency measures have to be taken. A temperature of 47°C is lethal.

Rising temperature will lead to a decrease of feed and increase of water intake. Water: feed intake ratio at 15°C for example is 1.82:1 while it is 4.9:1 at a temperature between 30-35°C, which is quite a common situation with open houses in hot climates. The following table 2 shows the effect of ambient temperature on production, egg weight and feed conversion:

Table 4: Effect of house temperature on egg production, average egg weight and feed consumption per egg, relative to the optimum of 16° C (Source: North, 1984)

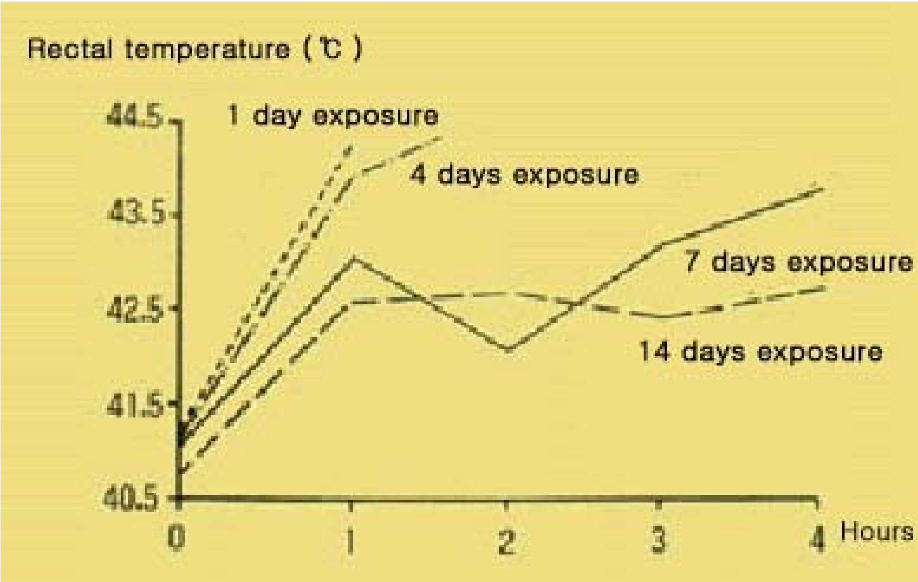
Temp.	Prod.	EW	Feed/egg
16° C	100	100	100
18° C	100	100	95
21° C	100	100	91
24° C	100	99	89
27° C	99	96	86
29° C	97	93	85
32° C	94	86	84

- **Adaptation**

Layers reared at high temperatures from a young age can adapt to some extent and reach good productivity. The hens develop larger wattles and combs and have less fat and feather coverage.

The following figure 3 after Sykes (1983) shows how the body temperature adapts to high temperatures within 14 days.

Fig. 3:



(Sykes. 1983)

Good management practices include attention to the following possibilities to minimize heat stress:

- **Stocking density**

Sensible heat loss depends on the difference between the body temperature of birds and ambient temperature. If stocking density is high, the radiant heat between the birds accumulates and the temperature increases. The birds therefore cannot lose body temperature.

Recommended stocking density with increasing house temperature:

Temp. (c°)	Litter (birds/m²)	Cages (cm²/bird)
25	5.5	450
30	4.5	550
35	3.5	650

- **Bird handling**

During the hot period of the day any additional stress on the birds should be avoided. Vaccination, beak treatment, transfer or any other kind of handling should be done during the coolest period of the day, if necessary at night. In any case, handle the birds as calmly and gently as possible.

- **Water temperature**

Leeson and Summers (2000) exposed layers to an environmental temperature of 33°C. Cool water of 2°C was given to half of the flock and the other group received water of 33°C. The birds with access to cool water consumed 12 g more feed per day than the group given warm water, resulting in 12% higher production, with slightly reduced egg weight due to the higher rate of lay.

Birds can reduce body temperature by drinking cool water. Therefore, cool water of good quality should be supplied at all times. This requires that the water tanks are properly insulated. The tanks should be light colored, shaded and filled up to 80% capacity to keep the water cool. Pipes should be insulated and/or buried 1-2 m underground. The lines in the house should be cooled by flushing waterlines with fresh cool water 2 – 3 times a day. The pipes in the house should not be installed close to the roof to avoid heat from the roof warming up the water in the pipes. If bell drinkers are used, water should be changed 2-3 times a day. Sufficient drinkers have to be available and for nipple drinkers use broiler nipple drinkers.

Changing the acid-base balance of the water through addition of NH4CL or HCL or KCL is recommended. The addition of 5% KCL has shown a significant increase of water intake.

- **Feeding time**

Feeding at the right time of the day is very important to support the birds in coping with heat stress. During late afternoon a significant rise in body temperature can be observed which can kill the birds in severe cases. This is not the hottest time of the day, but it is the peak time of digestion if the birds have been fed in the early-mid morning period. A good strategy to take an unnecessary heat load off the birds is to withdraw feed 8 hrs prior to the anticipated time of peak temperature. One third of the daily feed ration should be given in the morning and two thirds in the late afternoon. An additional advantage is the availability of calcium in the digestive system during shell formation at night and in the early morning hours. It will improve shell quality and prevent the birds from depleting bone calcium. So-called ‘midnight snacks’ are a good tool to give hens extra feeding time in the cooler parts of the night. This does not have to be exactly around midnight, but 3 hrs of darkness before and after the extra 1-2 hours of light is essential to avoid disturbing the lighting program

- **Feed stimulation**

Simple strategies to stimulate feed intake are:
- run the feeder chains more frequently, if necessary empty to avoid overflow.
- the feeders should run empty at least once a day to enhance the appetite and assure that also the fine particles of the feed (premixes, vitamins etc.) are consumed.
- the feed texture should not be too fine; use oil to avoid “dusty” feed.

- **Nutrition**

ME requirement decreases with increasing ambient temperature above 21°C resulting from a reduction of energy requirements for maintenance. The requirement for production is not influenced by environmental temperature. The energy requirement will decrease with the rise of temperature up to 27°C, above which it will start to increase again since the bird needs additional energy for panting to reduce body heat.

- **Oil**

Including oil in the diet has long proved to be beneficiary in hot climates and shows better effects than in moderate climates. For example the inclusion of oil increased feed intake by 17.2% at 31°C compared to only 4.5% at temperatures of 10-18°C (McNaughton and Reece, 1984).

Digestion of fat produces less heat than the digestion of carbohydrates and proteins. Oil binds the fine particles in the feed and stimulates feed intake and increases the energy level in the feed, which is very important to compensate the reduced energy intake due to less feed intake during heat periods. Fat has also been shown to slow down feed passage through the gastrointestinal tract and therefore increases nutrient utilisation. Up to 5% oil can be used.

An additional advantage of oil is the content of linoleic acid which improves the production and weight of the eggs.

The following table shows the contents of fatty acids in different oils.

Table 4: Fatty acid contents of different sources of fat and oil

Fatty acid	Animal fat	Poultry fat	Bone at	Coconut fat	Palm oil	Rape oil	Soybean oil	Sunflower oil
Laurin C 12:0	0 - 0.2	-	-	48	50	-	-	-
Palmitin C 16:0	23 – 27	20	19	9	7	5	8	6
Stearin C 18:0	14 – 18	8	16	2	2	2	4	4
OiL C 18:1	40 – 60	37	47	7	15	51	28	20
Linol C 18:2	7 - 10	25	8	1	1	24	53	70
Linolen C 18:3	0 - 1	4	1	-	-	6	6	-

Source: IG Fett. Hartfiel

- **Protein**

Whether protein levels should be increased or decreased in diets to minimize heat stress and maintain production has been studied with different results. Consensus appears to be that the key to good nutrition is to focus on daily intake of essential amino acids while reducing total digestible protein intake within the constraints of available raw materials.

- **Vitamins**

Vitamins are very important components of a chicken's diet and unless a formulated ration is used, it is likely that deficiencies will occur. Vitamin C is thought to support the birds in handling heat stress, but the effects are not yet fully understood. Some birds may not be able to synthesise sufficient ascorbic acid to replace the severe loss of vitamins during heat stress. Perek and Kendler (1962, 1963) showed that added Vitamin C improved egg weight, shell thickness and egg production. Experiments of Njoku and Nwazota (1989) demonstrated that adding ascorbic acid in the feed formula improved feed intake and feed utilisation. The optimal effect was shown by adding 250-400 mg ascorbic acid/kg.

Due to the lower feed intake at high temperatures sufficient supply of vitamins has to be guaranteed. Vitamin deficiencies can have the following negative effects:

Fat soluble vitamins

Vitamin A	Decreased egg production, weakness and lack of growth
Vitamin D	Thin shells, reduced egg production, retarded growth, rickets
Vitamin E	Enlarged hocks, encephalomalacia (crazy chick disease)
Vitamin K	Prolonged blood clotting, intramuscular bleeding

Water Soluble Vitamins

Thiamine (B1)	Loss of appetite and death
Riboflavin (B2)	Curly-toe paralysis, poor growth and poor egg production
Pantothenic Acid	Dermatitis and lesions on mouth and feet
Niacin	Bowed legs, inflammation of tongue and mouth cavity
Choline	Poor growth, fatty liver, decreased egg production
Vitamin B12	Anaemia, poor growth, embryonic mortality
Folic Acid	Poor growth, anaemia, poor feathering and egg production
Biotin	Dermatitis on feet and around eyes and beak

- **Electrolytes**

The electrolyte balance in birds is altered during heat stress due to panting. Panting increases carbon dioxide loss in the bird, which reduces the bird's ideal water intake. By adding electrolytes to the feed or water, birds increase their water intake which aids in keeping a constant body temperature and maintains an effective system of evaporative cooling.

- **Minerals**

During heat periods. mineral excretion is usually increased. Therefore it is advisable to increase the mineral level in the formula. Since it is difficult to react fast enough through dietary changes. application via drinking water is recommended.

The most important minerals and possible effects due to deficiency are:

Calcium	Poor shell quality and poor hatchability, rickets
Phosphorus	Poor shell quality and poor hatchability, rickets
Magnesium	Sudden death
Manganese	Perosis, poor hatchability
Iron	Anaemia
Copper	Anaemia
Iodine	Goitre
Zinc	Poor feathering, short bones
Cobalt	Reduced hatchability, retarded growth, mortality

To meet the Calcium requirements of laying hens, additional oyster shells or limestone chips should be offered.

1. Naturally ventilated houses

In naturally ventilated houses the air has to flow in and out of the house easily. High roofs help to remove heat from the birds. Naturally ventilated houses are usually open. They should be facing in an east-west direction to avoid direct sunlight heating up the building in the afternoon. Direct sunlight increases the effective temperature which the birds feel. The birds will try to move away from direct sunlight, contributing to heat stress due to higher stocking density in the shady part of the house.

- Construction
Natural ventilation is most effective in houses max 12 m wide. The faster the air flows, the more effective will be the cooling. For example: an air flow of 0.1 m/sec has no cooling effect, whereas an airflow of 1.25 m/sec has a cooling effect of 3.4°C (North, 1998). The walls should not be too high so that the air movement can reach the birds.

- Roof
The roof should be insulated to minimise heat absorption and be provided with open ridges (1 m) to allow hot air to escape from the house. Inexpensive locally available insulation materials such as palm leaves, reeds or corn stalks can be used but may attract wild birds, rodents etc..

Instead of good insulation materials such as sprayed polyurethane or polystyrene board, which may be relatively expensive or not available, one can also use simple solutions such as white wash to decrease the heat uptake on the roof. Good mixtures are 10 kg of hydrated lime + 20 l of water or 10 kg hydrated lime + 10 kg of white cement + 25 l of water.

The roof should have an overhang. Properly designed overhangs help to reduce direct and indirect sunlight getting into the house. The taller the side wall and the closer the side wall opening is to the ground, the longer should be the roof overhang. A minimum overhang of 0.6 m is recommended; taller houses and larger curtain openings will benefit from roof overhanging 1.25 m and more.

- Surroundings

The immediate surroundings also have an important effect on the inside temperature of the house. A green lawn around the house kept short and watered will help to reduce reflection of sunshine. Wet grass will also have a cooling effect through evaporation. Small tress can be planted around the house for shade, but they should not disturb the air movement. The temperature difference between shade and sun can be up to 15°C!

All obstacles that hinder air flow should be removed, even cobwebs on the fence.

- Fans

Additional equipment can be installed to control the house temperature. If natural air flow is not sufficient, fans should be installed. Slow speed, large industrial type fans are recommended, installed at 1 m above the ground to blow air horizontally over the birds. It is advantageous to operate the fans also during the night to assist birds to recover from heat stress during the day. The maximum ventilation rate recommended dictates the size and number of fans. As a simple rule of thumb, use 1 x 620 mm 900 rpm fan per 1.000 laying hens.

- Foggers

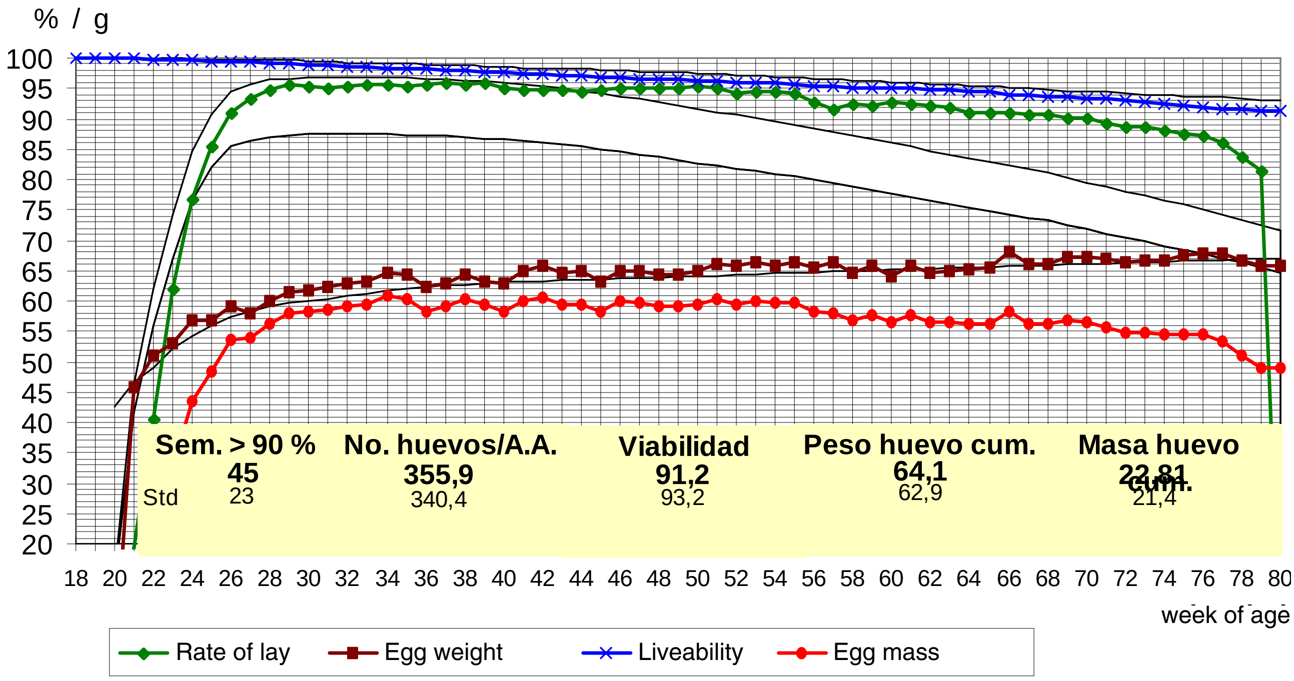
Foggers can help to decrease house temperature; the effect depends on the number of nozzles installed. In open, naturally ventilated houses the rule of thumb is to have a minimum of 0.35l/h fogging nozzle capacity for every square meter of floor space. Fogging should not be started below 28°C and not if the humidity exceeds 80%. Small cycle fogging is better than long cycles (8 sec / 15 sec @ 40% RH) (8 sec / 22 sec @ 70% RH).

- Gunny

The so-called “Gunny” is like a small sister of the cooling pad system - simply a cloth covering a part of the fence. soaked in water through a hose pipe. This simple device can reduce the surrounding temperature by up to 3°C due to evaporation.

Birds kept in open houses can have outstanding results despite high temperature, as shown in the example from South America, documented in figure 4, where the temperature averaged 30°C. These 14.300 LSL layers had only 7% mortality to 75 weeks of age and produced 355 eggs per hen housed, 15 eggs more than the current standard.

Fig. 4: An example for normal production in open housing despite high temperature



2. Power ventilated houses

An alternative to open houses are closed, environmentally controlled houses. They are more expensive in construction and maintenance, but also more effective in controlling temperature. More predictable, consistently high production and reduced mortality should cover the added cost.

Power ventilated houses can have positive or negative pressure systems. The type mostly used in hot climates is the negative pressure system, in which case the air is extracted from the building with fans and enters it through small inlets. Two different negative-pressure systems can be used: (i) the tunnel ventilation system in which the air enters the house at one end of the building and big exhaust fans are located at the other end of the house; (ii) the inlet ventilation system which has several air inlets and fans distributed over the entire building. The tunnel ventilation system is considered more effective in heat management due to a higher rate of air exchange and faster air movement which cools the birds more efficiently.

- Construction

New houses should be properly insulated and have a high standard of construction. Open houses may be transformed into power ventilated houses by closing the side walls with curtains, which requires minimal investment. In case of a power failure or technical problems, it must be possible to open the curtains to switch back to natural ventilation. But curtains do not insulate well and may sabotage the effects of the power ventilation. Roof and walls have to be well insulated.

The airflow has to be sufficient to keep the birds cool. A critical figure is the temperature of the air leaving the house. Transporting the excess heat from the birds, the building and the motors, the outgoing air should not be more than 2.8°C hotter than the outside temperature. The following formula is used to calculate the required air-flow in a power-ventilated house:

Air-Flow Rate = cross-sectional area of the house x required or maximum speed desired.

- Inlets

A minimum of 1m² inlet area per 14.000 m³/h exhaust fan capacity is recommended.
The inlet systems can be differentiated in 3 systems:
(i) cross ventilation (fans on one side of the house. inlets on the other side; works best in houses less than 10 m wide);
(ii) side-wall ventilation (fans and inlets on side-walls);
(iii) attic inlet ventilation (fans are distributed at the side-walls, inlets are in the roof).

- Tunnel ventilation

Tunnel ventilation does not only depend on the right air exchange rate, but also on the air speed. For layers an air speed of 2.5-3 m/s is recommended. The fans can be located either at the end of the building or on the side walls at the end.

3. Evaporation cooling

The principle is based on the fact that humid air contains more thermal energy than air with the same temperature but lower humidity. By spraying water or passing incoming air through cool cells (wet pad), humidity is increased and air temperature decreased. As shown in the following table 5, the cooling effect by evaporation will be best if the humidity of the initial air is low. This system is therefore widely used in desert areas.

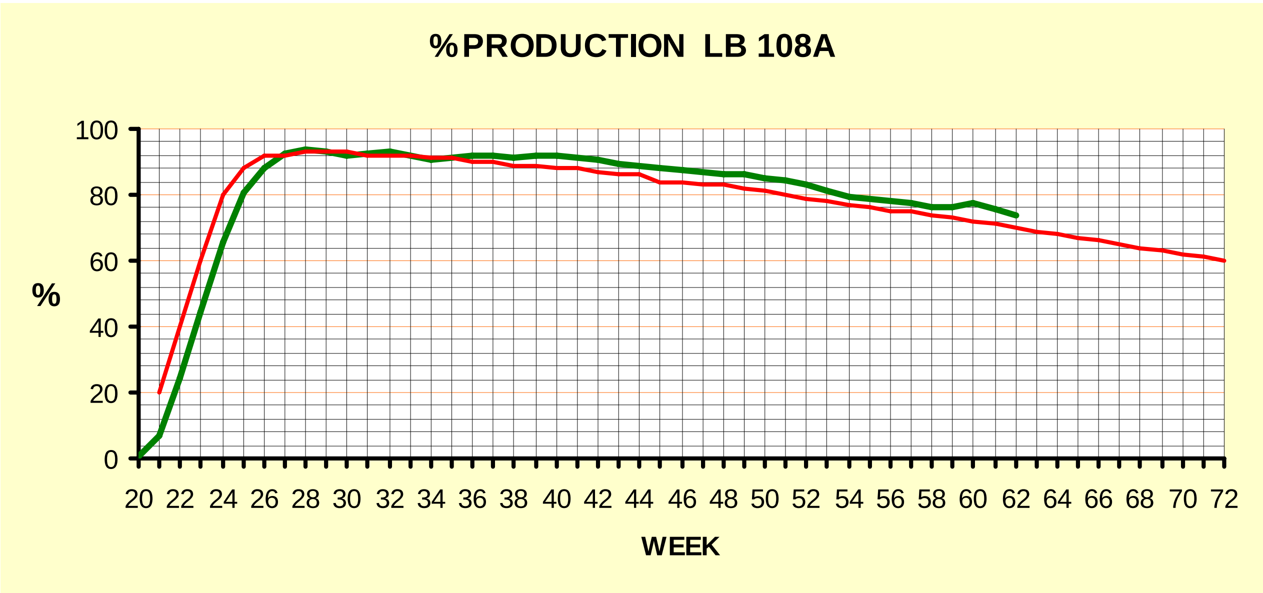
Normally a house with tunnel ventilation is used and the walls opposite the fans are equipped with the cooling pads. Cooling pads have to be in proportion to the fans installed.

Birds placed in environment-controlled houses can achieve outstanding results. Figure 5 shows the rate of production of a LB parent flock in Egypt in a closed 'brown-out' house with a dimension of 30 X 100 m with full litter and cooling pads with exhaust fans. The house is equipped with metal nests for manual egg collection. This parent flock peaked at 94%, produced at a rate above 90% for more than 13 weeks and had cumulative mortality of 6.5 % to 62 weeks of age.

Table 5: Effect of evaporative cooling depending on initial temperature and humidity

Initial temp.	Temp. after humidity increase		
	30% → 80%	40% → 80%	50% → 80%
30°C	20°C	21°C	22°C
35°C	23°C	26°C	28°C
40°C	28°C	31°C	34°C

Fig. 5: Egg production with environment controlled housing in Egypt



Summary

Animal production is an important agro-economic branch in developing countries, in which the poultry economy plays a fundamental role and has largely replaced the production of cow and mutton, above all in Asia. Especially egg production enjoyed a significant increase of per capita consumption in developing and newly industrialised countries like China, Mexico, India, Turkey and Colombia, where local populations were replaced by more efficient modern hybrids.

Intensive poultry production faces many problems, including heat stress, which limits the realization of genetic potential. This article explains what happens if ambient temperatures exceed the optimum range for layers and how the effects of heat stress can be minimized under practical conditions.

The ideal temperature range for layers is between 18-24°C. Above this level, the birds employ different mechanisms to get rid of excessive body heat. Up to 30°C, the hen can regulate body temperature by reducing feed intake (at the cost of egg output, because energy is used for cooling the body). Chickens can adapt to high temperatures to some extent, but from 41°C drastic measures must be taken to avoid mortality due to heat stroke.

The most important measures are:

- special care in designing new houses (location and position, roof construction, insulation)
- special equipment for cooling (pad cooling, ventilators, foggers, roof sprinklers)

- reduced bird density at housing
- cool drinking water
- feeding during early morning and afternoon
- special feed formulation with higher energy (added oil), lower total protein (balanced amino acids) and higher levels of minerals and vitamins
- if necessary stimulation of feed intake (midnight snack)

Strains of laying hens which are suppirior in moderate climates have no problem adapting to open houses with high temperatures, as demonstraited by the field records in figure 4.

In correctly constructed closed houses it should be easy to realize sufficient air movement and cooling the air down to the desired level by increasing humidity with cooling pads and tunnel ventilation. As illustrated with field records of a Lohmann Brown parent parent in Egypt, investments in environment control can pay off in terms of higher and more predictable egg output. If capital is available for investment in closed housing, the expected return on investment should be calculated from the difference between outside and inside temperature, humidity of outside air and the expected income from additional eggs produced.

Zusammenfassung

Managementempfehlungen für die Haltung von Legehennen zur Minimierung von Hitzestress

Tierproduktion ist ein wichtiger agrarwirtschaftlicher Zweig in Entwicklungsländern, wobei die Geflügelwirtschaft eine zunehmende Rolle spielt und vor allem in Asien häufig die Produktion von Rind- und Schaffleisch ersetzt. Insbesondere bei der Eierproduktion gab es einen Anstieg im pro Kopf Verzehr in Entwicklungs- und Schwellenländern wie China, Mexiko, Indien, der Türkei und Kolumbien, wo lokale Rassen durch Legehybriden ersetzt wurden.

Die intensive Geflügelhaltung ist nicht problemlos, insbesondere in diesen Ländern Hitzestress für die Tiere, unter dem sie nicht ihr volles genetisches Potential entfalten können. Dieser Artikel soll den Effekt von Hitzestress bei Legehennen erläutern und Hilfestellung beim Management leisten.

Die ideale Temperatur für Legehennen liegt bei 18-24°C. Wenn diese überschritten wird, hat das Huhn eine Reihe von Mechanismen zur Verfügung, um exzessive Körperwärme abzuführen, wobei mit steigender Temperatur vor allem Verdunstung eine tragende Rolle spielt.

Bis zu 30°C kann die Henne die Körpertemperatur auf Kosten von Eizahl und Größe gut regulieren, da sie die Energie für die Kühlung benötigt und weniger frisst. Hühner können sich bis zu einem bestimmten Grad auch an Hitze gewöhnen, aber ab 41°C müssen drastische Maßnahmen ergriffen werden, um Mortalität zu vermeiden.

Die wichtigsten Maßnahmen sind:

- richtige Konstruktion der Ställe (Lage, Dach, Isolierung)
- zusätzliche Kühltechnik (Padcooling, Ventilatoren, Nebelanlage, Dachberegner)
- geringere Besatzdichte bei der Einstallung
- kühles Trinkwasser
- optimale Futterzeiten
- Futteroptimierung in Anpassung an geringeren Verzehr (Öl als Energiequelle; weniger Rohprotein durch Zusatz limitierender Aminosäuren; erhöhte Vitamin- und Mineralstoffgehalte)
- ggf. Stimulierung erhöhter Futteraufnahme durch „midnight snack“

Dass die in Gebieten mit mäßigen Temperaturen marktführenden Herkünfte auch bei Offenstallhaltung in heißeren Regionen sehr gute Resultate erzielen können, wird an einem Beispiel von Lohmann LSL in Südamerika gezeigt. Geschlossene Ställe mit optimaler Klimakontrolle haben sich in ariden Gebieten bewährt. Ob sich diese Investition im Einzelfall rechnet, hängt nicht nur von der Differenz zwischen der Außentemperatur und der gewünschten Stalltemperatur ab, sondern auch von der Luftfeuchtigkeit der Außentemperatur und dem Verkaufserlös der zusätzlich produzierten Eier.

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The desired ideal: healthy gut and microbiota stability

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Introduction

The concepts of stability of the intestinal microbial composition and a therewith inferred so-called gut health seem to be increasingly popular. The search terms “healthy gut”, “gut health” and their synonyms, respectively, are cited more than 6000 times in the databases pubmed and Google scholar, which represents an exponential increase since their first mentioning in 1829[1] and 1913[2], respectively. Hence, within the scope of this article one might assume that the wide use of the respective terms implies a simple and well-established definition. Surprisingly, up to now a conclusive and generally-accepted definition of these terms has not been found. One might even get the impression that not one serious attempt has been made. Furthermore, it is interesting that the mere acknowledgement of this unsatisfactory situation and a thorough discussion of the problems arising due to this fact are more or less absent in the scientific literature. Therefore, the frequent use of the concept of a stable microbiota-dependent gut health is often quite uncritical and inaccurate and sometimes even careless.

This article is an attempt at an approach to these concepts using three central questions:
(1) **Why** is gut health and microbiota stability important at all;
(2) **How** can these concepts be defined; and
(3) **How** can they be measured?

Importance of gut health and microbiota stability

First of all, both concepts have found their way into the European regulatory framework (EC No. 1831/2003), which regulates the use of feed additives. Even more importantly, well-balanced microbiota and subsequently a healthy gut have a direct influence on the efficiency of nutrient utilisation and overall animal health.

The regulation EC 1831/2003 describes the functional group of “gut flora stabilisers” as microorganisms or substances, which have a “positive effect on the gut flora” of animals and thereby “favourably affecting animal production, performance or welfare”. Within this functional group an actual stabilisation is literally not necessarily the aim of the feed additive, but any effect on the microbiota deemed positive will suffice. Obviously, this is a rather vague definition and naturally the nature of the effects is the subject of controversial discussions. Nevertheless, for the topic of this article it should be noted that the regulation clearly states that microorganisms have an effect on welfare including the health of the animal.

This effect is the result of a very complex and highly interactive ecosystem within the intestine, which is formed between the consortium of all microorganisms present, host cells mainly of epithelial and immunological nature and diets of various compositions. The nature of the interaction between all components of this system is very difficult to describe both theoretically and experimentally. Microbiological factors, such as metabolite production, epithelial adhesion, pathogenicity factors, and nutrient utilization are an integral and indispensable part of this environment-host-interface which is formed on the other hand by the innate and acquired immune system, the mucous, epithelial surface factors, and the epithelial turnover rate. The efficiency of nutrient utilization in the small intestine is not only an economic issue in animal production but also important for the state of health of the individual animal. According to Anderson (2002)[3] the effects of the intestinal colonization can be characterized as mainly competitive to host interest in the small intestine and mainly cooperative in the large intestine. The main competitive factors are concurrence for dietary energy and nitrogen sources as well as the resulting production of harmful microbial metabolites. The main cooperative factors are the provision of energy by microbial utilization of nutrients which are indigestible by host enzymes as well as the competitive exclusion of pathogens. The extent of the competitive and cooperative effects depends on the composition of the intestinal microbial community, which is therefore a rewarding and frequently aimed at target for intervention strategies.

The comparison of conventional and germfree animals demonstrates how important the intestinal microbiota are for the physiological development of the host. Very extensive discussions of the differences are found, for example, in articles of Berg (1996)[4], Collinder (2001)[5] and Tannock (2001)[6] respectively. Amongst other things, microorganisms are responsible for morphological changes (e.g. larger intestinal surface, higher cell turnover, smaller caeca, faster peristalsis, higher mucin content, larger spleen and lymph nodes), immunological changes (more systemic γ-globulins, more intra-epithelial lymphocytes, more IgA producing lymphocytes, faster immunological reaction to antigens, inducible oral tolerance) and metabolic changes (e.g. higher amount of SCFA, bile acid and bilirubin degradation, cholesterol utilization, β-glucuronidase and urease activity). It is obvious that all these changes together play an important role for the health of the host.

Although it is clear that microorganisms are responsible for all these changes, most species remain to be identified. Furthermore, besides effects caused by the collectivity of all microorganisms and in addition to the fact that microorganisms are present at all, species and strain-specific effects as well as the composition of the microbial community are important for the nature of the effects.

In the GI tract a delicate and tightly-regulated homeostasis between intestinal microorganisms and the immune system exist.[7] A model put forward by Noverr *et al.* (2004) might serve as an example for a specific beneficial effect of the intestinal microbiota on health.[8] The proposed model describes how the gastrointestinal (GI) microbiota might even regulate pulmonary immune responses in the airways to inhaled antigens that are non-infectious (pollens) or of extremely low infectivity (mould spores). The key roles in this model of oral tolerance have regulatory T-cell networks. Under non-inflammatory conditions, swallowed antigens are acquired by immature dendritic cells in the GI tract, which then promote the development of a regulatory T-cell network and prevent the development of over-exuberant Th2 responses.

On the other hand, certain long-term alterations in the bacterial and fungal GI microbiota induced through antibiotic use, dietary changes or illness as well as the total absence of GI microbiota as in germfree animals would alter the developmental environment for regulatory T cell responses. Amongst other things, antibiotics lead to overgrowth of the yeast Candida albicans which can secrete potent prostaglandin-like immune response modulators from the microbiota. Under conditions of particular microbiota alteration mature dendritic cells are primed upon encounter of non-infectious/low infectious microorganisms and an inflammatory Th2 response initiated, which leads eventually to allergy. Both IL-4 and IL-13 are involved in perpetuating Th2 responses.

In addition to the development of oral tolerance, "healthy" gut microbiota promote e.g. the IFN-γ induced gene expression of indoleamine 2,3-dioxygenase (IDO), nitric oxide synthase 2 (NOS2), phagocyte oxidase (phox), natural-resistance-associated macrophage protein 1 (NRAMP1) and guanylate-binding proteins (GBPs), which are involved in the inhibition of bacterial, protozoal and viral replication.[9] The production of IFN-γ itself is promoted by regulatory T-cell networks and inhibited by Th2 responses. Just to name one example, Rhee *et al.* (2005)[10] report convincing experiments proving an IFN-γ dependent colonization resistance. They found an attenuated intestinal inflammatory response and a higher systemic bacterial burden of *Salmonella typhimurium* in pups (and adult IFN-γ knockout mice) compared with adults, which were caused by an age-dependent shortcoming in the intestinal expression of a number of IFN-γ-regulated genes involved in antimicrobial defence. The developmental up-regulation of the IFN-γ-regulated genes was dependent on both IFN-γ and a normal commensal microflora.

However, it has to be considered - as stated by Cebra (1999)[11] in a review of the influence of gut commensals on colonization resistance - that the underlying mechanisms are probably (and in my opinion very definitely) complex and various. For example, experiments of Lawley *et al.* (2008)[12] show that antibiotic treatment causes a higher susceptibility to the transmission of *Salmonella enterica* Serovar Typhimurium through disturbance of the indigenous intestinal microbiota. Very similar observations were also reported by Sekirov *et al.* (2008)[13]. In their experiments antibiotics had a dose-dependent effect on the intestinal microbiota composition although they did not significantly alter the total numbers of intestinal bacteria. Greater pre-infection perturbations in the microbiota resulted in increased susceptibility in mice to *Salmonella* serovar Typhimurium intestinal colonization, greater post-infection alterations in the microbiota, and more severe intestinal pathology.

Another aspect of the complex intestinal ecosystem is reported by Barman *et al.* (2008)[14]. They suggest that *Salmonella* infections in mice involved local mucosal host responses which take place prior to a disruption of the intestinal ecosystem. From alterations in microbiota composition which preceded the onset of diarrhoea in their experiments, they concluded that pathogen-commensal interactions and/or host responses unrelated to diarrhoea are involved.

Definition of gut health and microbiota stability

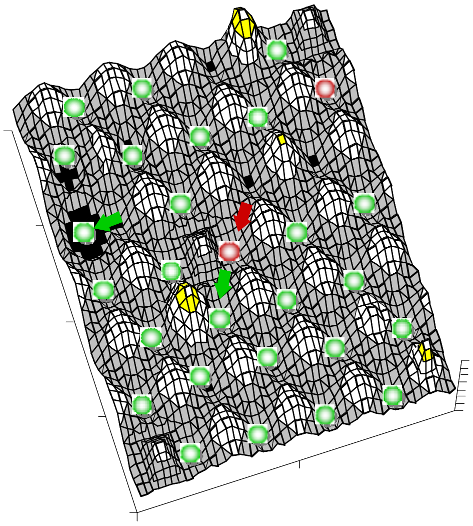
As suggested above, gut health and microbiota stability are very difficult to define due to the complexity of the underlining concepts. The closest approximation to a definition of gut health is the orientation at the WHO (1946)[15] definition of general health itself: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". This definition is also the best indication for the difficulties encountered when defining "gut health" since although not very precise it has not been amended since 1948. At least, deduced from the health definition, "gut health" should include not only the complete histological intactness of the intestinal mucosa but also the overall functional "well-being" of the intestinal ecosystem, i.e. the optimal performance of its nutritional and immunological duties for the overall well-being of the host. When reviewing the literature this additional meaning of health explains the historical differences between the terms "gut health" and "healthy gut", with the latter term appearing first in the literature of the early 20th century and relating initially only to the morphological intactness of the intestine while the former covers in its most frequent use all parts of the aspired definition. Nevertheless, it must be noted that both terms have been used so far in an inconsistent, versatile, ambiguous or at least unspecific way. Therefore, the definition of "gut health" remains unclear and is mainly determined by its ongoing use in the literature. Examples for this habitual use will be described in a later paragraph.

In this context, the term "healthy" is often also used to describe the state of the intestinal microbiota. For example, eubiosis was defined as "stable and healthy microflora in the digestive tract".[16] The "stability" mentioned is expected to preserve a composition of certain microbial populations, which is often believed to be positive for "gut health". Although "stability" and "dynamics" are antonyms in their colloquial use it must be noted that in ecological science "stability" is by no means a rigid, constant or everlasting condition. Botton *et al.* (2006)[17] define stability as the ability of a system "to return to an equilibrium state after a temporary disturbance". Consistently, eubiosis has been defined as "a state of a dynamic equilibrium of the microflora in stomach and intestinal tract".[18] The term dynamic equilibrium/ecological balance/biocoenotic balance describes the dynamic interrelationship of a biocoenosis (in open systems), which despite fluctuations in population frequency of single species or other disruptive factors (i.e. abiotic environmental factors) maintain the stability of the overall system as long as no principle milieu alteration occurs.[19] If a stress situation cannot be compensated, this results in the succession into another ecosystem which might be as stable as the former one. Therefore, stability as such implies no assessment of the quality of the system, i.e. „healthy" or „dysbiotic". The biocoenosis is not in equilibrium during the succession so that the term stability is not expedient during this period.

The ability to react to constantly changing environmental conditions refers to both the composition (structural component) and the function (process component) of the system. According to Botton *et al.* (2006)[17] and references therein, the stability of each of these components is usually not related and greater structural stability might even lead to less stability of function due to lower functional redundancy.

System stability can be depicted using a ball and cup heuristic, where valleys represent stability domains and balls the system.[17] Resilience of the system in this model is described as slopes of the landscape and width of the valleys. Disturbances would push the system up the slope and ecological change may modify the shape of the landscape (i.e. change resilience height or modulate equilibrium points). For details see the excellent review of Botton *et al.* (2006)[17]. A three dimensional representation of this landscape model is given in Figure 1. In the intestine several different stability domains exist, each possibly with different domain slopes regarding their valleys and slope shape, i.e. resilience characteristics. The form of the stability domain and the character of the microbial system, and consequently the immense number of possible stable systems will depend on the age of the host, the kind of host species and genotype, secretory products of the host, peristalsis, the type of diet (structure, viscosity, components), the environmental condition (e.g. management and housing), appliance of therapeutics, confounding illnesses and the kind of intestinal segment. Many of these stable systems might be characterized as “healthy” microbiota and just a few as “dysbiotic” conditions. Nevertheless, this multiplicity of possible “healthy” communities and processes complicates and hampers the establishment of a definition of gut health.

Figure 1: Three dimensional representation of a possible section of a landscape model of system stability within the gut. Green balls depict “healthy” microbiota and red balls “dysbiosis”. Valley width and slope steepness characterize resilience of the system. The landscape shape (system characteristics) varies in the intestine depending on several factors (see body of the text).



In addition, there are not only several possible „healthy” microbiota compositions, but also the analysis and characterization of the composition of the intestinal microbiota is methodological difficult if not in its entirety completely impossible.

A very simplified and surely too naïve idea of microbiota characterization is its classification into taxa (mostly on the genus level) with “harmful effects” on one side and those with “health promoting functions” on the other side.[20] In these models Clostridium spp. are placed univocally in the former category while *Lactobacillus* spp. are placed in the latter. These models are problematic due to their generalization and simplification. Tannock (2003)[21] reviews several reports on exceptions of this simplified classification: *Lactobacilli* (inter alia L. *rhamnosus, L. reuteri*) as well as other Probiotic organism containing genera can cause bacteraemia, rarely with localisation on heart valves or liver abscess. Nevertheless, the bacteraemia is most often only caused together with underlying conditions such as cancer, diabetes mellitus, or recent surgery and is often polymicrobic.[22-28] Quite similarly, *Saccaromyces boulardii* strains might cause fungemia.[29-31] In addition, potentially harmful antibiotic resistance can be found in several *Lactobacillus* and *Bifidobacterium* strains.[32-33] It should also has to be noted that *Clostridiacea* and *Enterobacteriacea* can not be generally classified as harmful. Butyrate production in the large intestine by *Clostridium* spp. is an important ecological function[34-38] and *Escherichia coli* and *Salmonella* strains have probiotic functions.[39-44]

A further model divides the microbiota into “main flora”, which consist of the most common gram positive and/or gram negative bacteria (i. e. *Lactobacillus* spp., *Bifidobacterium* spp., *Bacteroides* spp., *Eubacterium* spp.), the “secondary flora” (i. e. *Enterococcus* spp., *E. coli*) and the “residual flora” (potentially pathogenic *Proteus* spp., *Staphylococcus* spp., *Pseudomonas* spp.). The state is referred to as „eubiosis” if the ratio of main:secondary:residual flora is 90:1:0.01.[45] This classification is also problematic in at least two aspects. By concentration on group frequencies it ignores that very low counts of pathogens might cause illnesses without changing the proposed ratios of main, secondary and residual flora. In addition, shifts in species composition within these groups will not be noticed although sufficient to cause either beneficial or harmful effects.

To get a more realistic picture of the complexity of the intestinal microbiota, the following facts should be recognized why it is so difficult to characterize the intestinal microbiota in detail and why simple classification approaches are insufficient:

- The intestine contains about 10^{14} bacteria, which to use a common comparison is more than the number of humans who have ever lived.
- The intestine harbours at least 10 Phyla in at least 34 families and 51 genera. Estimation of species richness range from about 1.000 up to as much as 16.000 species, which might have to be subdivided into more than 30.000 subspecies.[46-48]
- An estimated 20–90% of phylotypes (depending on habitat) are thought to have eluded cultivation so far and it is estimated that from at least 20% of phylotypes not even DNA sequences are known.[46, 48-50]
- high variability and heterogeneity:
  a) Inter-individual: host specificity, genetic relatedness, environmental variation (region, diet, age etc.), health status.[46, 49, 51-53]
  b) Intra-individual: site-specific distributions lead to differences between body regions, proximal:distal intestinal sites and luminal:mucosal sites, temporal variation.[49-50] For example, in chickens about 70-90% of sequences from the small intestine are related to those of *Lactobacillus* spp.. In contrast, Clostridiaceae-related sequences (60-80%) are the most abundant group detected in the cecum.[54-57]
- Taxonomic diversity and functional diversity are not congruent with each other.

Proposed indicator for gut health and microbiota stability

From the previous paragraphs it has to be concluded that no tangible, generally-accepted and applicable definition of both, gut health and microbiota stability exists so far. Nevertheless, several feed additives claim effects on both variables and support this by studies investigating what might be called "soft" indicators (e.g., overall health and performance, absence of pathogens, abundance of GRAS organisms, high colonic butyrate concentration, high diversity, quotients of selected microbial groups, immunological variables, etc.). All of these indicators have in common that they have been correlated somehow to both gut health and microbiota stability, but evidence of a clear dependency is missing. In addition, most studies cover only one or very few of these indicators so that these indicators can not be correlated conclusively among each other and a true countercheck of their effects remains missing. The use of these indicators arises more or less from tradition and a subjective impression of the gut ecosystem rather than being based on established facts. Nevertheless, recently available methods of measuring "normal" function of the gut and immune system as well as a "healthy gut flora" have been reviewed and definitions for these conditions attempted.[58] Unfortunately, this review confines itself to the human ecosystem and remains incomplete. Some commonly used indicators shall be presented here exemplary.

Some investigators look into the concentration of so called beneficial and harmful genera, respectively. For example, Pierce *et al.* (2006, 2007)[59-60] conclude in studies with weaned piglets that "the inclusion of high dietary concentrations of lactose resulted in improved intestinal health through (.....) increases in lactobacilli (.....)".The problems associated with this indicator have already been discussed.

Other reports concentrate on the investigation of the composition of the total or dominant microbial community using techniques such as G + C profiling, Fluorescence- in situ-hybridization and genetic fingerprinting. Using G + C profiling Apajalahti *et al.* (2007)[61] compared two broiler farms, one inconspicuous control farm and one farm with high Campylobacter prevalence. In caecum samples of the affected farm they observed a higher frequency of Lactobacillus spp. and a lower frequency of species of the Clostridium cluster IV. In addition, the Campylobacter burdened farm showed higher inter-individual variations. Since these observations were in accordance with earlier investigations of this work group, they judge similar deviations from an average "normal" G + C profile as destruction of gut health.

Vaahtovuo *et al.* (2007)[62] found a positive correlation between a Microbial Balance index (MBI) and performance (but not health) of weaner and grower pigs. In this index, which divides numbers of *Bifidobacterium* spp. and *Faecalibacterium* prausnitzii by numbers of the Bacteroides–Porphyromonas–

Prevotella-group and the enteric group, we meet again the simplified classification of microbiota in harmful and beneficial taxonomic groups of higher order.

Botton *et al.* (2006)[17] recently reviewed the literature on the correlation between microbial diversity and stability of the ecosystem function. The first references to stability due to higher biodiversity by Darwin (1859)[63] and Mac Arthur (1955)[64] were subsequently experimentally confirmed by others. This stability-diversity relationship concept is used, for example, by Scanlan *et al.* (2006)[65], who detected higher diversity and temporal stability in fecal samples of the control group compared to Crohn's patients based on Denaturing Gradient Gel Electrophoresis (DGGE). However, often a straightforward diversity-stability relationship does not exist. Ecosystem function and stability are more directly related to functional diversity than to taxonomic diversity.[17] Higher species diversity might indirectly support functional stability of an ecosystem (redundancy and insurance hypotheses) due to functional overlap of different species. Further irregularities in the stability-diversity relationship, which go beyond the scope of this article, are discussed by Botton *et al.* (2006).

Therefore, other applied indicators approach the intestinal microbiota not solely on the basis of their taxonomic composition but also through their functional characteristics such as metabolite production. Pierce *et al.* (2006, 2007)[59-60] believe that an increase in lactic acid production and short chain fatty acid concentration accompanied by a reduction of intestinal pH "may delay the multiplication of pathogenic bacteria thereby improving gastrointestinal health".

Kuzmuk *et al.* (2005)[66] detected in dogs receiving an animal-product based diet higher intestinal butyrate concentrations but also higher ammonia concentrations than in dogs receiving a plant-product based diet. Summarizing they concluded regarding the connection to gut health that butyrate was "shown to play a central role in maintaining the intestinal mucosal barrier. In contrast, (…..) ammonia is a putrefactive compound that induces faster turnover of epithelial cells and is toxic to colonocytes." In the same study villous height and crypt depth are described as "direct representations of the intestinal environment and may be used as indicators of intestinal health".[66] Ammonia has been negatively correlated to reduced villous height by disturbing the development of the intestinal mucosa".[59]

In accordance with the indicators presented so far, Jeurissen *et al.* (2002)[67] conclude that the health status of the intestine is determined by both characteristics of the microorganisms and characteristics of the intestinal wall. Their review describes indicators for immunity (e.g., CD4 & CD8 cell numbers and their ratio, immune cell function), integrity (villous height, crypt depth, expression of Ecadherin or trefoil factor) and functionality (permeability, mucus composition and secretion level) of the intestinal wall as characteristics of intestinal health. These authors believe that using a combination of these indicators "an accurate and detailed insight into the intestinal health of poultry can be obtained".

Further indicators used to characterize gut health are gene expression analysis. For example, van Hemert *et al.* (2003)[68] compared healthy chickens with those affected by the malabsorption syndrome (MAS). They found up-regulated genes in MAS affected intestine (e.g. lysozyme G and two interferon induced proteins) as well as down-regulated genes (apolipoprotein B, calbindin, and cytochrome). They conclude that "because Malabsorption syndrome (MAS) mainly affects the intestine, it can be used as a model to study intestinal health and intestinal disturbances in young broilers".

Another indicator proposed is the intestinal fatty acid binding protein (I-FABP).[69-71] Niewold *et al.* (2004) state that "in pigs circulating I-FABP is a useful marker for (mild) intestinal injury, and could possibly be used to monitor (intestinal) health in clinical practice".[71]

The use of other indicators of gastrointestinal health (e. g., Cyclooxygenase-2, Citrulline) – sometimes only for the characterization of very special conditions- is discussed in the literature but their complete description is beyond the scope of this article.[72-73] The most frequently-used indicators are cited here as an example for their diverse nature and to illustrate that from a single indicator no conclusive proof of the gut health level can be expected.

Conclusion

It has been demonstrated that "healthy" intestinal microbiota are essential to ensure the mutually beneficial interaction between microbiota and host as well as his diet, which affect a multitude of metabolic, morphological and immunological processes. Nevertheless, the composition of such "healthy" microbiota remains an open question. This is problematic since a specific and purposeful manipulation or even optimization of the intestinal microbiocoenosis is impossible without detailed knowledge of the composition and function of the microbial communities within the intestine as well as their conclusively established correlation to animal health and performance. Therefore, further efforts should be undertaken to characterize the composition as well as the function of the intestinal microbiota in conjunction with accompanying epidemiological investigations to eventually form a precise, generally accepted and coherent definition of gut health. Thereby even the opportunity will arise to identify indicators which have a prognostic significance with respect to the future development of gut health within one animal or flock.

Summary

Well-balanced microbiota and subsequently a healthy gut have a direct influence on the efficiency of nutrient utilization and overall animal health. This effect is the result of a very complex and highly interactive ecosystem within the intestine formed by the intestinal microorganisms, host cells and diet components. The experimental inaccessibility of many of these interactions, largely unknown microbiota composition as well as a multiplicity of possible stable and "healthy" microbial community compositions and processes complicate and hamper the definition of gut health. Therefore, a conclusive and generally-accepted definition of these terms has not been found to date.

Nevertheless, several definitions for gut health and microbiota stability have been attempted in the past as well as measurable indicators for these conditions proposed. The indicators aim at characterizing the intestinal wall (e.g. villous height, crypt depth) and its functionality (e. g. mucus composition, permeability), the immune system (e.g., CD4 & CD8 cell numbers and their ratio) and the composition (e.g. number of beneficial and harmful organisms, genetic fingerprinting, diversity indices) and function (e.g. metabolite concentration) of the intestinal microbiota.

However, these indicators can not be regarded as principally applicable or by themselves sufficient to define gut health or microbiota stability. To influence microbiota stability and gut health systematically with feed additives requires the characterization of microbiota composition and representative indicators of gut health more specifically.

Zusammenfassung

Das mikrobielle Gleichgewicht und die u. a. dadurch bedingte Darmgesundheit haben einen direkten Einfluss auf die Effizienz der Nährstoffverwertung und die Tiergesundheit. Diese Wirkung ist die Folge eines sehr komplexen und hoch interaktiven Darmökosystems aus Darmbakterien, Wirtszellen und Futterkomponenten. Die experimentelle Unzugänglichkeit vieler dieser Interaktionen, die zu einem großen Teil unbekannte Zusammensetzung der Mikrobiota sowie die Mannigfaltigkeit der möglichen stabilen „gesunden“ Zusammensetzungen mikrobieller Gemeinschaften und Prozesse kompliziert und behindert die Etablierung einer Definition der Darmgesundheit. Deswegen gibt es bislang keine schlüssige und allgemein anerkannte Definition der eingangs genannten Begriffe.

Nichtsdestotrotz gibt es viele Definitionsversuche für Darmgesundheit und Mikrobiota-Stabilität und einige messbare Indikatoren für diese Konzepte wurden vorgeschlagen. Diese Indikatoren charakterisieren den Zustand der Darmwand (z. B. Villushöhe und Kryptentiefe) und ihre Funktion (z. B. Mucuszusammensetzung, Permeabilität), das Immunsystem (z. B. CD4- & CD8-Anzahl und ihr Quotient) sowie die Zusammensetzung (z. B. Anzahl günstiger und gesundheitsschädlicher Bakterien, genetische Fingerabdrücke, Diversitätsindizes) und Funktion (z. B. Metaboliten-konzentrationen) der intestinalen Mikrobiota.

Allerdings können diese Indikatoren keineswegs als grundsätzlich anwendbar oder durch sich selbst hinreichend zur Definition von Darmgesundheit und Mikrobiota-Stabilität gelten. Um Mikrobiota-Stabiltität und Darmgesundheit durch Futterzusatzstoffe systematisch und gerichtet zu beeinflussen, wird es in Zukunft notwendig sein, die mikrobielle Zusammensetzung detaillierter zu charakterisieren und spezifische und wirklich repräsentative Indikatoren für die Darmgesundheit zu identifizieren.

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Holistic measures on combating Salmonella in broiler farms

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Introduction

A detailed and extensive report was written by Voss (2007) on the legal background on combating Salmonella in the EU and the resulting timeframe.

The results of the baseline studies in the individual EU member states serve as the basis for determining the Community targets to reduce the prevalence of Salmonella. In order to achieve these targets the member states must develop "national combat programmes" which must be submitted to the EU Commission for approval.

The complexity of the measures results from the epidemiological – infectiological properties of the pathogenic agent which can lead to the three infection mechanisms observed (Blaha, 2008):

1. **Vertical infection path:** Placement of young animals which were already infected at the breeding establishment (e.g. hatching eggs). Thus, the Salmonella is introduced via the animals from the previous stage in production.
2. **Horizontal infection path:** At some point in time Salmonella is carried „from outside" into a Salmonella-free flock (humans, rodents, feed, water, litter, etc.)
3. **Circulation of the infection:** Infected animals shed Salmonella intermittently and thus contaminate the environment in the house with the result that other animals can now become infected directly or indirectly.

The permanent circulation of Salmonella over several production cycles then leads to residual Salmonella strains that are not removed by the regular cleaning and disinfection procedures at the end of a production cycle so that new animals introduced into the cleaned and disinfected barns and houses become infected with these residual Salmonella strains (similar to the phenomenon of the „hospitalism" that may occur in hospitals, but without its additional problem of the resistance against disinfectants and antimicrobials in the bacteria in question) although the original source of entry no longer exists.

For this reason Salmonella can only be reduced successfully when founded upon a targeted (risk-oriented) analysis of the Salmonella-specific weak points in the production chain. The analysis should identify the location and elimination of all possible sources of entry and reservoirs for Salmonella.

Within a research project **„Holistic approach to combating zoonotic pathogens in poultry"**, which is subsidised by the Ministry of Agriculture and Economics, Lower Saxony (Landwirtschafts- und Wirtschaftsministerium Niedersachsen) and partly by EU means, specific studies were carried out on the sanitation of Salmonella in broiler farms.

In the process extensive observation and monitoring measures were developed and tested for their suitability for practical use. Furthermore, hygiene analyses and their microbiological evaluation were established.

Materials and methods

Holding: 2 broiler houses, each with a capacity for 27 000 broilers
(1 conventional closed house, 1 open 'Louisiana' house)

Salmonella status prior to the intervention measures

Salmonella Java (S. Paratyphi B, d-Tartrat +) from sock swabs (in accordance with EU Regulation 646/2007) and ambient samples (house environment, nipple drinkers)

Pathogen has been persistent in the house over a longer period

Risk-oriented analysis

- Formulation of a questionnaire to record the specifications of the holding during the initial visit.
  Epidemiological questions on the risk assessment of sources of entry
  Questions on cleaning and disinfection procedures to assess the anti-infective measures
  Questions on parameters determining health and performance
  Hygiene analysis and quantitative evaluation of the hygiene status (Hygiene Index)
  Consideration of 3 weighting factors of certain risk areas
  Three-step evaluation of certain risk areas for the external and internal protection of the holding
- Control and evaluation of the cleaning and disinfection measures
  Procedural analysis of the measures
  Swab samples from critical points and quantitative analysis of indicator organisms
- Control and evaluation of rodent and insect control
  Procedural analysis
  Monitoring the documentation
- Specific systematic examination of sources of entry and pathogen reservoirs
  Close-meshed monitoring during the production phase (weekly sock swabs, starting from the 1st week of life) and ambient samples

Results

- The source of entry had disappeared by the time the project started. The pathogens were circulating in the flocks.
- The disinfection of the house surfaces proved to be successful.
- The **hygiene analyses** were able to detect various weak points (evidence of enterobacteria in the drinkers in the conventional house;
  Evidence of S. Java in the drinkers in both houses on placement of the animals, but not, however, before the water filters, inadequate staff hygiene, shortcomings in the cleaning and disinfection of the pre-rooms, shortcomings in handling carcasses, removal of pets from the holding)
- Inconsistent **rodent control** was identified as the cause of the establishment of Salmonella in the flocks.

Procedure:

- Improvement of the hygiene status by making constructional amendments (thermal insulation, renewal of the feeders in the conventional house, relocation of the carcass box, regular disposal of all carcasses into the box)
- Staff hygiene
  Instruction on the necessity of the measures, establishment and management of facilities for the disinfection of hands and shoes)
  Extensive cleaning and disinfection measures during the service period, including the microbiological control of the success
  Drinking water management: extensive cleaning and disinfection of the system (alkaline cleaning to remove the biofilm, disinfection using organic peroxides) including filters and heating loop
  Constructional amendments (e.g. regular inclusion of the heating loop in all hygiene measures, exchange the water filter insert)
  Daily rinsing of drinker lines with fresh water over the entire production cycle
  Use of acid mixtures to disinfect drinking water from the 4^{th} day of life

Following the implementation of the complex measures with intensive monitoring (weekly sampling) no S. Java could be isolated on the farm for the duration of 3 production cycles to date.

Discussion

The monitoring system which has been developed and extended is suitable in its individual parts to assess the risk of spreading zoonotic pathogens in broiler holdings, to identify the infection path and to deduce appropriate measures. With the help of these measures it was possible to improve the hygiene status, to sanitize the flock and minimise the risk of re-entry.

For the sanitation of broiler holdings which have tested positive on several occasions it is necessary to carry out complex, simultaneous hygiene measures which cover all vectors and reservoirs. In addition to organisational and constructional amendments it is necessary to carry out extensive cleaning and disinfection measures as well as effective rodent control measures, the success of which must be controlled and documented regularly. The advising veterinarian as well as the farmer and his adviser must jointly establish individual steps in conjunction with the sanitation of the flocks and work on their implementation. In the sanitation process the routine hygiene measures are equally as important as lowering the pressure of infection and eliminating the pathogens during the service period.

The main aspects in connection with Salmonella-related problems are the insufficient knowledge of the farmer and his adviser on epidemiological correlation and the evaluation of hygiene measures. taff hygiene measures are often carried out inadequately and are difficult to establish.

As a result of long-term persistence and its high tenacity S. Java is able to hospitalise in the houses (Bolder, 2004) and thus represents a permanent source of infection for the chicks.

The sanitation of the flock was carried out on the basis of a risk-oriented hygiene analysis and evaluation. After the shortcomings had been remedied and in particular after the drinking water management had been optimised there were no further findings of S. Java.

In order to maintain this status all measures must be maintained and checked regularly by carrying out audits.

Zusammenfassung:

Holistische Maßnahmen zur Salmonella – Bekämpfung in Masthähnchenfarmen

Im Rahmen eines Forschungsprojektes „Ganzheitlicher (Holistischer) Ansatz zur Bekämpfung von Zoonoseerregern beim Geflügel“, welches durch das Landwirtschafts- und Wirtschaftsministerium Niedersachsen und

teilweise durch EU Mittel gefördert wird, wurden zielgerichtete Untersuchungen zur Salmonella - Sanierung von Masthähnchenbetrieben durchgeführt.

Dabei wurden umfangreiche Beobachtungs- und Überwachungsmaßnahmen entwickelt und auf die Eignung bei der praktischen Anwendung geprüft sowie Hygieneanalysen und deren mikrobiologische Bewertung etabliert.

Das entwickelte erweiterte Monitoringsystem mit den einzelnen Bestandteilen ist geeignet, das Risiko der Verbreitung von Zoonoseerregern in Masthähnchenbetrieben zu bewerten, Infektionswege zu erkennen und entsprechende Maßnahmen abzuleiten. Mit Hilfe dieser Maßnahmen ist es gelungen, den Hygienestatus zu verbessern, den Bestand zu sanieren und das Risiko eines erneuten Eintrags zu minimieren

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Genetic differences in the development of aggressive behaviour of male domestic rabbits at the age of 8 – 30 weeks

Georg Heil and Leo Dempfle

Introduction

Domestic rabbits are usually fattened in groups, which may occasionally lead to bite injuries toward the end of the fattening period. The reason for this are bucks attacking pen or cage mates. As early as 1917, Starke recommended for rabbit husbandry: "The bucks should be kept together as long as they get along peacefully, but they have to be separated at the age of 4 months." Injuries to males are mostly around the testicles. Reasons to minimize these injuries include animal welfare as well as economical considerations because some of the injured animals die or have to be killed. Moreover, the meat of injured animals is not useable for human consumption, because their carcasses are rejected by the official meat inspection.

Aggressive behaviour among rabbits may cause problems in backyard keeping for private use (Koetter and Werner, 1985) as well as in commercial production, especially when kept in larger groups as recommended by animal welfare (Bigler and Oester, 1994). It is unknown to what extent differences among and within genetic groups affect the age at which aggressive behaviours start and the frequency at which they occur. Should genetic differences in these traits exist among lines, the fattening period could be optimised in order to minimise bite injuries. In case there are substantial genetic differences among families within lines, it should be determined to what extent this problem could be reduced by selection.

Parts of the submitted investigations have been presented as lectures at two conferences (Heil, 1997 and Heil, 2003) and in a short article by Heil and Dempfle (2008).

Animals and animal management

The bucks studied originated from 5 genetic groups, 3 commercial crosses and 2 pure-lines of the breeds Californian and New Zealand White. Both pure breeds came from the Bavarian Institute for Animal Production in Kitzingen, where they are kept as closed populations. From each of these genetic groups 3 random samples were taken in their respective breeding station. The pedigree structure is shown in Table 1.

Table 1: Origin of genetic groups

Genetic group	1	2	3	4	5	Total
Position in the breeding programme / or breed	Dam of the commercial product Single cross (A*B)	Single cross (B*A)	Commercial product Four-way cross	Californian Pure breed	New Zealand White Pure breed	
Number of sires	12	7	13	8	9	49
Number of dams	37	14	21	29	27	128
Pairs with pedigree	41	14	21	33	33	142
Pairs without pedigree	3	1	47	-	-	51

Most of the pairs were full sibs. In 2 of the 3 random samples of genetic group 3, all mothers were inseminated with mixed semen from 10 bucks. Therefore the sires in these pairs of animals are unknown.

The experiment consisted of 9 test periods. Animals of the same test run were caged in the same compartment of the stable. They differed in age by a maximum of 3 days, originated from 1 breeding station and belonged to 1 or 2 of the genetic groups. If both compartments were occupied at the same time, it was treated as 2 separate test runs.

The bucks were kept in galvanized wire cages (40 cm wide, 60 cm long and 25 cm high), which were laid out in a flat deck arrangement. In each cage there was a feed dispenser for manual refilling at the front and 2 nipple water dispensers at the rear. Two compartments of a stable with 24 cages each were available for the tests. Compartments were separated by a solid wall and were aired independently. Pelleted whole feed for rabbit breeding and fattening was provided with the composition as declared by the manufacturers is shown in Table 2.

Table 2: Feed composition according to manufacturer's declaration

Percentage of content	Additives per kg mixed feed	Minerals %	Amino acids %	Energy MJ
Crude protein 17,0	Vit. A 10000 I.E.	Calcium 1.0	Lysine 0.85	Digestible energy 10.4
Raw fat 2,5	Vit. D3 800 I.E.	Phosphorus 0.6	Methionine 0.35	
Raw fibre 16,0	Vit. E 25 mg	Sodium 0.2		
Raw ashes 8.0	Copper 25 mg			

In the first test run the daily allotment of the feed was only as much as could be consumed in the morning. This was intended to evoke more biting during feeding to facilitate observation and control of its development. In this test run no biting was observed during and after feeding. Therefore, starting with the second test run, feed was provided ad libitum. Water was offered ad libitum via the nipple drinkers.

In the windowless stables a daily light cycle of 12 hours darkness and 12 hours light was kept. In the first 7 test runs the light cycle started and ended within one-hour of dusk or dawn. Starting with the 8th test run, the dusk or dawn period was reduced to 15 minutes in order to observe further features of behaviour. The light intensity at animal level was kept at 3.5 lux during dusk or dawn and 48 lux during the remaining light cycle.

The temperature of the heated stables was between 15° and 25° C depending on the season. The relative humidity of the air ranged between 60 and 70 %.

Data Collection

The data were collected between May 1993 and March 1996. The experimental unit consisted of 2 bucks in 1 fattening cage. In order to simulate commercial practice, 2 males and 2 females from the same litter were caged together in the first test run. At 18 weeks of age – before any biting was observed - the does were removed from the cages, because some of them were already pregnant. To avoid having to slaughter pregnant does, only 2 male litter mates were caged together for the second and subsequent test runs. The age at housing was between 6 and 12 weeks, depending on the breeding station of their origin. In 7 test runs the observations ended at the age of 31 weeks whereas in the 1st run the observations had to be stopped in week 27 due to an outbreak of a Pasteurella disease and in the 4th run the observations were stopped in week 28 as only 2 out of 24 cages were still occupied.

All animals were weighed at the beginning of a test run, at 8 to 13 weeks of age. Pairs of bucks were separated when the caretakers observed attacks or bite injuries during their usual cleaning rounds and observation patrols. Age on the day of separation and the weight of the animals with injuries (victim) and without injury (aggressor) were recorded. It was never observed that both animals had been injured.

In the first few test runs, attacks and bite injuries were less frequently than expected. Therefore the correlation between sexual activity and aggression was more closely examined from the 6th run on. Additional observations were made with 72 pairs of genetic groups 3, 4 and 5.

Sexual activity was indirectly measured by the trait "mounting with mating movements" to the homosexual partner. The bucks were observed in the mornings within the first hour after dusk through mirrored glass panes. This timing seemed particularly opportune as the animals, which are generally active at dusk or dawn are intensely active during this short interval around the shift of lighting. The phase of activity before the end of the lighting phase could not be observed for technical reasons.

Along both far ends of the two adjoining compartments there were 2 mirrored windows for each compartment, there being 4 windows per compartment in all. Through one window the animals in 6 of the 24 cages of one compartment could be observed from the hall side, so that all animals could be observed through the 4 windows of a compartment. The animals in 6 cages were observed together for 5 minutes each and recorded whether "mounting with mating movements" had occurred. The observations started at 9 weeks of age and were conducted 5 times each week by 2 persons, with few exceptions. Both observers watched different cage groupings simultaneously from the two opposite sides of the hall. After all cages on a side of the hall were observed, the observers changed to the other hall side.

At any day on which observation was taken we obtained information for all cages, taken during 2 periods of 5 minutes by 2 different people. For each observation period the observers were randomly assigned to which hall sides to start and to the order of the cage groupings to be observed.

While observing behaviours during the 6th and 7th run, we became aware of the following activities: the bucks in a cage were chasing each other in circles around the cage for 5 to 10 seconds, which appeared as if one animal was driving the other in front of it. This behaviour was observed in very irregular periods and will be called "chasing". In order to investigate whether chasing occurred more often and therefore may signal an upcoming biting, it was recorded in the 8th and 9th run in addition to mounting behaviour.

Definition of Observed Traits

For all pairs the following traits were recorded:

SA Separation of the animals due to attacks and bite injuries (aggression): no = 0; yes = 1.
SD Separation of the animals because of disease or death: no = 0; yes = 1.

For pairs separated because of attacks and bite injuries:

ASA Age at separation because of attacks and bite injuries in days.
WDC Weight difference between the aggressor and the victim at the beginning of a test run („caging"), at 8 to 13 weeks of age.
WDS Weight difference between the aggressor and the victim at the time of separation.

Additional traits in runs 6 and 9 for genetic groups 3, 4 and 5:

NM Average number of 5-minute observation periods per week when mounting was observed (except for rare occasions, 10 observation periods per week).

Additional trait in runs 8 and 9 with genetic groups 3, 4 and 5:

NC Average number of 5-minute observation periods per week when chasing was observed.
NCS Average number of 5-minute observation periods per day when chasing was observed (calculated for the last 6 days for pairs separated because of aggressive attacks).

Biometric evaluation

Out of all pairs of bucks, 43 % were separated because of aggressive behaviour, 22 % due to illness or death. With these frequencies of a binominal distribution, the theoretical assumptions for the analysis of variance are approximately fulfilled, and a transformation of the variables was considered as unnecessary. The models used are listed in Table 3.

Estimation of fixed effects (models 1, 3, 4 and 5)

With model 1 the differences between the genetic groups were estimated for the traits SA, SD, ASA, WDC and WDS.

Model 3 was used to estimate systematic effects for traits NM and NC. Animals of a genetic group expressing trait NC (chasing) were only observed within one run. Therefore the random effect for runs within the genetic groups is omitted. The interaction between the genetic groups and the reasons for the separation of the pairs was not taken into account in model 2, because the interaction was not statistically significant (error probability $p < 0.42$ for NM and $p < 0.65$ for NS) and not all reasons for separation had occurred in all genetic groups. Model 4 was used to investigate whether pairs which were separated because of aggressive attacks showed increased frequencies of NM and NC before separation.

During the last few weeks before separation NC was observed more frequently than earlier. Therefore, starting with model 5, it was investigated whether NCS changed within the last 6 days before separation. First, the ages of the animals during the last few weeks before separation (LIFEWK) were included in the model as a fixed effect. This effect was statistically significant. However, from the differences between weeks of age no tendency could be derived. Therefore 3 biologically defined age classes of various lengths were defined instead of age in weeks and were used in model 4. The different lengths of age classes were expected to reveal whether the pairs behaved differently concerning the feature NCS around sexual maturity compared to the 2 periods after sexual maturity.

Estimation of random effects for the traits SA, SD and ASA (model 2)

With model 2, additive genetic variance was estimated for the traits SA, SD and ASA within the genetic groups. For this analysis data from all pairs with known dam were used. As there was only one cage per parents within the genetic group and run available for ASA, the residual variance could not be estimated.

Statistical Methods and Interpretation of Results

Statistical calculations were performed according to the Restricted Maximum Likelihood Method (REML) with the Procedure MIXED (SAS Institute Inc. 1999) and the program „The SAS System for Windows“ Release 8.1. The significance of fixed effects was statistically checked with the F-test and the Null-hypothesis rejected if the probability of a type I error was below $\alpha = 0.05$.

Estimation of heritability

The sire component of variance ($\hat{\sigma}^2_{sire}$) in model 2 estimates ¼ of the additive-genetic variance ($\hat{\sigma}^2_A$) and is largely free of environmental, dominance and epistatic effects. It is particularly apt to estimate the heritability in the narrow sense (formulae 1). The average heritability was estimated across all genetic groups. To estimate the heritability for each genetic group would have required a larger number of sires per genetic group.

$$\hat{h}^2 = \hat{\sigma}^2_A / \hat{\sigma}^2_P \qquad (1)$$

$$\hat{\sigma}^2_A = 4\hat{\sigma}^2_{sire}$$

$$\hat{\sigma}^2_P = \hat{\sigma}^2_{sire} + \hat{\sigma}^2_{dam} + \hat{\sigma}^2_{residual}$$

Table 3: Models used for statistical analysis

Model:	Traits[1]
1. $Y_{ijk} = \mu + \text{GENETIC GROUP}_i + \text{run}_{ij} + \text{residual}_{ijk}$	SA; SD; ASA; WDC; WDS / all pairs
2. $Y_{ijklmn} = \mu + \text{GENETIC GROUP}_i + \text{run}_{ij} + \text{sire}_{ijk} + \text{dam}_{ijkl} + \text{pairs of siblings}_{ijklm} + \text{residual}_{ijklmn}$	SA; SD; ASA / only pairs with a pedigree
Additional observation periods for runs 6 to 9 with animals of genetic groups 3, 4 and 5	
3. $Y_{ijklmn} = \mu + \text{GENETIC GROUP}_i + \text{run}_{ij} + \text{SEPAREAS}_k + \text{pair of siblings}_{ijkl} + \text{LIFEWK}_m + (\text{GENETIC GROUP*LIFEWK})_{im} + (\text{SEPAREAS*LIFEWK})_{km} + \text{residual}_{ijklmn}$	NM; NC / all pairs
4. $Y_{ijlmn} = \mu + \text{GENETIC GROUP}_i + \text{run}_{ij} + \text{pair of siblings}_{ijl} + \text{LIFEWK}_m + (\text{GENETIC GROUP*LIFEWK})_{im} + b_1\,\text{ABSTREN}_{ijlm} + b_2\,\text{ABSTREN}_{ijlm}^2 + \text{residual}_{ijlmn}$	NM; NC / only pairs which were separated because of aggressive attacks
5. $Y_{ilon} = \mu + \text{GENETIC GROUP}_i + \text{pair of siblings}_{il} + \text{LAK}_o + b_1\,\text{TVTA}_{ilon} + b_2\,\text{TVTA}_{ilon}^2 + \text{residual}_{ilon}$	NSC / last six days of the pairs which were separated because of aggressive attacks

where:

Y	observation value of a pair of siblings
μ	overall mean
GENETIC GROUP_i	fixed effect of the genetic group i
run_{ij}	random effect of the run j of the genetic group i (random sample of the genetic group with N pairs of siblings).
SEPAREAS_k	fixed effect of the reason for the separation k of the pair of siblings (aggressive attacks; disease or death; no separation)
$\text{pair of siblings}_{ijkl}$	random effect of the pair of siblings l with a reason for the separation k in run j of the genetic group i (random sample of the genetic group with N pairs of sibling bucks)
LIFEWK_m	fixed age effect, life week m
$\text{GENETIC GROUP}_i * \text{LIFEWK}_m$	fixed effect of the interaction between genetic group i and life week m
$\text{SEPAREAS}_k\text{*LIFEWK}_m$	fixed effect interaction between reason for separation k and life week m
$b_1\,\text{ABSTREN}$	linear regression of NM or NC on difference between week of separation and week of observation
$b_2\,\text{ABSTREN}^2$	quadratic regression of NM or NC on difference between week of separation and week of observation
LAK_o	fixed effect of the age period category o in which the animals were separated 1 period around sexual maturity — age period 09 – 12 weeks 2 medium observation period — age period 13 – 20 weeks 3 last observation period — age period 21 – 28 weeks
$b_1\,\text{TVTA}$	linear regression of NSC on difference between day of separation and day of observation
$b_2\,\text{TVTA}^2$	quadratic regression of NSC on difference between day of separation and day of observation
sire_{ijk}	random effect of the sire k in run j of genetic group i. The animals of the various runs descended from different sires.
dam_{ijkl}	random effect of the dam l within sire k in run j of genetic group i. The animals of the various runs descended from different dams.
residual	random error

[1] Abbreviations of the traits:
SA (separation of the animals due to attacks and bite injuries); SD (separation of the animals because of disease or death); ASA (age at separation because of attacks and bite injuries in days); WDC (weight difference between the aggressor and the victim at the beginning of a test run („caging"), at 8 to 13 weeks of age); WDS (weight difference between the aggressor and the victim at the time of separation); NM (average number of 5-minute observation periods per week when mounting was observed); NC (average number of 5-minute observation periods per week when chasing was observed); NCS (average number of 5-minute observation periods per day when chasing was observed.

The variance of heritability was calculated with the following formula, derived by means of a Taylor series:

$$Var(\hat{h}^2) = (E\hat{\sigma}^2_A / E\hat{\sigma}^2_P)^2 [Var(\hat{\sigma}^2_A) / (E\hat{\sigma}^2_A)^2 + Var(\hat{\sigma}^2_P) / (E\hat{\sigma}^2_P)^2 - 2\,Cov(\hat{\sigma}^2_A \hat{\sigma}^2_P) / (E\hat{\sigma}^2_A E\hat{\sigma}^2_P)]$$

Assumptions for the prediction of selection response for the trait SA

Based on parameters estimated in the current statistical analysis, the following conditions for a breeding programme were assumed available.

1. Aggressive behaviour is checked as described in this test series. For the setup, a stable with 100 cages is available.
2. The trait SA is divided into 2 categories: „separation because of aggressive attacks“ and „no separation because of aggressive attacks”.
3. It is desired that pairs do not have to be separated.
4. Half of the pairs have to be separated in the base generation (p=0.5).
5. SA has a heritability of 0.3. The heritability is not changed through selection.
6. The phenotypic variance of SA changes with the selection success and equals the variance of the binomial distribution.
   $V_p = p(1-p)$.
   p = fraction of the pairs separated because of aggression
7. The fraction of pairs (p) which do not have to be separated, increases as a result of selection. In order to be able to continue selecting in spite of this fact, the number of pairs checked per sire is increased in generations 2 and 5. As a consequence, fewer sires can be used due to a constant testing capacity and selection intensities and accuracy of the estimated breeding values change. The number of sires used per generation and pairs of siblings from different dams are shown in table 4. A minimum of 20 sires per generation were tested.

Table 4: Number of sires and pairs of full sibs per sire tested per generation

Generation	Number of sires tested	Number of sib pairs per sire
0	50	2
1	50	2
2	25	4
3	25	4
5 and later	20	5

8. For the next generation all sires were selected whose offspring did not show any aggression, if possible.
9. As only the sires of the next generation were selected, the selection response was calculated with the following formula:
   $SR = ½ (i\, \sigma_A\, r_{IG})$
   Definitions:
   i Selection intensity (standardized selection difference).
   σ_A additive-genetic standard deviation
   r_{IG} accuracy of estimating the breeding value (correlation between the source of information and the overall breeding value).

Results and Discussion

Traits: separation because of aggression (SA), separation because of disease (SD); age at separation because of aggression (ASA); weight differences at caging (WDC) and weight differences at separation (WDS) (Model 1)

Overview

Table 5 shows the results of the statistical analysis based on model 1. The difference between these traits within the individual observation runs with the various genetic groups was of minor importance whereas statistically significant effects for the traits SA and ASA were found among the genetic groups. The genetic differences will be discussed in detail below because of their fundamental importance for all 5 traits.

Table 5: Results of statistical analyses based on model 1: fixed effects and variance components for the random effects of the traits: SA (separation because of aggressive attacks and bite injuries); SD (separation of the animals because of disease or death); ASA (age at separation because of attacks and bite injuries in days); WDC (weight difference between the aggressor and the victim at the beginning of a test run („caging“), at 8 to 13 weeks of age); WDS (weight difference between the aggressor and the victim at the time of separation).

Trait	SA	SD	ASA	WDC	WDS
Fixed effects					
GENETIC GROUP[1)]	n.s.	**	+	n.s.	n.s.
Random effects	Estimates of the variance components				
Run (GENETIC GROUP)	neg.[2)]	neg.[2)]	neg.[2)]	0.004	0.009
Residual	0.25	0.16	26,7	0.045	0.152

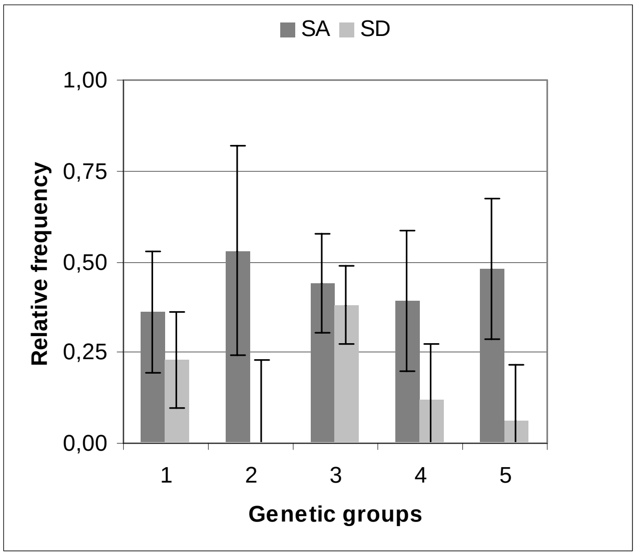
1) Identification of the level of significance: n.s. not significant; + ≤ 0.10 ; * ≤ 0.05; ** ≤ 0.01
2) negative variance components

Traits: separation because of aggression (SA) and separation because of disease (SD)

Within the genetic groups between 36 % and 53 % of the pairs had to be separated because of bite injuries or biting (SA, Figure 1). Differences between genetic groups were not significant ($\alpha < 0.73$). For all genetic groups a high potential of aggression was observed, which resulted in a considerable number of aggressive attacks. Although they did not start in all cases directly after the beginning of sexual maturity, they eventually did start in all genetic groups and often only noticed as bite injuries. With the trait SD there were differences among genetic groups ($\alpha = 0.01$; Figure 1). Pasteurella infections, manifested mostly in form of festering, were the most common cause of loss. Some of this festering may have resulted from unnoticed bite injuries. In this way they could be an indirect consequence of an attack. Should this be the case in the majority of illnesses, SA and SD should be correlated. The average values of the traits SA and SD among genetic groups did not support this hypothesis. Especially in genetic group 2 there was the highest number of SA and no pair with SD, whereas in genetic group 3 there was the highest frequency of SD-pairs (38 %) and a high frequency of SA-pairs (44 %).

Almost 40 % “losses” suggest that these hybrids, which are designed to be slaughtered before sexual maturity, should not be kept in groups longer than sexual maturity is reached.

Figure 1: Relative frequency (average values and 0.95 confidence limits) at which the animals of the genetic groups were separated in the course of the tests because of SA (separation because of aggressive attacks and bite injuries) or SD (separation because of illness or death). (BLUE – estimates from model 1)



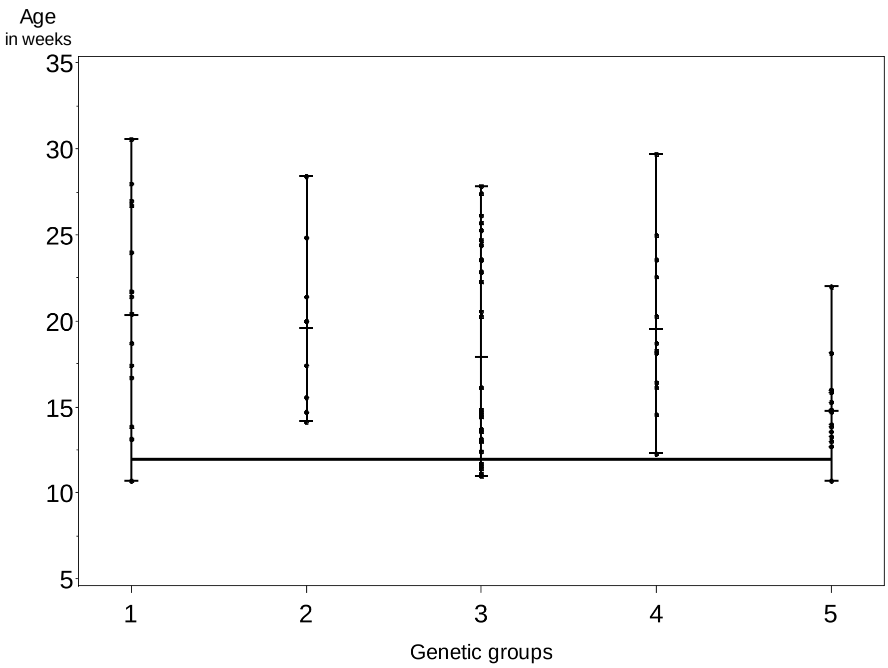
For trait SD, differences between genetic groups are statistically significant ($\alpha < 0.05$).

Trait: age at separation because of aggression (ASA)

The genetic groups differed slightly in their average age at which the pairs had to be separated because of aggressive attacks and bite injuries. The average age for genetic groups 1 – 5 were 20.3, 10.6, 17.9, 19.5 and 14.0 weeks ($\alpha \leq 0.09$; BLUE – estimation from model 1). But these differences do not seem to be of practical significance for rabbit fattening. As illustrated in figure 2, pairs from all genetic groups had to be separated during the observation period to stop biting.

The age at which the first pairs had to be separated, seems to be of particular importance for the fattening of rabbits. With respect to this trait, the differences among genetic groups were also of minor importance. In 3 groups the first separation because of aggressive attacks became necessary at the end of week 11, in the other 2 groups at the beginning of weeks 13 and 14.

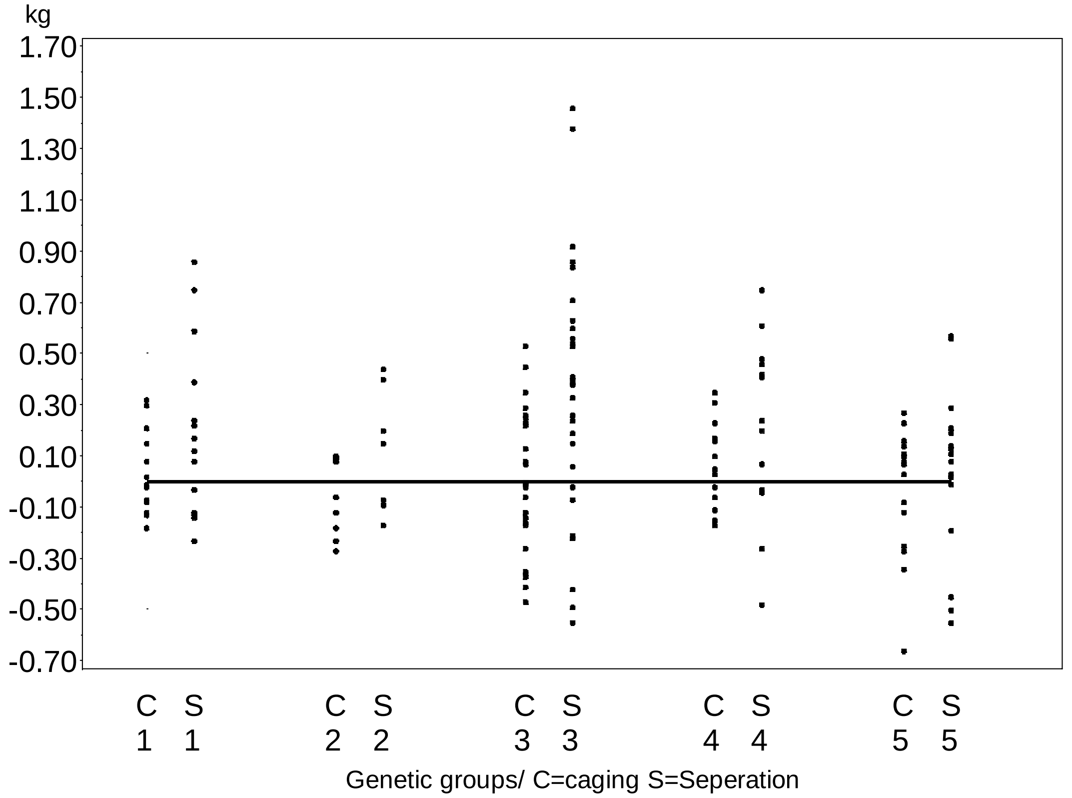
Figure 2: Age of the genetic groups at the separation because of aggressive attacks (ASA). Age of 12 weeks is indicated by a solid line. Around this age the animals were generally sexually mature. Among the genetic groups there is some indication of differences ($\alpha < 0.09$).



Traits: weight differences at caging (WDC) and weight differences at separation (WDS)

As shown in Figure 3, the attacking rabbits were not substantially heavier than the victims when caged (WDC) nor when separated (WDS). Differences among genetic groups were not significant for these traits (α = 0.34), but the data indicate that aggressive attacks were more frequent if the weight difference exceeded + 0.5 kg near the end of the fattening period. This observation is confirmed by those of Koetter and Werner (1985) who reported that when rabbits are fattened in groups and aggressive attacks take place, the heavier bucks almost always attack other members of the group.

Figure 3: Weight difference between attacker and victim at the time of „caging" (WDC) and at the time of separation (WDS)



The overall average of the differences (WDC = 0.000 kg; WDS= 0.044 kg) are not statistically significant (α=0.70). Differences among the genetic groups are different (α=0.34).

Models 3, 4 and 5

Overview

In Table 6 the results of the statistical analyses are shown for traits NM and NC, based on model 3. For NM, the interaction between genetic group (GENETIC GROUP) and age (LIFEWK) was statistically significant and these two effects are described in detail below. For NC, neither the differences between the genetic groups nor their interaction were significant. The detailed presentation for this trait only describes the influence of age (LIFEWK) and its interaction with the reason for separating (REASSEP) the pair of cage mates.

Table 6: Results of the statistical tests[1] about the fixed effects and the estimated values of the variance components of the random effects of model 3. Traits: NM (Average number of 5-minute observation periods per week when mounting was observed); NC (Average number of 5-minute observation periods per week when chasing was observed)

Trait	NM	NC
Fixed effects		
GENETIC GROUPS	n.s.	n.s.
SEPAREAS	+	n.s.
LIFEWK	*	*
GENETIC GROUPS*LIFEWK	**	n.s.
SEPAREAS.*LIFEWK	n.s.	**
Random effects	Estimates of variance components	
run (GENETIC GROUP)	0.00001	– [2]
pair of siblings (GENETIC GROUP, run, SEPREAS)	0.00030	0.0008
residual	0.03587	0.0060

1) Significance levels: n.s. not significant; + ≤ 0.10; * ≤ 0.05; ** ≤ 0.01
2) Can not be estimated, because within three genetic groups only the animals of one run had been observed

As far as random effects are concerned, the residual variance, i.e. variation between repeated observations of the same pair in different weeks of age, was substantially greater than that between pairs within genetic group, run and reason for separation. Even the random differences between runs within a genetic group were of minor importance for trait NM. A comprehensive presentation of these factors therefore seems unnecessary.

Trait: number of mountings (NM)

Model 3: all pairs of bucks
Mounting (NM) was recorded in 2.5 % of all 5 minute observation periods. This means, on average this presumed sexually stimulated behaviour could be observed in 1 of 40 observation periods (3h:20m), i.e. relatively seldom, even during the first hour of the lighting period, when the animals were intensely active.

Figure 4 shows how the frequency of mounting changes within the genetic groups with increasing age. Between genetic group and age there is a significant interaction ($\alpha < 0.01$). Bucks of genetic groups 3 and 4 started with the mutual mounting almost 2 weeks earlier than genetic group 5. This observation indicates that animals of genetic group 5 reach sexual maturity later than genetic groups 3 and 4 under the same environmental conditions. There are obvious differences in age when the animals start with mounting and the frequency of it, yet there is no tendency concerning frequency and age.

Figure 5 shows the relative frequency of observed mounting within those pairs of bucks which were separated later because of aggressive attacks, of illness or death or which stayed together until the end of the test. Although he differences between the 3 groups were not significant, ($\alpha > 0.08$) there was a tendency. Regardless, the difference does not seem to be of practical importance because the pairs of bucks which could be kept together till the end of the test showed the highest frequency of observed mounting. Therefore these results do not indicate that aggressive attacks and sexual activity, observed here as mounting between animals of the same sex, correlate in an undesirable way.

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Figure 4: Average relative frequency (BLUE – estimate and upper 0.95 confidence limit) of mounting (NM) which had been observed within 3 genetic groups in the various life weeks. The interaction between genetic group and life week was statistically significant ($\alpha < 0.01$).

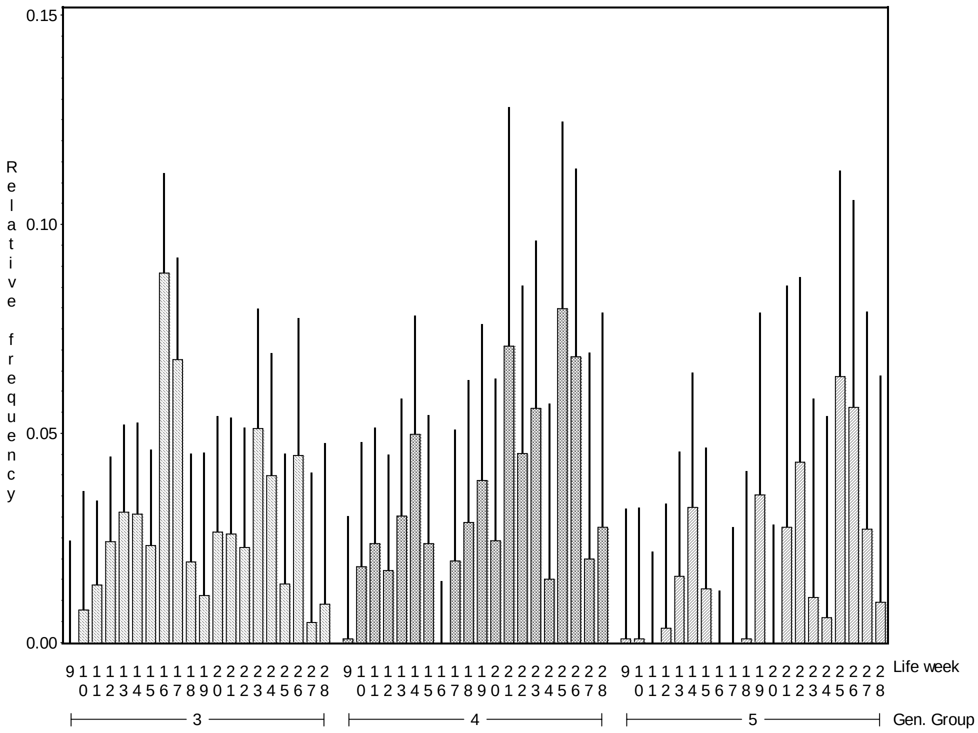
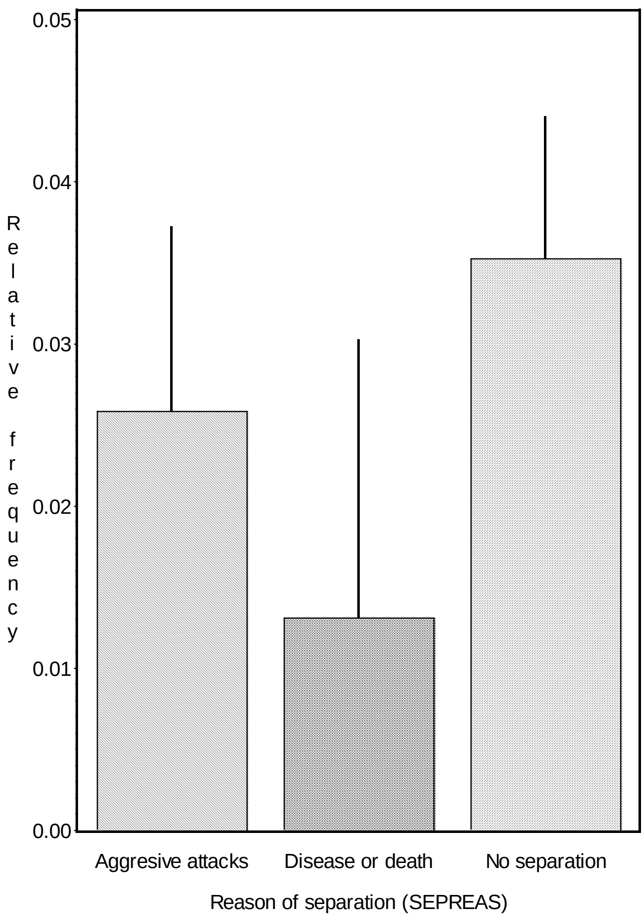


Figure 5: Average relative frequency

(BLUE – estimate and upper 0.95 confidence limit) at which NM (Average number of 5-minute observation periods per week when mounting was observed) was observed in the pairs of bucks which had to be separated for different reasons. Reasons for separation indicate differences approaching statistical significance ($\alpha < 0.08$).

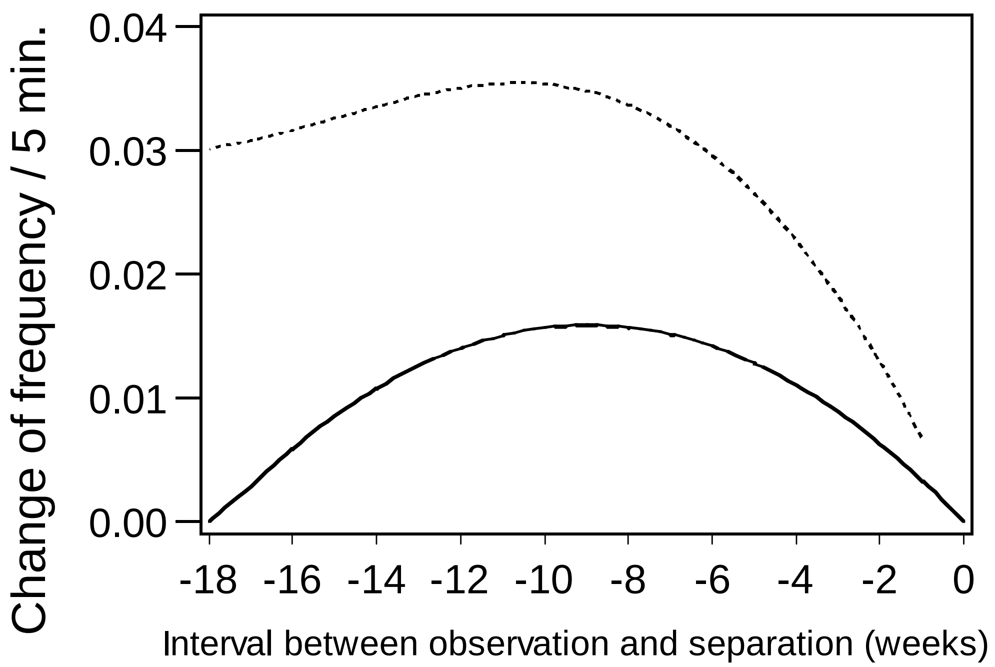


Model 4 – pairs of bucks which had to be separated because of aggression

In order to investigate whether the frequency of mounting increases before the animals have to be separated because of aggression the trait NM was analysed with model 4 within these pairs of bucks. For the linear and quadratic term of the regression function on time of separation in weeks approached significance (α = 0.06 or 0.07).

In Figure 6 the change in trait NM is presented as the within pair quadratic regression of aggressive attacks on the age period when separation became necessary. The points of the regression curve show the deviation of the week (0) in which the animals were separated. As expected the estimated values become less precise as the period of separation gets longer and the number of observations decreases. However, the data does not support the hypothesis, that incidence of mounting increases before aggressive attacks. The contrary seems to be the case. From the 1st to the 9th week before separation, the incidence of observed mounting between animals of the same age distinctly increased. The hypothesis that there is a causal connection between mounting and the occurrence of aggressive attacks is not supported by our data.

Figure 6: Change of frequency in mounting (NM) depending on the interval between the observation and the time of separation. Regression curve and upper 0.95 confidence limits.



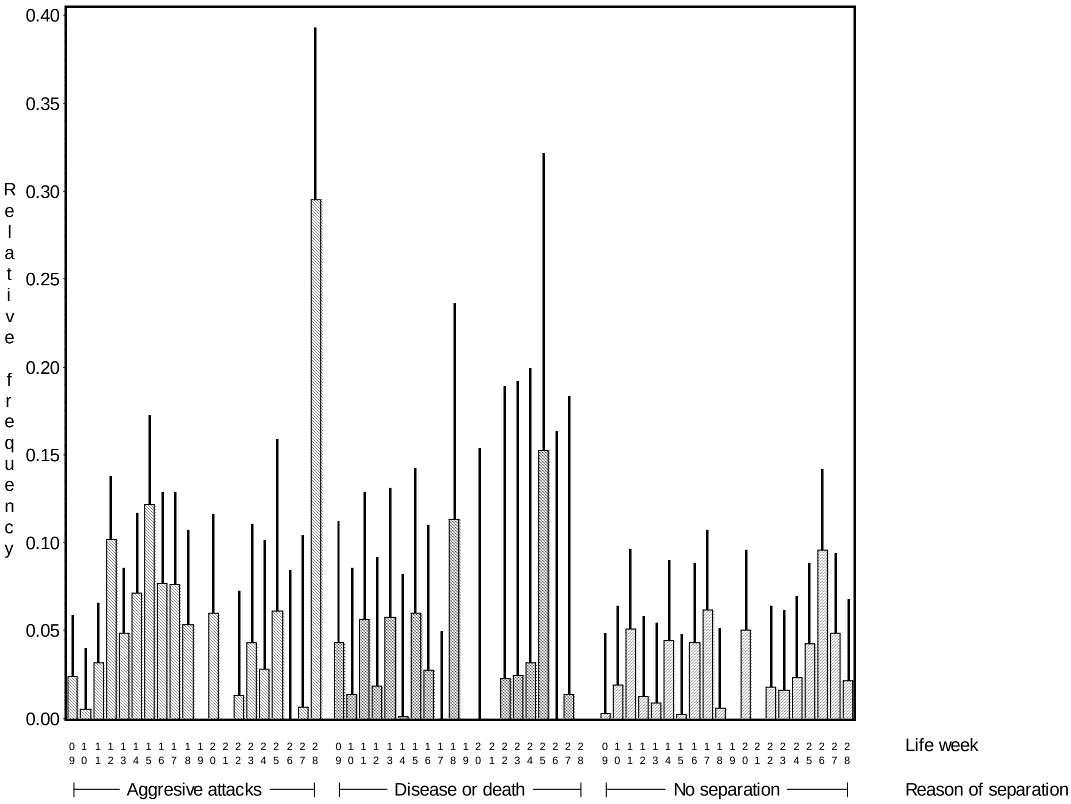
Trait: number of chasings (NC)

Model 3: All pairs of bucks

Chasing (NC) was recorded in 4.5 % of all 5-minute observation periods. Thus the feature could be observed twice as often as mounting, but still relatively seldom. Figure 7 shows how the observed frequency of chasing changes with age. In this figure the pairs were grouped according to the reasons for their separation (SEPAREAS). The influence of age on NC was evident (α = 0.05). In Figure 7 it can be seen that chasing was observed less frequently during the first weeks, when this behaviour had a different quality and was not recorded as such. Early on, the pairs circulated very slowly, which cannot be described as actual chasing. Therefore it can be assumed that chasing as well as mounting starts with sexual maturity. After 14 weeks of age no definite development can be noticed.

The interaction between the reason for separation and age was significant (α< 0.01). To check whether these interactions manifest themselves in different trends, the regression of the presented averages was estimated separately for each group. The regression coefficients in the groups “separation because of aggressive attacks, death/disease and no separation at all” do not differ significantly. The observed interaction cannot be classified according to any of the causes, because of their irregular occurrence.

Figure 7: Average relative frequency (BLUE – estimate and upper 0.95 confidence limit) at which chasing was observed (NC) in the various life weeks*) within the pairs which had to separated because of various reasons. The interaction between reason for separation and age was significant (α< 0.01).



*) No results for weeks 19 and 21 are given, because observations were incomplete around Christmas.

Model 4: Pairs of bucks separated because of aggressive attacks

Similar to mounting (NM), the trait chasing (NC) was analysed according to model 4 to determine whether it was observed more often in pairs separated because of aggressive attacks. Besides the effect of age ($\alpha = 0.01$) the quadratic regression on the period of separation was significant ($\alpha<0.02$). In Figure 8 the relation between NC and the period of separation is presented in weeks. Again the points on the regression curve show the deviation of one week (0) in which the pairs had been separated. As shown in the figure, chasing was observed most frequently in the week prior to separation suggesting a connection between chasing and occurrence of aggressive attacks.

Trait: number of chasings before separation (NCS)

Model 5: Pairs of bucks separated because of aggressive attacks

Using model 5, we could determine if NCS changed within the last six days for pairs which were separated because of aggressive attacks. In this model the quadratic regression was significant on the day before the separation took place ($\alpha < 0.01$) and the regression function is presented in Figure 9.

Figure 8: Change of the frequency of chasing (NC) depending on the interval between the observation and the separation: regression curve and upper and lower 0.95 confidence limits.

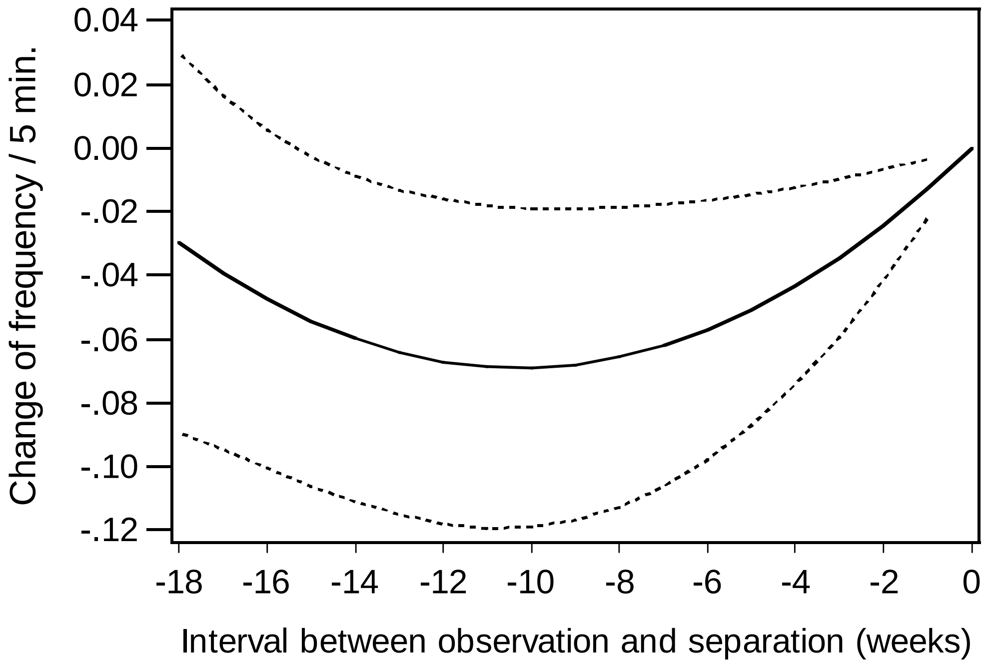
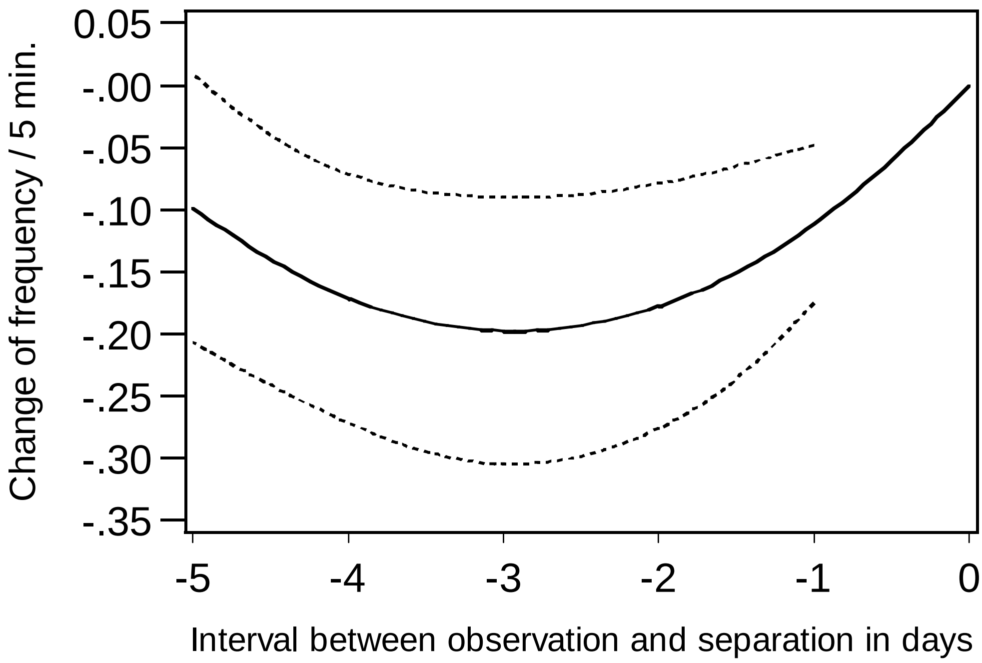


Figure 9: Change of the frequency of chasing (NC) during 5 days preceding the separation: regression curve with upper and lower 0.95 confidence limits.



Analogous to Figures 7 and 8 the points of the regression function were presented as a deviation from day 0, this is the day when the pairs of bucks were separated. The figure shows that chasing was observed distinctly more frequently in the morning before the day of separation and in the morning of the separation day itself. From this observation a connection between chasing and the occurrence of aggressive attacks can be derived. As the occurrence of chasing was only observed within a 5-

minute observation period for 20% of all pairs even in the morning of the day at which the animals had to be separated, this trait does not lend itself for prediction of aggressive attacks with injuries. It should also be noted that chasing occurred only slightly less frequently in pairs which did not have to be separated. The question remains when and why the harmless chasing turns into aggressive attacks which may lead to injuries. There may be an ontogeny of behaviour where chasing is a “play behaviour” that occurs prior to aggressive behaviour.

Model 2: Differences within genetic groups

The estimates of variance components from model 2 are presented in Table 7. Negative estimates were interpreted as random deviations from 0 and were ignored in the further calculations.

Table 7: Variance components in percentages and in absolute values for the random effects and their standard errors. Traits: SA (separation because of aggressive attacks and bite injuries); SD (separation of the animals because of disease or death); ASA (age at separation because of attacks and bite injuries in days).

	SA			SD			ASA		
Causes for variance	variance comp.		standard errors	variance comp.		standard errors	variance comp.		standard errors
	abs.	%	+/-	abs.	%	+/-	abs.	%	+/-
run (GENETIC GROUP)	neg.	-	-	neg.	-	-	0.9	3	5.2
sire (GENETIC GROUP; run)	0.021	8	0.023	0.020	16	0.017	6.3	22	8.1
dam (GENETIC GROUP; run; sire)	0.144	57	0.048	0.073	59	0.019	-	-	-
residual	0.086	34	0.034	0.031	25	0.010	21.3	75	6.4
total	0.251	x	x	0.124	x	x	28.5	x	x

Variability between runs within genetic groups

In no trait were important differences found between the random samples of the same genetic groups. The test animals were kept during a period of 3 ½ years together. During such a long period, the breeding populations and/or the conditions of keeping may change. Yet these changes have not influenced the investigated traits compared to the overall variability, which confirms the general experience of rabbit keepers that injuries caused by aggressive attacks happen time and again in many different environments and in all rabbit breeds and lines when sexually mature bucks are kept in groups.

Estimates of heritability

The heritability estimates are presented in Table 8. Across the investigated genetic groups, considerable genetic differences were found for all 3 traits. However, the heritability estimates had high standard errors due to the limited number of animals. Below we will suggest how a population average can be changed in the desired direction by selection, if the estimated h^2 are confirmed by a sufficient number of observations.

Table 8: Heritability estimates with standard errors

Trait	h^2	s_h^2
Separation of the animals because of an aggressive attack or a bite injury (SA)	0.32	0.36
Separation of the animals because of illness or death (SD)	0.65	0.53
Age at separation because of an aggressive attack or a bite injury in days (ASA)	0.92	1,05

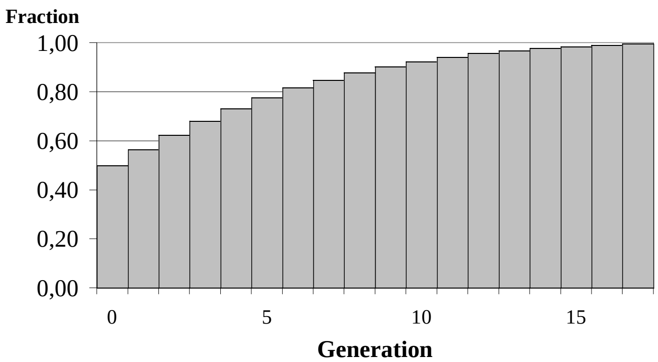
Expected selection response

Trait: separation because of aggression (SA)

The response to selection is expected to decline as the fraction of aggressive bucks decreases from generation to generation (Figure 10). Under the circumstances assumed it seems possible, however, to develop within a foreseeable period of time populations which only rarely show injuries by aggressive attacks among bucks in the testing environment. Within 5 generations, the fraction of bucks not attacking their cage mates during the testing period is expected to increase from 50 to 77 %, within the following 5 generations even to 92 %. Assuming a generation interval of 1.5 years, it appears possible to develop a population with the desired low frequency of aggressive behaviour within 15 – 20 years.

If these improvements could be achieved under conditions of commercial rabbit fattening, attacks of bucks would become so infrequent in these lines that fattening could take place in larger groups, as demanded by animal welfare (Bigler and Oester, 1994), without excessive injuries.

Figure 10: Expected increase of the fraction of "non-aggressive" bucks if the population is selected according to the conditions discussed in the text.



Trait age at separation because of aggression (ASA)

It does not seem to make much sense to consider for selection „Age at the Start of Biting". In all populations the fraction of pairs not showing any aggressive attacks during the observation period was large enough to select only these for reproduction of the next generation. With the kind of observation applied until age of 30 weeks, the same pairs will be selected as if selection is based on trait SA.

Correlated Selection Effects

As there is no information available concerning genetic correlations with other traits, no statement can be made as to the effects of such a selection on conventional traits like fertility and fattening performance. The high fraction of bucks not showing any noticeable aggressive behaviour leads us to expect that correlations to conventional selection traits are not prohibitive. However, adding any additional trait to a selection program will slow down potential progress in all other traits.

Summary

Domestic male rabbits kept in groups tend to develop bite injuries toward the end of the fattening period due to bucks being attacked by other bucks. The frequency of aggressive behaviour and age at onset of biting among genetic groups was measured. A total of 193 pairs of bucks, 142 of known parental origin from 5 different genetic groups, were kept under similar conditions. The experimental unit consisted of two male litter mates kept in conventional fattening cages.

To stop bite injuries and attacks, 43 % of all pairs had to be separated. The difference among genetic groups was not statistically significant and seems to be of minor importance for commercial fattening of rabbits. Genetic groups differed significantly in average age when the aggressive behaviour was observed, however, this difference seems to be of no more practical interest than the differences in age at which the first pairs had to be separated.

There was no statistically significant difference in body weight between the aggressor and the recipient among genetic groups at housing and at separation. There was no correlation between the frequency of mounting and the probability of separating cage mates because of aggressive assaults. The genetic groups, however, differed in age at the beginning of the mounting. Chasing increased significantly with age. This behaviour was seldom observed during the first weeks, suggesting that this behaviour, like mounting, is associated with sexual maturation. Chasing behaviour, however, was too infrequent and irregular to be used as a correlated trait to prevent bite injuries.

Pooled heritability estimates for the 5 genetic groups were $h^2 = 0.32$ for the frequency of injuries and $h^2 = 0.92$ for the age at which the injuries occurred. If these estimates are confirmed within specific lines, they would indicate good possibilities to reduce the frequency of attacks and bite injuries through targeted selection.

Zusammenfassung

Wenn man männliche Hauskaninchen in Gruppen mästet, kommt es gegen Ende der Mast von 12 Wochen vereinzelt zu Bissverletzungen. Untersucht wurde die Bedeutung erblicher Einflüsse auf die Häufigkeit, mit der aggressives Verhalten zwischen Rammlern auftritt, sowie auf das Alter, in dem die Aggressionen beginnen. 193 Rammlerpaare, davon 142 mit bekannter elterlicher Abstammung, aus 5 verschiedenen genetischen Gruppen wurden unter gleichen Bedingungen gehalten. Als Versuchseinheit dienten 2 männliche Wurfgeschwister in einem herkömmlichen Mastkäfig.

43 % aller Paare mussten wegen Bissverletzungen oder Angriffen getrennt werden. Die Unterschiede zwischen den genetischen Gruppen waren statistisch nicht signifikant und erscheinen auch im Hinblick auf ihre Größenordnung für die Kaninchenmast von geringer Bedeutung.

Die zur Trennung der Paare führenden Bissverletzungen und Angriffe traten bei allen genetischen Gruppen im gesamten Beobachtungszeitraum auf. Die genetischen Gruppen unterschieden sich statistisch signifikant im durchschnittlichen Alter, in dem eine Trennung wegen Aggressionen vorgenommen wurde. Diese Unterschiede scheinen allerdings ebenso wenig von praktischem Interesse wie die Unterschiede im Alter, in dem die erste Gruppe getrennt werden musste.

Im Durchschnitt aller genetischen Gruppen waren Gewichtsunterschiede zwischen dem Angreifer und dem Opfer weder beim Einstallen noch bei der Trennung statistisch signifikant. Auch zwischen den genetischen Gruppen gab es hinsichtlich dieser Merkmale keine signifikanten Unterschiede.

Die Häufigkeit der Aufsprünge und die Trennung wegen Aggression waren nicht korreliert. Die genetischen Gruppen unterschieden sich hinsichtlich des Alters beim Beginn der Aufsprünge.

Das „Treiben" war statistisch signifikant altersabhängig. Dieses Merkmal wurde in den ersten Wochen deutlich seltener beobachtet und hängt offenbar mit der Geschlechtsreife zusammen. Kurz vor der Trennung wegen Aggression wurde Treiben häufiger beobachtet. Dieses Verhalten ist aber zu selten und zu unregelmäßig, um es in der Kaninchenmast zur Vorbeuge gegen drohende Verletzungen nutzen zu können.

Im Durchschnitt der 5 genetischen Gruppen wurde für die Häufigkeit der Verletzungen eine mittlere Heritabilität von 0,32 geschätzt; für das Alter, bei dem die Verletzungen auftraten, war die geschätzte Heritabilität mit 0,92 erstaunlich hoch. Falls sich diese Werte innerhalb einer Linie bestätigen, bietet dies gute Voraussetzungen, um die Häufigkeit von Angriffen und Bissverletzungen durch gezielte Selektion zu verändern.

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WPSA support for Germany's exit from conventional cages

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Introduction

The logo of the World Poultry Science Association (WPSA) contains three key words: education – organization - research. Many people think of **education** in terms of public schools and universities, but equally important is continued "learning by doing" and keeping up with international developments connected with the field chosen for a professional career. The WPSA has more than 7000 members with branches in some 70 countries. An important element of the **organization** is the Federation of European WPSA Branches, with more than 3000 members in 28 countries, of which Germany has the largest branch with more than 350 members. As a major contribution to continuous education, the European Federation of WPSA established "Working Groups" which maintain networks among colleagues with common interests and organize symposia from time to time to update each other on current **research** and new results. Working Group "Poultry Welfare and Management" (WG9) has contributed substantial scientific information on alternatives to cage management of laying hens, which has also been used by the EU and national legislation in defining minimum requirements for housing systems. During the 8th European Symposium on Poultry Welfare (18-20 May in Cervia, Italy), colleagues from many countries will update each other on latest developments in response to the ban on conventional cages in the EU beyond 2012.

Developments in Germany are of special interest in this context. Due to a liberal import policy and tougher welfare regulations for domestic egg production than in other countries, Germany has been the largest importer of table eggs (mainly from neighbouring Netherlands) for many years. Presently the German egg industry struggles with the national ban on cages effective in 2009, three years ahead of the EU deadline. At the end of 2008, about 40 million hens produced 70% of domestic egg consumption; predictions are that only 30 million hens will be left at the end of 2009 when the current transition period ends.

Shell eggs sold in German food outlets have to be individually stamped to identify country of origin, type of production (0 = organic; 1 = free range; 2 = barn; 3 = cage) and farm number to assure complete traceability.

The German WPSA branch has offered the egg industry support during a critical period of adjustment by helping to inform interested consumers and the general public about the new management systems for laying hens, using the competence of its members and the internet to make existing knowledge available and analyzing data from audited records. This report will try to explain the reasons for this commitment and how we plan to proceed in the years ahead.

Management systems for laying hens in Germany conforming to 2009 regulations

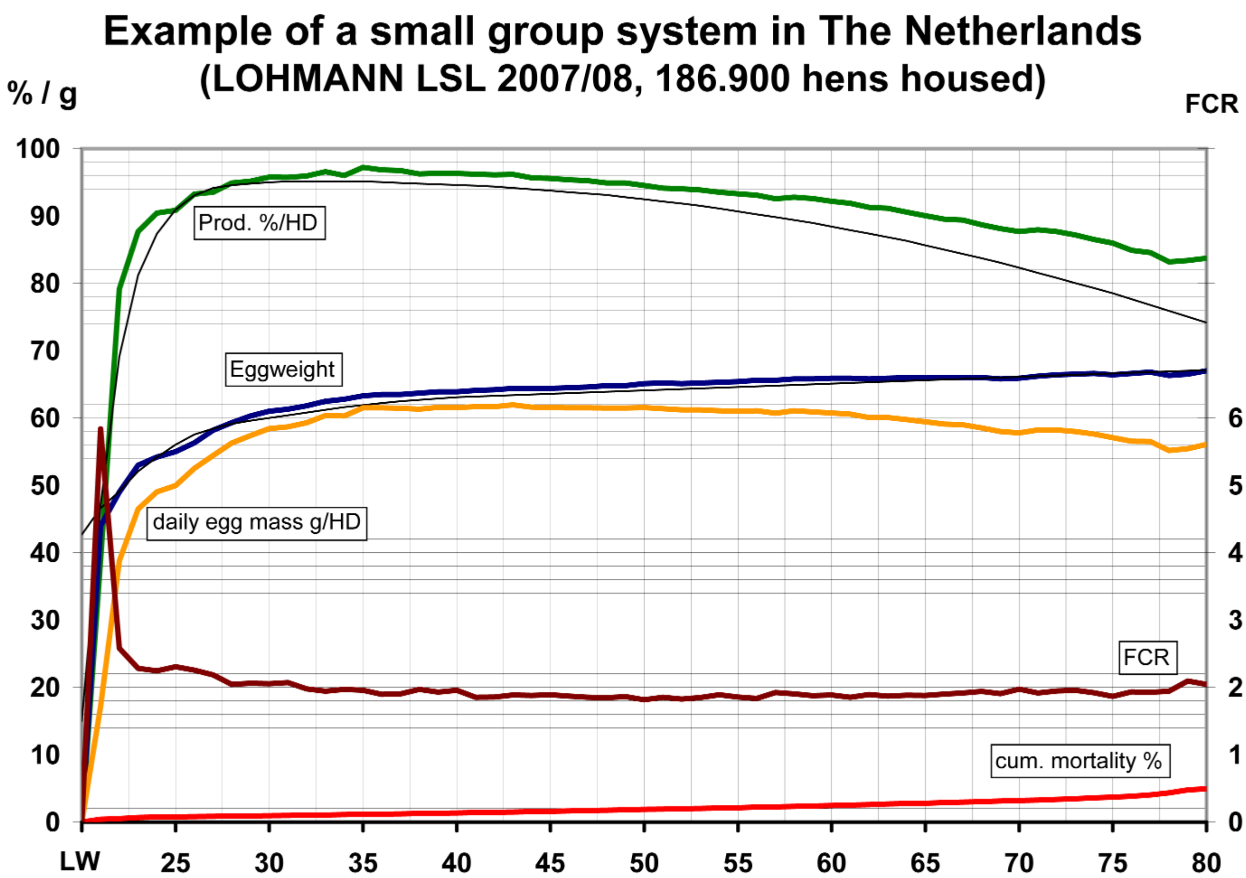
Detailed regulations for the four types of management can be found on the website of the German WPSA Branch www.wpsa.de. Several equipment companies are offering their specific solutions within these legal limits, but it is virtually impossible to get independent and reliable information to compare different models in terms of all relevant criteria. Potential investors have many questions which would need to be answered before a return on investment can be predicted for the next 15 years, during which the equipment is usually depreciated. In the end, decisions are usually made on (1) cost per hen place (the only hard figure); (2) expected saleability and margin per egg from a given management system; and (3) recommendations by known contact persons or the sales representatives of equipment companies. Major "unknowns" are egg prices for different categories, the adaptability of specific flocks of laying hens (genetic strain and rearing environment), and decisions of major players in the food market which type of eggs they will list.

The demand for **organic and free range eggs** has been increasing during past years, but it should be clear that this will remain a niche market. Rapid expansion of production in excess of demand could easily eliminate the current margins. Consumers may also question the free range status during times when hens have to be kept inside to minimize HPAI and other health risks.

Barn eggs can be produced in single-tier and multiple-tier systems. Some of these systems ("Volieren") reach similar bird densities per m³ housing space as enriched cages and require considerable management skill to get good results in terms of clean, saleable eggs. It seems doubtful whether enough barn eggs will be produced in Germany to make up for the loss of cage eggs, creating opportunities for additional imports. Also, people who object to cage management will probably take some convincing before they accept these systems as satisfactory solutions.

Cage eggs can still be imported after the ban on conventional cages becomes effective this year. As a compromise in response to pressure from organized animal welfare to abolish all types of cages and opposite arguments of the egg industry to save jobs for German producers, it was decided by the German authorities to accept "Kleingruppenhaltung" (small group management) as a production system conforming to German animal welfare laws. This system is based on extensive research at different scientific institutions in cooperation with the industry. While retaining advantages of conventional cages (efficiency of production, good air quality, clean eggs, easy to manage), it offers substantial improvements for hen welfare (more space, a nest, scratch area to 'sandbathe', perches to rest on). Recent field results from The Netherlands documented in figure 1 (Flock, 2009) confirm positive experience in Germany on several test farms.

Figure 1



cum. EN/HH	59,7	126,4	192,2	256,0	317,1	374,6
target	60,0	125,5	189,3	250,4	307,3	358,9

What does "Tiergerechte Haltungsform" mean?

Earlier this year, a new organization "Verein zur Förderung nachhaltiger und tiergerechter Haltungssysteme" was established to promote sustainable and animal-friendly egg production in Germany. Members of this organization may use the "seal" shown in figure 2 on egg cartons and/or individual eggs from their own production to promote eggs - provided they participate in an auditing system and supply certain data for statistical analysis. The WPSA has listed details of criteria which must be confirmed during auditing. All types of production allowed in Germany after 2009 will be represented in the scheme, hopefully with sufficient numbers of flocks to enable scientists to draw valid conclusions, which can then be used to further improve management practices.

Figure 2: Logo which may be used on egg cartons or stamped on eggs to identify participation of the producer in the WPSA data base

During the starting phase of the scheme, the WPSA had to make its intentions clear:

(1) to contribute to the **transparency** of egg production by offering the general public and individual egg consumers information on egg production in different production systems; and

(2) to provide **statistical summaries** of field data which may be used to learn from the best flocks in each system how to improve the management of laying hens.

Some critics of the scheme are questioning whether a scientific organization like the WPSA should run the risk of having the "seal" misused for advertising before audited records can be analyzed. Initially, the participants in the scheme can only subscribe to the intention of sustainable and animal-friendly egg production and provide reliable data from their own egg production. To realize the second intention will require time to collect and analyze data and general observations. The text around the seal *("von der Deutschen Vereinigung für Geflügelwissenschaft e.V. begleitet")* indicates that the German WPSA is committed to keep an independent eye on the different systems by analyzing and interpreting the information which will be supplied by the industry partners.

Not surprisingly, the first questions regarding the involvement of WPSA in this information campaign came from organizations which have been arguing against laying cages. Will they admit there is a difference between conventional cages and the *Kleingruppenhaltung* which meets German animal protection laws? It will be difficult for them to use *"tiergerecht"* in the broader sense to include modern 'cages' which provide all components considered essential by ethologists (sufficient space to move around and escape, a darkened nest, a kind of sandbath to scratch, and perches to rest on).
The truth to be explained by scientists is certainly more complex than the simple message some animal welfarists prefer: "a cage is a cage".

Consumers and producers can both benefit from the "WPSA-Seal"

Egg consumers and the interested general public are the first target group for this initiative. It is hoped that more and more consumers will note the new seal on egg cartons and visit the WPSA homepage to find out more about animal welfare standards in different systems. The information on the WPSA website will be presented in easy to understand language, between "too scientific" (more technical and detailed than most people need) and "promotional".

Egg producers will hopefully convince themselves that eggs with this "seal" can be sold in food stores with a sufficiently higher margin to recover the cost of record keeping and auditing. However, there is a third party in the food chain between producers and consumers:

Food stores, especially the decision makers of discounters, are major players in the egg business. They decide the range of products from which consumers can actually choose. In the highly competitive food business, the management has to focus on monthly margins per m² shelf area, which depends on the number of comparable products the buyer can choose from. Most German egg consumers are relatively flexible in what kind of eggs they buy, as long as they are fresh and have the desired size (mainly M and L).

There are some preferences for shell colour, housing system and/or regional origin, but many shoppers would e.g. buy imported brown-shelled barn eggs (with a higher margin for the seller?) when they actually prefer cheaper white-shelled eggs from cage operations in the region. To determine real consumer preferences would require a designed experiment, where the same margin per m² shelf area is added to eggs of different production cost (depending on production system).

It will be easy to convince egg producers that "*Kleingruppenhaltung*" is the most promising alternative to conventional cages. From the limited experience with this system, there is little doubt that it is easy to operate; liveability, egg production per hen housed and feed cost per egg will be better, on average, than in floor systems.

Open questions are (1) whether the food industry is willing to list eggs with the code DE-3 to offer consumers a choice and (2) whether animal welfare organizations are prepared to accept "*Kleingruppenhaltung*" as a step in the right direction and perhaps better than importing eggs from countries with lower animal welfare standards.

While equipment companies are busy installing the systems currently available, we expect a continued demand for further developments of all systems, for which the WPSA can contribute valuable input from the analysis of field records and new international literature. The German government is currently planning to establish mandatory technical testing and monitoring (TÜV) for all poultry and animal housing systems. Such a system could also benefit from cooperation with experts of the WPSA, especially members of Working Group 9 (Poultry Welfare and Management).

Zusammenfassung

Die Deutsche Gesellschaft für Geflügelwissenschaft e.V. begleitet die Umstellung der konventionellen Legehennenhaltung auf nachhaltige und tierfreundliche Haltungsformen mit einem Angebot wissenschaftlich fundierter Informationen, die dazu beitragen sollen, alle in Deutschland zulässigen Systeme für die interessierte Öffentlichkeit transparent darzustellen und aufgrund statistischer Analysen umfangreicher Praxisdaten aus allen Haltungssystemen Anregungen für weitere Verbesserungen verschiedener Systeme im Sinne tierfreundlicher, umweltverträglicher und wirtschaftlich tragfähiger Eierproduktion zu geben.

Literature

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