

# ENVIRONMENT, WELL-BEING, AND BEHAVIOR

## Production, Egg Quality, Bone Strength, Claw Length, and Keel Bone Deformities of Laying Hens Housed in Furnished Cages with Different Group Sizes

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**ABSTRACT** The effects of 3 different furnished cage systems (Aviplus, Eurovent 625a, Eurovent 625A) on 2 different laying hen strains [Lohmann Selected Leghorn (LSL), Lohmann Brown (LB)] were examined for the traits of production, egg quality, bone strength, claw length, and keel bone status. Two trials were carried out in which all hens received identical feeding and management.

In brown hens, the traits egg production per average hen housed, cracked eggs, feed conversion, egg weight, and humerus breaking strength were significantly higher than in white hens. Furthermore, the claws of the brown hens were shorter than those of white hens. There were more dirty eggs, higher shell density, and fewer keel bone deformities in white hens than in brown hens. In the Aviplus system, egg production per average hen

housed was higher than in the other systems, whereas shell thickness and density were lower. Humerus strength was also higher in the Aviplus than in the Eurovent 625a system, whereas there was no significant difference in tibia strength among the 3 systems. The shortest claws were found in the Aviplus system, and the fewest keel bone deformities occurred in the Eurovent 625a system. The study showed that the high standards of conventional cages for production and egg quality were met in furnished cages and that bone strength was significantly greater than in conventional cages. Claw shortening devices in furnished cages seemed satisfactory, because claws were generally short. However, the occurrence of keel bone deformities due to the intensive use of perches seemed to be a problem of furnished cages.

(*Key words:* furnished cage, laying hen, productivity, health, welfare)

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### INTRODUCTION

Presently most laying hens in Germany are housed in conventional cages, although it is a widely criticized housing system due to welfare problems (Baxter, 1994). In conventional cages laying hens lack the opportunities to fulfill most of their natural behaviors, which leads to a high amount of frustration and stress. Furthermore, the hens are given only limited space so that they are very restricted in their movements and activities. This lack of exercise can lead to a severe bone loss, resulting in what is referred to as cage-layer fatigue (Couch, 1955). Because of these critical issues the European Union (EU) passed a directive in 1999 (CEC, 1999), banning conventional cages for laying hens in all European countries by the end of 2011. Poultry farmers therefore will have to replace their conventional cages with alternative

housing systems or furnished cages. The furnished cage is a relatively new housing system for laying hens, the aim of which is to give laying hens the opportunity to perform some of their natural behaviors while maintaining the high economic and hygiene standards of the conventional cages (Appleby, 1993a). Deviating from the EU directive, in Germany conventional cages will be forbidden by the end of 2006; furthermore, furnished cages will be allowed only until the end of 2011. Poultry farmers in Germany now see themselves at a competitive disadvantage because most of the other European countries plan to allow furnished cages after the year 2012. This situation has led in the European Union, but especially in Germany, to increased interest in scientific research about alternative housing systems and furnished cages, because by the time that conventional cages are not allowed both will become more or less important.

The present study was conducted to investigate different economic and welfare aspects of laying hens in fur-

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**Abbreviation Key:** EU = European Union; LB = Lohmann Brown; LSL = Lohmann Selected Leghorn.

nished cages. This investigation was intended to make possible evaluation and classification of furnished cages, as only little information is as yet available about furnished cages used under practical conditions (Appleby, 1993b; Abrahamsson et al., 1995; Leyendecker, 2003).

## MATERIALS AND METHODS

### *Housing Conditions*

Three different furnished cage systems (Aviplus, Eurovent 625a, Eurovent 625A)<sup>2</sup> were installed in one experimental building. Each system consisted of 4 tiers of double-decker cages. Hens were housed in groups of 10 and 20 per cage in the Aviplus and Eurovent 625A systems and in groups of 40 and 60 per cage in the Eurovent 625a system. All furnished cages met the demands of the EU directive 1999/74/EG (CEC, 1999), which stipulates that each hen has at least 750 cm<sup>2</sup> of floor space and that every cage is equipped with perches, a nest box, a dust bath and devices to shorten the claws. The perches were incorporated parallel to the front of the cage. Only in the groups of 10 hens in the Eurovent 625A system was there another rectangular perch. The nest box was installed in all systems at one side of the cage. The nest boxes were equipped with nontransparent plastic curtains. The dust bath was placed in the back of the cage in the Aviplus system, but it was placed at one side of the cage in the 2 Eurovent systems. Wood shavings were used as litter. The claw-shortening devices were different in the 3 furnished cage types. In the Aviplus system it consisted of either 2 abrasive blocks per cage or a perforated metal plate. In the Eurovent 625a system one abrasive block per cage was installed, whereas the system Eurovent 625A contained adhesive stripes.

### *Breed, Feeding, and Stocking*

Two different trials were conducted, the first from July 2002 until July 2003 and the second from September 2003 until June 2004. The first trial was conducted with a brown layer line (Lohmann Brown; LB) and a white layer line (Lohmann Selected Leghorn; LSL). The pullets were reared in cages until the age of 17 (LB) and 19 (LSL) wk, respectively, when they were transferred in equal numbers to the furnished cages. At the beginning of the first trial each of the 3 furnished cages contained 2,880 laying hens so that a total of 8,640 laying hens were accommodated in the experimental building.

The second trial used only a single white layer line (LSL). Half of the pullets were reared in cages, while the other half was reared on the floor. At 18 wk of age the laying hens were moved to the furnished cages at the same stocking density as in the first trial.

During the first 9 mo the hens were fed a standard layer diet (LM1) containing 11.49 MJ of ME, 17.12% crude protein, 3.6% calcium, and 0.55% phosphorus. From the 10th laying month on the hens were switched to another standard layer diet (LM2) containing 11.4 MJ of ME, 16.5% crude protein, 3.9% calcium and 0.51% phosphorus. Food was provided 3 or 4 times a day, and water was provided ad libitum. The light was turned on at 0400 h and turned off at 1800 h with a 20-min dimming period. During the laying period the hens were vaccinated every 2 mo against Newcastle disease and infectious bronchitis. For 2 d after each vaccination they received vitamins A, D<sub>3</sub>, and E. During the entire laying period all hens in the 3 different furnished cage systems were subjected to the same management conditions.

### *Production Traits*

Eggs were transported daily on conveyor belts to a collecting point, where they were counted separately according to housing system, group size, and layer line. Furthermore, the eggs were sorted according to quality traits such as dirty, cracked, or broken eggs. The daily egg production per average hen housed and the proportions of dirty and cracked eggs were calculated on the basis of the number of eggs collected. Once a week all eggs from each housing system, group size, and layer line were weighed for calculation of a mean egg weight. The feed consumption was assessed daily for each housing system and group size. Feed conversion rate was generated from the daily feed consumption and the egg mass produced.

### *Egg Quality Traits*

Every 4 wk, a sample of 180 eggs was collected in equal numbers from each housing system, group size, and layer line. In the first trial, the collection of eggs started at the seventh laying month, whereas in the second trial eggs were collected from the second laying month. The egg samples were stored for 1 d at +4°C and then analyzed for internal and external egg quality traits. A total of 2,420 eggs were analyzed.

All eggs were weighed, and the weight was recorded in grams. Eggshell breaking strength was measured using the machine "Zwicki-Z2,5/TNIS",<sup>3</sup> which subjected the egg to pressure (N = Newtons) until the shell broke. The eggs were then cracked on a plate, and the albumen height (in mm) was determined using a semiautomatic device<sup>4</sup> to record the distance between the plate and the thickest part of the white egg. The albumen height was converted to Haugh units (Haugh, 1937). For the measurement of the eggshell thickness, a sample was taken from the egg equator region, removed from the membrane and put into a micrometer.<sup>4</sup> For the calculation of eggshell density (eggshell weight per surface area) the eggshells were dried in a microwave oven and weighed in grams. The surface area of the egg was calculated from the weight of the egg by the formula  $S = 4.67 \times$

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$G^{2/3}$ , where S = surface area, and G = egg weight. Eggshell density (in mg/cm<sup>2</sup>) was calculated by dividing eggshell weight by the surface area. All measurements were carried out by the same person.

### **Bone Breaking Strength, Claw Length, and Keel Bone Deformities**

In the first trial, 48 hens were removed from each of the 3 furnished cages at the end of the 6th, 9th, and 12th laying months and at the end of the 3rd, 6th, and 9th laying months in the second trial. Hens were chosen at random in equal numbers from the different group sizes and layer lines. A pathological examination of every hen was carried out after slaughter. Hens found to have broken bones were excluded from the measurement of bone breaking strength. The humerus and tibia bones were removed and cleaned of tendons and muscles. After 1 d of storage at +4°C one humerus and one tibia were analyzed from each hen. After measurement of the length and weight of the bones (in cm and g, respectively), the bone breaking strength was determined with a 3-point bending machine.<sup>3</sup> For this test the bones were placed on 2 supports (9 cm apart for the tibia; 4 cm apart for the humerus), and a perpendicular force (N) was applied until the bones fractured. A total of 852 humerus and 855 tibia bones were tested.

The claw length for each slaughtered hen was measured on a scale of 1 to 4 (where 1 = <2 cm, 2 = 2 to 3 cm, 3 = 3 to 4 cm, and 4 = >4 cm). The presence of keel bone deformities was assessed visually, again on a scale of 1 to 4 (where 1 = no deformities, 2 = slight deformities, 3 = moderate deformities, and 4 = severe deformities).

### **Statistical Analyses**

All analyses were performed using the GLM procedure of the SAS package (version 9.1.3<sup>5</sup>). The univariate linear models used for analysis are shown below. Production traits were analyzed for the effects of housing system, group size, layer line in trial, and the interaction between housing system and layer line in trial. The age of the hens at examination was used as a covariable. Egg quality traits were analyzed for the effects of housing system, group size, layer line in trial, laying month, and the interaction between housing system and layer line in trial. Bone breaking strength, claw length, and keel bone deformities were analyzed for the effects of housing system, group size, layer line in rearing system, laying month, trial, and the interaction between housing system and layer line in rearing system. The body weight of the hens was used as a covariable. Least square means (LSM) were estimated for all parameters investigated here. The results of the statistical tests were significant when the probability of error was  $P \leq 0.05$ .

### **Model for Production Traits**

$$Y_{ijklm} = \mu + \text{SYS}_i + \text{GR}(\text{SYS})_j + \text{LL\_TR}_k \\ + (\text{SYS} \times \text{LL\_TR})_{ik} + b_1 \text{Age} (\text{SYS} \times \text{LL\_TR})_{ikl} \\ + b_2 (\text{Age} (\text{SYS} \times \text{LL\_TR}))_{ikl}^2 \\ + b_3 \ln (\text{Age} (\text{SYS} \times \text{LL\_TR}))_{ikl} \\ + b_4 (\ln (\text{Age} (\text{SYS} \times \text{LL\_TR})))_{ikl}^2 + e_{ijklm}$$

where  $Y_{ijklm}$  = observation of the production traits egg production, proportion of dirty and cracked eggs, feed consumption, and feed conversion;  $\mu$  = model constant;  $\text{SYS}_i$  = effect of the housing system ( $i = 1$  to 3);  $\text{GR}(\text{SYS})_j$  = effect of the different group sizes in housing system ( $j = 1$  to 6);  $\text{LL\_TR}_k$  = effect of the layer lines in the trial ( $k = 1$  to 3);  $(\text{SYS} \times \text{LL\_TR})_{ik}$  = interaction between housing system and layer line in the trial;  $b_1 - b_4$  = partial regression coefficients; Age = age of the hens at examination; and  $e_{ijklm}$  random error variation.

### **Model for Egg Quality Traits**

$$Y_{ijklm} = \mu + \text{SYS}_i + \text{GR}(\text{SYS})_j + \text{LL\_TR}_k \\ + \text{MON}_l + (\text{SYS} \times \text{LL\_TR})_{ik} + e_{ijklm}$$

where  $Y_{ijklm}$  = observation of the egg quality traits egg weight, Haugh units, shell thickness, shell density, and shell breaking strength; and  $\text{MON}_l$  = effect of the laying month in which the examination took place ( $l = 1$  to 11).

### **Model for Bone Breaking Strength, Claw Length, and Keel Bone Deformities**

$$Y_{ijklmno} = \mu + \text{SYS}_i + \text{GR}(\text{SYS})_j + \text{LL\_RS}_k \\ + \text{MON}_l + \text{TR}_m + (\text{SYS} \times \text{LL\_RS})_{ik} \\ + b \text{BW} (\text{LL\_RS})_{kn} + e_{ijklmno}$$

$Y_{ijklmno}$  = observation of humerus breaking strength, tibia breaking strength, degree of claw length, and keel bone deformities;  $\text{LL\_RS}_k$  = effect of layer line in the rearing system ( $k = 1$  to 3);  $\text{MON}_l$  = effect of the laying month in which the examination took place ( $l = 1$  to 4);  $\text{TR}_m$  = effect of the trial ( $m = 1$  to 2);  $(\text{SYS} \times \text{LL\_RS})_{ik}$  = interaction between housing system and layer line in rearing system; and BW = body weight of the hens at examination.

## **RESULTS**

Table 1 shows the analyses of variance for the different traits investigated here. The effect of housing system was significant for most of these traits. Group size within housing system had a significant influence on all production traits and Haugh units. Layer line within trial was significant for all production traits except feed consumption, egg weight, Haugh units, and shell density,

<sup>5</sup>Statistical Analysis System Institute Inc., Cary, NC.

**Table 1.** Analysis of variance for the production traits, egg quality traits, bone strength, claw length, and keel bone status<sup>1</sup>

Trait	SYS		GR(SYS)		LL_TR/ LL_RS		SYS × LL_TR/ SYS × LL_RS	
	MSR	P	MSR	P	MSR	P	MSR	P
Egg production/average hen housed	0.002	NS	0.08	***	0.27	***	0.002	NS
Dirty eggs	<0.001	NS	0.06	***	0.001	**	0.001	**
Cracked eggs	<0.001	*	<0.001	**	0.001	***	<0.001	***
Feed consumption	208.0	NS	8,608.6	***	19.4	NS	9.26	NS
Feed conversion	0.34	***	3.08	***	3.91	***	0.08	NS
Egg weight	282.0	***	8.92	NS	908.4	***	25.6	NS
Haugh units	740.5	***	153.7	*	3,756.5	***	264.4	***
Shell thickness	4,104.7	**	701.6	NS	1,631.8	NS	199.9	NS
Shell density	524.0	***	38.2	NS	658.7	***	427.2	***
Shell breaking strength	139.2	NS	72.1	NS	22.5	NS	156.7	NS
Humerus breaking strength	6,640.0	*	1,443.6	NS	3,958.3	NS	7,576.2	**
Tibia breaking strength	650.4	NS	1,174.2	NS	385.8	NS	1,378.9	NS
Claw length	1.81	**	0.65	NS	0.04	NS	1.19	**
Keel bone status	3.84	***	0.11	NS	0.28	NS	0.33	NS

<sup>1</sup>SYS = housing system; GR(SYS) = group size within housing system; LL\_TR = layer line in trial (for production and egg quality traits); LL\_RS = layer line in rearing system (for bone strength, claw length, keel bone status); SYS × LL\_TR = interaction of housing system and layer line in trial (for production and egg quality traits); SYS × LL\_RS = interaction of housing system and layer line in rearing system (for bone strength, claw length, keel bone status); MSR = mean sum of squares. NS at  $P > 0.05$ ; \* $P \leq 0.05$ ; \*\* $P \leq 0.01$ ; \*\*\* $P \leq 0.001$ .

whereas layer line within rearing system was not significant for any effect investigated here. The interaction of housing system and layer line within trial had a significant effect on the proportion of dirty and cracked eggs, Haugh units, and shell density, whereas the interaction between housing system and layer line within rearing system was significant for humerus strength and claw length.

Production and egg quality traits were significantly influenced by the layer line (Table 2). Egg production per average hen housed was higher (89.3%) in the LB line, which also laid heavier eggs (64.6 g) than the LSL hens. The proportion of dirty eggs was higher for the LSL hens (4.0% in the first trial; 4.1% in the second trial) than for the LB hens (2.0%). The proportion of cracked eggs was higher for the LB hens (1.0%) than for the LSL hens (0.6% in the first trial; 0.3% in the second trial). Shell thickness was higher for the LB hens (326.9  $\mu\text{m}$ ) than for the LSL hens (323.4  $\mu\text{m}$  in the first trial; 325.6  $\mu\text{m}$  in the second trial), but shell density was higher for the LSL hens (98.6  $\text{mg}/\text{cm}^2$  in the first trial; 97.6  $\text{mg}/$

$\text{cm}^2$  in the second trial) than for the LB hens (96.3  $\text{mg}/\text{cm}^2$ ). There was no significant difference in shell breaking strength between the lines.

The interaction of layer line and rearing system had a significant influence on bone breaking strength, claw length, and keel bone status (Table 3). The humerus bones of the LB hens were stronger (254.5 N) than those of the LSL hens (177.1 N), whereas there was no significant difference in tibia breaking strength between the lines. Hens from the LB layer line had shorter claws (1.1) and more keel bone deformities than the LSL hens. It was also shown that the mean body weight of the LB hens was higher (2,170.2 g) than that of the LSL hens (1,730.2 g). The different rearing systems also had significant effects on bone strength. Both humerus and tibia breaking strength were higher for the LSL hens reared in cages than for those reared on the floor. The claws of the hens reared in cages were shorter (1.8) than those of hens reared on the floor (2.0), whereas the keel bones of hens reared on the floor showed fewer deformities (1.2) than those from hens reared in cages (1.5).

**Table 2.** Least square means (LSM), their standard errors (SE), and significant differences between layer lines (Lohmann Selected Leghorn, LSL; and Lohmann Brown, LB) in the different trials for production traits and egg quality traits

Trait	1st trial, LSL		1st trial, LB		2nd trial, LSL	
	LSM	SE	LSM	SE	LSM	SE
Egg production/average hen housed (%)	89.0 <sup>c</sup>	0.1	89.3 <sup>a</sup>	0.1	84.4 <sup>b</sup>	0.4
Dirty eggs (%)	4.0 <sup>a</sup>	0.02	2.0 <sup>b</sup>	0.02	4.1 <sup>a</sup>	0.08
Cracked eggs (%)	0.6 <sup>c</sup>	0.01	1.0 <sup>a</sup>	0.01	0.3 <sup>b</sup>	0.03
Egg weight (g)	62.0 <sup>b</sup>	0.3	64.6 <sup>a</sup>	0.3	63.3 <sup>c</sup>	0.2
Haugh units	84.3 <sup>a</sup>	0.4	78.8 <sup>b</sup>	0.4	82.0 <sup>c</sup>	0.3
Shell thickness ( $\mu\text{m}$ )	323.4 <sup>b</sup>	1.4	326.9 <sup>a</sup>	1.4	325.6 <sup>ab</sup>	1.0
Shell density ( $\text{mg}/\text{cm}^2$ )	98.6 <sup>a</sup>	0.4	96.3 <sup>b</sup>	0.4	97.6 <sup>b</sup>	0.3
Shell breaking strength (N)	39.8	0.5	40.2	0.5	40.1	0.3

<sup>a-c</sup>Different superscripts within a row indicate significant differences among LSM ( $P < 0.05$ ).

**Table 3.** Least square means (LSM), their standard errors (SE), and significant differences between the layer lines (Lohmann Selected Leghorn, LSL; and Lohmann Brown, LB) in different rearing systems for bone strength, claw length, and keel bone status<sup>1</sup>

Trait	LSL_Cage		LSL_Floor		LB_Cage	
	LSM	SE	LSM	SE	LSM	SE
Humerus breaking strength (N)	177.1 <sup>c</sup>	2.7	141.0 <sup>b</sup>	4.1	254.5 <sup>a</sup>	6.0
Tibia breaking strength (N)	147.4 <sup>a</sup>	1.6	138.9 <sup>b</sup>	2.4	140.9 <sup>ab</sup>	3.5
Claw length (1 to 4)	1.8 <sup>c</sup>	0.03	2.0 <sup>a</sup>	0.05	1.1 <sup>b</sup>	0.09
Keel bone status (1 to 4)	1.5 <sup>a</sup>	0.04	1.2 <sup>b</sup>	0.06	1.7 <sup>a</sup>	0.09

<sup>a-c</sup>Different superscripts within a row indicate significant differences among LSM ( $P < 0.05$ ).

<sup>1</sup>Cage = cage rearing; Floor = floor rearing.

Table 4 shows the differences among the 3 housing systems under study for all traits examined. Egg production per average hen housed (88.9%) and feed consumption (112.3 g) were higher among hens housed in the Aviplus system than in the other systems. The proportion of dirty eggs was highest in the system Eurovent 625A (3.8%), but there were no differences among the housing systems in the proportion of cracked eggs. The egg quality traits shell thickness and shell density were significantly lower in the Aviplus system than in the 2 Eurovent systems, whereas the Haugh Units were highest in the Aviplus system. There were only minor differences among the housing systems in bone breaking strength. The humerus strength was higher (195.6 N) in the Aviplus system than in the Eurovent 625a system (185.3 N), but there were no significant differences among the housing systems for tibia strength. The shortest claws were found in the Aviplus system (1.5), whereas there were fewer keel bone deformities (1.3) of hens from the Eurovent 625a system than in the other systems.

Table 5 shows the results for the different group sizes in each housing system. The highest egg production per average hen housed (89.4%) was found in the groups of 20 hens in the Aviplus system. The highest proportion of dirty eggs (4.3%) was found in the groups of 10 hens

in the Eurovent 625A system, whereas the proportion of cracked eggs was higher (0.7%) in groups of 60 hens than in the other group sizes. Feed consumption was highest (114.4 g) in the groups of 10 hens in the Aviplus system. The heaviest eggs (64.1 g) were produced in the groups of 60 hens. Shell thickness, density, and strength were lowest in the groups of 10 and 20 hens in the Aviplus system and highest in the groups of 10 hens in the Eurovent 625A system. The strongest humerus bones (198.2 N) were found in the groups with 10 hens in the Aviplus system, and tibia strength was greater (146.7 N) in the groups of 20 hens in the Eurovent 625A system. Furthermore, the shortest claws (1.5) were found in the groups of 10 hens in the Aviplus system.

## DISCUSSION

The objective of the present investigation was to analyze different types of furnished cages for their effects on production and egg quality traits, bone strength, claw length, and keel bone status. Two different layer lines were also investigated.

### Breed

There were remarkable differences between the 2 layer lines. Egg production of the brown LB layer line was

**Table 4.** Least square means (LSM), their standard errors (SE), and significant differences between the different housing systems<sup>1</sup> for production traits, egg quality traits, bone strength, claw length, and keel bone status

Trait	Aviplus		Eurovent 625a		Eurovent 625A	
	LSM	SE	LSM	SE	LSM	SE
Egg production/average hen housed (%)	88.9 <sup>a</sup>	0.2	87.6 <sup>c</sup>	0.3	86.2 <sup>b</sup>	0.3
Dirty eggs (%)	3.0 <sup>b</sup>	0.05	3.4 <sup>c</sup>	0.05	3.8 <sup>a</sup>	0.05
Cracked eggs (%)	0.6	0.02	0.6	0.02	0.6	0.02
Feed consumption (g)	112.3 <sup>a</sup>	0.3	111.4 <sup>a</sup>	0.3	109.9 <sup>b</sup>	0.3
Feed conversion (kg/kg)	2.07	0.01	2.05	0.01	2.06	0.01
Egg weight (g)	62.6 <sup>b</sup>	0.2	64.0 <sup>a</sup>	0.2	63.3 <sup>c</sup>	0.2
Haugh units	82.9 <sup>a</sup>	0.3	81.3 <sup>b</sup>	0.3	80.8 <sup>b</sup>	0.3
Shell thickness ( $\mu\text{m}$ )	322.4 <sup>b</sup>	1.1	326.9 <sup>a</sup>	1.1	326.6 <sup>a</sup>	1.2
Shell density ( $\text{mg}/\text{cm}^2$ )	96.5 <sup>b</sup>	0.3	98.1 <sup>a</sup>	0.3	98.0 <sup>a</sup>	0.4
Shell breaking strength (N)	39.5	0.4	40.2	0.4	40.4	0.4
Humerus breaking strength (N)	195.6 <sup>a</sup>	3.4	185.3 <sup>b</sup>	3.4	191.7 <sup>ab</sup>	3.7
Tibia breaking strength (N)	140.5	2.0	143.5	1.9	143.2	2.2
Claw length (1 to 4)	1.5 <sup>b</sup>	0.05	1.7 <sup>a</sup>	0.04	1.6 <sup>a</sup>	0.05
Keel bone status (1 to 4)	1.6 <sup>a</sup>	0.05	1.3 <sup>b</sup>	0.05	1.4 <sup>a</sup>	0.06

<sup>a-c</sup>Values with different superscripts within a row indicate significant differences among LSM ( $P < 0.05$ ).

<sup>1</sup>Big Dutchman, Vechta, Germany.

**Table 5.** Least square means (LSM), their standard errors ( $\pm$  SE), and significant differences between the different group sizes in each housing system<sup>1</sup> for production traits, egg quality traits, bone strength, claw length, and keel bone status

Trait	Aviplus		Eurovent 625a		Eurovent 625A	
	10	20	40	60	10	20
Egg production per average hen housed (%)	88.3 <sup>b</sup> $\pm$ 0.3	89.4 <sup>a</sup> $\pm$ 0.3	87.9 <sup>d</sup> $\pm$ 0.3	87.3 <sup>c</sup> $\pm$ 0.3	85.7 <sup>b</sup> $\pm$ 0.3	86.8 <sup>c</sup> $\pm$ 0.3
Dirty eggs (%)	2.7 <sup>b</sup> $\pm$ 0.06	3.3 <sup>d</sup> $\pm$ 0.06	3.8 <sup>e</sup> $\pm$ 0.06	3.0 <sup>c</sup> $\pm$ 0.06	4.3 <sup>a</sup> $\pm$ 0.06	3.2 <sup>d</sup> $\pm$ 0.06
Cracked eggs (%)	0.6 <sup>ab</sup> $\pm$ 0.02	0.6 <sup>b</sup> $\pm$ 0.02	0.6 <sup>b</sup> $\pm$ 0.02	0.7 <sup>a</sup> $\pm$ 0.02	0.6 <sup>ab</sup> $\pm$ 0.02	0.6 <sup>ab</sup> $\pm$ 0.02
Feed consumption (g)	114.4 <sup>a</sup> $\pm$ 0.4	110.1 <sup>bc</sup> $\pm$ 0.4	109.7 <sup>bc</sup> $\pm$ 0.4	113.2 <sup>d</sup> $\pm$ 0.4	109.3 <sup>b</sup> $\pm$ 0.4	110.5 <sup>c</sup> $\pm$ 0.4
Feed conversion (kg/kg)	2.11 <sup>a</sup> $\pm$ 0.01	2.03 <sup>bc</sup> $\pm$ 0.01	2.02 <sup>b</sup> $\pm$ 0.01	2.09 <sup>d</sup> $\pm$ 0.01	2.07 <sup>d</sup> $\pm$ 0.01	2.05 <sup>c</sup> $\pm$ 0.01
Egg weight (g)	62.7 <sup>b</sup> $\pm$ 0.3	62.6 <sup>b</sup> $\pm$ 0.3	63.8 <sup>ac</sup> $\pm$ 0.3	64.1 <sup>a</sup> $\pm$ 0.3	63.4 <sup>abc</sup> $\pm$ 0.4	63.2 <sup>bc</sup> $\pm$ 0.3
Haugh units	82.7 <sup>a</sup> $\pm$ 0.4	83.1 <sup>a</sup> $\pm$ 0.4	81.7 <sup>c</sup> $\pm$ 0.4	81.0 <sup>c</sup> $\pm$ 0.4	81.8 <sup>ac</sup> $\pm$ 0.6	79.8 <sup>b</sup> $\pm$ 0.4
Shell thickness ( $\mu$ m)	322.6 <sup>b</sup> $\pm$ 1.5	322.2 <sup>b</sup> $\pm$ 1.5	325.9 <sup>ab</sup> $\pm$ 1.5	327.9 <sup>a</sup> $\pm$ 1.5	328.6 <sup>a</sup> $\pm$ 2.2	324.7 <sup>ab</sup> $\pm$ 1.5
Shell density (mg/cm <sup>2</sup> )	96.4 <sup>b</sup> $\pm$ 0.4	96.5 <sup>b</sup> $\pm$ 0.4	98.5 <sup>a</sup> $\pm$ 0.4	97.8 <sup>a</sup> $\pm$ 0.4	98.2 <sup>a</sup> $\pm$ 0.7	97.7 <sup>a</sup> $\pm$ 0.4
Shell strength (N)	39.3 <sup>b</sup> $\pm$ 0.5	39.7 <sup>ab</sup> $\pm$ 0.5	40.6 <sup>a</sup> $\pm$ 0.5	39.9 <sup>ab</sup> $\pm$ 0.5	40.8 <sup>ab</sup> $\pm$ 0.7	40.0 <sup>ab</sup> $\pm$ 0.5
Humerus breaking strength (N)	198.2 <sup>a</sup> $\pm$ 4.3	192.9 <sup>abc</sup> $\pm$ 4.3	184.0 <sup>b</sup> $\pm$ 4.3	186.6 <sup>bc</sup> $\pm$ 4.3	188.4 <sup>abc</sup> $\pm$ 6.2	195.1 <sup>ac</sup> $\pm$ 4.3
Tibia breaking strength (N)	142.7 <sup>ab</sup> $\pm$ 2.5	138.3 <sup>b</sup> $\pm$ 2.5	143.4 <sup>ab</sup> $\pm$ 2.5	143.7 <sup>ab</sup> $\pm$ 2.5	139.6 <sup>ab</sup> $\pm$ 3.6	146.7 <sup>a</sup> $\pm$ 2.5
Claw length (1 to 4)	1.5 <sup>b</sup> $\pm$ 0.05	1.6 <sup>bc</sup> $\pm$ 0.05	1.6 <sup>c</sup> $\pm$ 0.05	1.8 <sup>a</sup> $\pm$ 0.05	1.7 <sup>ac</sup> $\pm$ 0.09	1.6 <sup>c</sup> $\pm$ 0.05
Keel bone status (1 to 4)	1.5 <sup>a</sup> $\pm$ 0.07	1.6 <sup>a</sup> $\pm$ 0.07	1.3 <sup>b</sup> $\pm$ 0.07	1.3 <sup>b</sup> $\pm$ 0.07	1.5 <sup>ab</sup> $\pm$ 0.09	1.4 <sup>ab</sup> $\pm$ 0.07

<sup>a-e</sup>Values with different superscripts within a row indicate significant differences among LSM ( $P < 0.05$ ).

<sup>1</sup>Big Dutchman, Vechta, Germany.

higher than that of the white LSL layer line. Egg production is highly influenced by breed. However, our results differ from those of Lange (1996), who found egg production in conventional cages to be higher for a white strain than for a brown strain. These results were in accordance with those of Abrahamsson et al. (1995), who also detected higher egg production for the LSL hens in a comparison of LSL and ISA Brown hens in conventional and furnished cages.

We also found that the proportion of dirty eggs was significantly influenced by the layer line. The higher proportion of dirty eggs for the LSL layer line could have been due to the fact that dirt is easier to see on white-shelled eggs than on brown ones. It seems likely that some dirt on the brown shelled eggs was simply overlooked. The lower proportion of cracked eggs for the LSL layer line could be explained by the higher shell density of this line. Other studies also showed that the LSL layer line is characterized by excellent shell stability (Flock, 1992; Leyendecker et al., 2001b). These findings suggested that shell stability could be influenced by breeding, and Cordts et al. (2001) estimated heritabilities of between 0.22 and 0.53 for shell stability. Layer line significantly influenced bone strength. Body weight should be taken into consideration for the interpretation of different bone strengths, because these 2 traits are positively correlated. The hens of the LB layer line in this investigation were heavier than those of the LSL layer line, which explains the higher humerus strength of the former. These results agree with those of other investigations (Harner and Wilson, 1985; Knowles and Broom, 1990; Knowles et al., 1993). The rearing system also had an effect on bone strength. Both humerus and tibia strength were greater in hens reared in cages than in those reared on the floor. At the beginning of the laying period it was observed that hens reared on the floor were unwilling to move on the wire floor of the furnished cages. Therefore, it is possible that this lack of movement was the reason for the differences in bone

strength noted here. In another study, humerus strength was also higher in hens reared in cages than in those reared on the floor (Gregory et al., 1991).

The claws of the LB hens were shorter than those of the LSL hens due to differences in claw strength and growth rate. Claws of white hens grow faster and are stronger than those of brown hens and are thus more resistant to abrasion (Van Emous, 2003). Furthermore, brown hens show more scratching behavior (Van Emous, 2003). Layer line also had a significant influence on the occurrence of keel bone deformities. Brown hens had more keel bone deformities than the white hens. This result was confirmed in other studies (Abrahamsson et al., 1998; Wahlström et al., 2001). Differences in bone strength, the way of sitting on the perch, and body weight seem to be the reasons for differences in keel bone deformities between the layer lines (Appleby et al., 1992; Wahlström et al., 2001). However, in the present study, differences in body weight might be the most likely explanation for the differences in keel bone deformities, because the brown hens were significantly heavier than the white hens (data not shown).

## Housing Systems

Housing systems have a strong influence on egg production. In many studies egg production of hens housed in conventional cages is higher than of those housed in alternative systems such as aviaries, floor pens, or free range (Lange, 1996; Abrahamsson et al., 1996b; Horn and Suto, 1997; Tauson et al., 1999; Leyendecker et al., 2001a). In alternative housing systems, egg production is subjected to higher variations, making it less stable and predictable than in conventional cages. Nevertheless, there have been some studies in which egg production was found to be comparable in alternative housing systems and conventional cages (Abrahamsson and Tauson, 1995; Van Horne, 1996; Van Horne and Van Niekerk, 1998). Studies in different European countries have

shown that egg production in furnished cages is comparable with that in conventional cages (Smith et al., 1993; Abrahamsson et al., 1995; Abrahamsson and Tauson, 1997; Van Niekerk, 1999). Correspondingly, the present study confirmed reports that egg production in the furnished cages studied here was comparable with that in conventional cages. Furthermore it was shown that laying performances were greater in the Aviplus furnished cage, especially in the groups with 20 hens, than in the 2 Eurovent systems.

The proportion of dirty eggs is often higher in alternative housing systems than in conventional cages (Loick, 1996; Leyendecker et al., 2001a) due to contaminated nest boxes or the depositing of eggs in the litter. Comparisons of furnished and conventional cages showed that there were fewer dirty eggs in furnished cages (Abrahamsson and Tauson, 1997). In the present study the highest proportion of dirty eggs was found in the Eurovent 625A system, especially in the groups of 10 hens. One possible reason for this may be dirty nest boxes if they are not used for their intended purpose.

The high proportion of cracked eggs is sometimes a problem in furnished cages (Van Niekerk and Reuvekamp, 1999). In furnished cages the area in which eggs are laid is small, and collisions can occur between eggs in the nest box, which in turn can damage the eggshell (Wall et al., 2002). On the other hand, Leyendecker (2003) found a lower proportion of cracked eggs in furnished cages than in conventional cages. In the present investigation the overall proportion of cracked eggs was low. There were more cracked eggs in the groups with 60 hens than in the other group sizes. This finding might have been due to the larger group size, which results in more eggs in the nest box and/or on the conveyor belt at the same time.

Feed conversion can be influenced by the housing system. Feed conversion is poorer in aviary and free-range systems than in cages (Hughes et al., 1985; Van Horne and Van Niekerk, 1998). In alternative housing systems, hens have to use some of their energy for heat production (Preisinger, 2000) and movement, because of lower stocking densities and sometimes lower temperatures in these systems. This leads to higher feed consumption and unfavorable feed conversion. In the present investigation there was no significant difference in feed conversion among the housing systems. Although it might have been expected that feed conversion would have been unfavorable in groups of 40 and 60 hens because of the larger floor space available, this was not found to be the case.

Eggshell thickness and density were lower in the Aviplus furnished cage than in the 2 Eurovent systems. This finding might have been associated with the higher egg production in the Aviplus system. Although the hens laid more eggs, feed consumption was only slightly higher. Thus, there was less calcium available to the hens in this system for egg shell formation, which could have led to inferior egg shell quality. Nevertheless this loss in quality was not high enough to affect shell break-

ing strength or the proportion of cracked eggs. If the shell breaking strengths of the present investigation are compared with references in the literature for shell breaking strengths of eggs from conventional cages (Leyendecker et al., 2001b), the eggshells of the furnished cages were stronger than those from conventional cages.

The housing system also has a strong effect on the development of osteoporosis. In conventional cages the movement of hens is very restricted. This lack of exercise leads to a severe loss of bone content, resulting in a higher susceptibility to fracture. There are many studies in which bone breaking strength has been found to be lower in conventional cages than in alternative systems such as aviary systems or floor pens (Knowles and Broom, 1990; Newman and Leeson, 1998; Leyendecker et al., 2001c). The increased exercise in alternative housing systems leads to improved bone strength (Fleming et al., 1994). Nevertheless, the incidence of fractures due to accidents is higher in alternative housing systems (Gregory et al., 1990). It should be possible to improve bone strength in furnished cages by providing more floor space and by incorporating perches. Different studies have shown that it is possible to increase bone strength in cages by providing perches (Hughes and Appleby, 1989; Barnett et al., 1997). In a comparison of bone strength in conventional cages, furnished cages, and an aviary, humerus strength was found to be significantly higher in furnished cages than in conventional cages, although it was not as high as that of the aviary (Leyendecker, 2003). In the present investigation, humerus strength was found to be greater in the Aviplus system than in the Eurovent 625a system, but there was no difference in tibia strength among the housing systems. These slight differences might be explained by different degrees of acceptance and usage of the perches in the different housing systems. Bishop et al. (2000) found negative correlations between shell stability and bone strength. It therefore appears possible that hens in the Aviplus system used their calcium for bone remodeling rather than for eggshell formation, because shell density was significantly lower in the Aviplus system than in the other systems. Nevertheless, both humerus and tibia breaking strengths from all 3 systems investigated here were clearly higher than those from another investigation, in which conventional cages were analyzed (Leyendecker et al., 2001c). Furthermore, the humerus strengths of the LB hens in the present investigation were comparable with those of hens from aviaries (Leyendecker et al., 2001c).

Claw length is influenced by the housing system. In alternative systems hens have the opportunity to walk on a structured surface and to scratch with their claws in the litter, which prevents excessive claw growth. In contrast, conventional cages provide no opportunity for the hens to shorten their claws. Therefore claws are longer in conventional cages, which can lead to a higher risk of injuries. According to a EU directive (CEC, 1999), furnished cages must be equipped with suitable claw shortening devices. In the present investigation the

claws of the hens housed in the Aviplus system were shorter than those of hens from the other systems. This might have been due to the different claw shortening devices in the furnished cages. The Eurovent 625a system contained 1 abrasive block per cage, the Eurovent 625A system had adhesive strips, and the Aviplus system had 2 abrasive blocks per cage or 1 perforated metal plate. The shortest claws were found in the cages with 2 abrasive blocks per cage (data not shown), which were present only in the Aviplus system.

Keel bone deformities can be affected by housing systems. In alternative housing systems there is a high risk of traumatic keel bone fractures when perches are approached incorrectly, whereas in conventional cages most keel bone deformities are due to osteoporosis (Keutgen et al., 1999). In furnished cages keel bone deformities are caused by the intensive use of perches (Wahlström et al., 2001), particularly frequently in cages with high stocking densities. With rising stocking density it becomes increasingly difficult for the hens to change their position on the perches, which leads to an increased pressure on a certain part of the keel bone (Tauson and Abrahamsson, 1994). There is a higher incidence of keel bone deformities in furnished cages than in conventional cages (Tauson and Abrahamsson, 1994; Abrahamsson et al., 1996a). The incidence of keel bone deformities in the present study was nearly 33% (data not shown), which makes it clear that this is a serious problem in furnished cages. Hens from the Eurovent 625a system had fewer keel bone deformities than hens in the other systems. It appeared that hens in the Eurovent 625a system used the perches less, which led to fewer keel bone deformities. This finding would be in accordance with the lower humerus strength in the system Eurovent 625a, because the use of perches also positively influences bone breaking strength (Barnett et al., 1997).

## Conclusions

The results of the present investigation showed that high laying production and satisfactory egg quality can be achieved in furnished cages. From an economic point of view, the furnished cage seems to be a worthwhile alternative to existing housing systems for laying hens. Moreover, the furnished cage offers certain health and welfare benefits. More floor space and the incorporation of perches led to a significant increase in bone strength in comparison with conventional cages. In some cases bone strengths were comparable with those of hens kept in aviaries. Nevertheless a number of problems remain to be solved, such as the high incidence of keel bone deformities and various ethological aspects not discussed in the present study. Generally, furnished cages could become important in the future laying hen husbandry if certain features are developed further. Nevertheless, it must be kept in mind that all aspects investigated here can be strongly influenced by the management of the housing systems.

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