56th Annual Meeting of the European Association for Animal Production, Uppsala, Sweden, June5th –8th, 2005, Session 25, CSLMP5

Feeding of layers of different genotypes in an organic feed environment

G. Lagerkvist[1] , K. Elwinger[2] and R. Tauson[2] . Department of Animal Breeding and Genetics[1], Department of Animal Nutrition and Management[2], Swedish University of Agricultural Sciences (SLU), S-750 07 Uppsala, Sweden. Corresponding author: Gabrielle.Lagerkvist@hgen.slu.se

Abstract

Prohibition on use of synthetic amino acids, GMO or products derived there from, and limited access to approved raw materials restrict possibilities to compose a nutritionally balanced diet in organic egg production. Differences exist between genotypes of birds to resist feather pecking and cannibalism. An experimental genotype (SH), selected for egg production for over 25 generations on low protein diet, was tested against two common commercial hybrids; LSL (Expt. 1) and Hyline (Expt. 2). The birds were fed a control or organic diets, with different sources of protein. LSL and Hyline had a higher production (20-76/80 weeks) than SH, but production deteriorated more severely in the former genotypes when fed the low protein/methionin diet (2 g methionine/kg). Plumage condition was better in SH, compared to LSL. In Expt. 2, feathering was almost complete throughout the whole cycle. However, all genotypes were inferior when fed the low protein diet. SH used the outdoor runs more than LSL, as well as the groups fed the low protein diets, probably due to an increased feed scavenging. On the contrary, Hyline used the outdoor-area twice as much as SH. The experiments showed differences between genotypes but all performed better on a diet with a high protein quality. Consequently, it is difficult to fulfil KRAV´s standards of 100% organic feed stuffs, without supplements with synthetic methionine or fish meal.

Introduction

Prohibition on use of synthetic amino acids, GMO or products derived there from, and limited access to approved raw materials restrict possibilities to compose a nutritionally balanced diet in organic egg production. The main challenge for poultry nutritionists is to fulfil the protein requirement, especially regarding the amino acid methionine. Shortage of methionine is known to reduce production in singel hen cages (Schutte *et al*, 1994). In floor systems a methionine deficiency may also cause severe welfare problems such as feather pecking and cannibalism (Tiller, 2001). It is known that differences exist between genotypes of birds to resist feather pecking and cannibalism (Hughes and Duncan, 1972; Odén *et al.*, 2002; Wahlström *et al.*, 1998). In many countries beak trimming is practised to prevent feather pecking and cannibalism, but this is not allowed in Sweden, Finland and Norway.

The aim of the present study was to study effects of a low dietary protein supply on performance of three different layer genotypes. Two common commercial hybrids, Lohmann Selected Leghorn - LSL (Expt.1) and Hyline (Expt. 2), were tested against an experimental genotype, SLU-1329 (SH, “Swedish Hen”), selected for egg production for over 25 generations on a low protein diet (13,5 % cp, 0,23 % met, 0,59% lys). The SH is a cross-bred of Rhode Island Red and White Leghorn experimental strains, founded in the 70´s. The selection procedures and formation of the experimental strains were described by Liljedahl & Weyde (1980).

MATERIAL AND METHODS

Experiment 1

Birds and housing

The experiment comprised 600 hens of each genotype LSL and SH. The birds were reared from day old in the same environment on the same farm, but kept in separate groups. At 16 w of age the pullets were transferred to the laying house. The animals were housed i 12 identical pens of the Marielund aviary system (Abrahamsson & Tauson, 1995). The Marielund system consists of three welded wire tiers where the two lower tiers have feed troughs and the top resting tier has perches. Nipple drinkers were available on all tiers. Single nests were placed on three levels on the wall. Wood shavings were used in the litter area on the floor. Manure was removed twice a week by belts under the tiers. Each pen measured 3.0 x 5,8 m.

The birds were housed in groups of 100 (6 hens per m^2). From 16 w they were receiving 9 h of light per day, which was successively increased to 14 h at 24 w. Windows were initially covered and day light let in successively, beginning at w 24. The nests were kept closed until 17 w. From 18 w the nests were opened and closed ½ h before light was turned on and off, respectively. The birds had access to an outdoor-area (26 x 3 m) from 25 w (October 2001) corresponding to 0,8 m^2 per hen; i.e. not fulfilling the standard for organic production, stating that each hen shall have access to at least 4 m^2 (KRAV standards, January 2005). When morning outdoor temperature exceeded +3°C the birds had access to the open air run from 8 am to 4 pm. The birds were vaccinated against coccidiosis, Mareks disease, infectious bronchitis and avian influenza. They were slaughtered at 76 w of age (October 2002).

Diets and Feeding

The pullets were fed a grower's diet without coccidostats until 16 w, when the experimental diets were introduced. The hens were fed four different diets according to Table 1. Each diet was fed to two groups of each hybrid. Diet A was a control diet containing extracted soybean meal. Diets B, C, and D were based on feedstuffs supposed to be available to grow and process according to standards for organic egg production. Diet B included fishmeal and was supposed to satisfy the requirement of all essential amino acids. Diet C was based on vegetable feedstuffs and lower in methionine content than diets A and B. The diet D had a nutrient content similar to that used in the selection program of the SH bird. Diets C and D were fed to the same groups, C from 16 to 24 w and D from 25 weeks of age.

Recording of data and statistical analysis

Egg production, number of misplaced eggs (on litter floor, wire tires and outdoors), feed consumption and mortality were recorded daily. Dead birds were autopsied at the National Veterinary Institute, Uppsala. Egg weight was recorded once a week. Egg content of DM, albumen height, yolk colour (using La Roche scale), shell deformation (using a load of 500 g), shell thickness (using a micrometer), blood and meat spots were all determined on 10 eggs of each pen at 39, 50 and 72 w.

The integument of 20 birds in each group was scored at 40 and 58 weeks of age according to Tauson *et al*. (1984). Neck, breast, back, wings, tail and cloaca were separately scored on a 4 point scale (1=worst and 4=best). Scores were added in order to get a complete plumage condition score for the whole body (6-24 points). The birds were also weighed on these occasions.

Table 1. Composition and calculated nutrient content in rearing and experimental layer diets.

	Starter 0-6 w	Grower 6-16 w	A 16 w-	B 16 w	C 16-24 w	D[1] 25 w-
Barley, %	38.90	41.75	21.36	24.0	13.0	20
Wheat	15.00	20.00	30.00	30.0	30.0	30
Oats	20.00	20.00	15.00	24.0	21.0	18.7
Lucerne meal	0.00	0.00	3.60	3.5	3.5	3.5
Soybean meal	16.00	8.00	14.50	0.0	0	0.0
Fishmeal	0.00	0.00	0.00	5.0	0	0.0
Rapeseed meal	5.00	5.00	0.00	0.0	0	0.0
Potato prot. Conc. (79% cp)	0.00	0.00	0.00	4.0	5.0	0.0
Rapeseed cake (32% cp)	0.00	0.00	0.00	0.0	7.5	7.5
Peas	0.00	0.00	0.00	0.0	10.0	10
Vegetable fat (soap stock)	1.40	1.40	4.50	0.0	0.0	0.0
Vitamine premix	1.00	1.00	1.00	1.0	1.0	1.0
Calcium carbonate	1.00	1.30	8.00	7.8	8.0	8.0
Salt	0.30	0.30	0.30	0.2	0.3	0.3
Dicalcium phosphate	1.30	1.20	1.50	0.5	0.7	1.0
Methionine	0.10	0.05	0.18	0.0	0.0	0.0
Lysine-HCL	0.00	0.00	0.06	0.0	0.0	0.0
Sum	100.00	100.00	100.00	100.0	100.0	100.0
Calc. nutrient content						
ME MJ/ kg	11.1	11.3	10.8	10.8	10.6	10.5
Protein, g/kg	177	160	160	169	169	135
Lysine	8.8	6.8	8	8.7	8.8	5.9
Methionine	3.8	2.9	4.3	3.7	3.1	2.3
Met+cys	7.4	6.2	7	6.7	6.5	5.1
Fat	41	40	66	31	37	35
Linoleic acid	12.8	12.3	15.5	10.4	11.9	11.7
Starch	384	419	350	387	362	391
Sugar	43	49	49	37	38	41
Crude fibre	52	45	42	43	52	52
Ca	9.1	9.9	36	35	35	35
P-tot	6.5	6.1	6.1	5.9	6	5.6
P-av	3.7	3.5	3.9	3.4	2.9	3.2
Na	1.6	1.6	1.5	1.6	1.7	1.7
Xantophyll, mg/kg	0	0	10	9.8	10	10

[1] D was given to former C groups from 25 weeks of age

Multi-factorial analyses of variance were performed using the GLM procedure of SAS software (SAS Institute Inc.,1989). All factors were regarded as fixed and the residual standard deviation was used as a measure of random variation.

Experiment 2

Birds and housing

The experiment comprised 600 hens of each genotype Hyline and SH. The pullets were reared from one day old in cages (70 x 60 cm), 32 birds per cage. At 6 w of age they were transferred to the laying house. They were housed in the same 12 identical pens of the Marielund aviary system as described in Expt. 1. The first days the birds were restricted to the bottom tire. Then movements between floor and first tire and between first and second tire were facilitated by wire netting ladders. They had access to the outdoor-area from 18 w (Late June 2003), and on the consecetutive spring from May 5. The birds were vaccinated against coccidiosis, Mareks disease and avian encephalomyelitis.

The birds had only been exposed to artificial light during the first 14 w (8 am – 4 pm). Day light was then let in successively and from 18 w the birds were exposed to natural diurnal photoperiod, but protected from direct sun light.

Diets and feeding
The hens were fed a grower's diet without coccidostats until 15 w, when the experimental diets were introduced. The hens were fed four different diets according to Table 2.

Table 2. Composition and calculated nutrient content in rearing and experimental layer diets. From 37 w methionine supplement was removed (C-) from one group of each genotype on C feed.

	Starter 0-6 w	Grower 6-15 w	A 15 w-	B 15 w-	C+/C- 15/37 w-
Wheat, %	10.50	12.63	24.26	15.00	15.00
Barley	25.00	25.00	22.00	27.15	9.45
Oats	18.00	20.00	15.00	20.00	10.00
Wheat middlings				5.00	2.00
Maize gluten meal				5.00	
Lucerne meal	5.00	5.00	3.60		3.20
Soybean meal			19.00		
Rapeseed cake (32% cp)	10.00	9.00		15.00	15.00
Peas	20.00	20.00			35.00
Potatoe prot. Conc (79% cp)	8.00	5.00		2.50	
Rapeseed oil			4.70		
Calcium carbonate	0.90	0.70	8.50	8.00	7.80
Salt	0.30	0.27	0.30	0.25	0.25
Dicalcium phosphate	1.30	1.40	1.40	1.10	1.10
Vitamine premix	1.00	1.00	1.00	1.00	1.00
DL-methionine			0.16		0.20/0
L-lysine HCl			0.08		
Sum	*100.00*	*100.00*	*100.00*	*100.00*	*100.00*

Calc. nutrient content

ME MJ/ kg	11.5	11.4	11.1	11.0	10.5
Protein, g/kg	194	172	158	156	150
Lysine	11.8	10.0	8.3	6.4	8.7
Methionine	3.5	3.0	3.9	3.0	4.0/2.0
Met+Cys	7.4	6.6	6.8	6.5	6.9
Fat	55	52	68.1	67.5	60.5
Linolic acid	12.9	12.8	18.1	18.4	14.3
Starch	363	384	331	324	334
Sugar	33	34	47	25	40
Crude fibre	48	48	45	64	64
Ca	10	9.3	38	35	35
P tot	7.8	7.4	6.0	6.0	6.0
P av	4.1	4.1	3.7	3.3	3.3
Na	1.9	1.7	1.6	1.6	1.5
Xantophyll, mg/kg	15	15	10.1	14.5	10.0

Each diet was fed to two groups of each hybrid. From 37 w methionine supplement was removed (C-) from one group of each genotype on C+ feed.

Recording of data and statistical analysis

Data was collected and statistical analyses carried out as described in Expt. 1. Egg quality was determined on 10 eggs of each pen at 35, 50 and 70 w. Birds were weighed and feather status subjectively judged penwise before slaughter at 80 w (September 2004). The number of hens in the outdoor-area of each pen was counted twice a day, approximately at 9 am and at 3 pm. Birds location in the pen was recorded on 8 occasions in July 2003, once an hour from 6 pm to 6 am. The number of hens on perch, floor or litter area was counted or estimated in each pen.

RESULTS

Experiment 1

Production performance

Some mortality occurred in the beginning of the experiment mainly caused by peritonitis induced by a coli infection. Birds on the C/D diet had significantly lower body weights, higher feed consumption, inferior feed efficiency. Laying rate was not significantly affected by diet, but egg weight and egg mass production was reduced on the C/D diet (Table 3).

Unexpectedly SH, the heavier genotype, had a lower feed consumption than LSL, but the feed efficiency was higher in LSL except for birds on the C/D diet. There was no significant difference in egg weight between genotypes, but LSL had a higher laying rate and a higher egg mass production. The rate of misplaced eggs was significantly higher in SH.

Table 3. Production performance 20-76 weeks of age

Diet	**A**		**B**		**C/D**		**Stat analysis, p<**		
Genotype	**LSL**	**SH**	**LSL**	**SH**	**LSL**	**SH**	**Diet**	**Gen**	**Int**
Mortality, %	4.1	10	7.4	5.6	4.0	6.0	0.59	0.24	0.23
Live wt at 57 w, g	1736	1946	1697	1946	1554	1891	*0.04*	*0.001*	0.29
Feed consump., g/h/d	107	103	113	107	118	114	*0.002*	*0.02*	0.75
FCR, kg/kg	1.97	2.12	2.00	2.19	2.57	2.44	*0.001*	*0.001*	0.29
Laying percentage	86	77	90	78	85	78	0.43	*0.001*	0.41
Egg weight, g	63.5	63.0	62.6	62.8	58.5	59.7	*0.001*	*0.34*	0.07
Egg mass prod, g/h/d	54.6	48.7	56.4	48.9	49.9	46.8	*0.04*	*0.002*	0.30
Misplaced eggs, %	0.5	4.5	0.5	6.3	0.3	6.0	0.65	*0.002*	0.62

Egg quality

Albumen quality (H-units) was higher in LSL compared with SH whereas there was only a minor difference between birds fed diet C/D at 50 w (Table 4). LSL hens showed better shell quality characteristics than SH, but SH had higher yolk colour scores. The genotype significantly affected albumen quality, shell deformation, shell percentage, and yolk colour ($p<0.001$). The diet had significant effects on egg weight and albumen DM ($p<0.001$), and yolk colour ($p<0.003$). The period (39, 50 and 72 w) had highly significant effects on all parameters. No significant interaction effects were found between diet, genotype and period.

Plumage condition

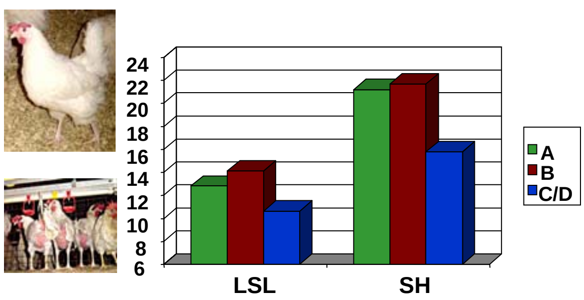
Regardless of diet the plumage condition of SH was significantly better than LSL. LSL also showed a higher incidence of skin peck injuries, both on comb and in the cloacae region. There were no significant differences in plumage condition between birds fed diets A and B, but C/D hens were significantly inferior compared with the others, and incidence of peck injuries in the cloacae/rear body parts was severe as scored at 58 w (Figure 1).

Table 4. Egg quality parameters at 39, 50 och 72 weeks of age

Diet		A		B		C/D	
Genotype		LSL	SH	LSL	SH	LSL	SH
Egg weight, g	39 w	65.3	64.2	61.7	60.8	58.7	59.2
	50	66.1	67.8	66.3	66.7	63.7	65.5
	72	69.1	68.7	68.7	75.2	64.7	66.1
Albumen quality, H-units[1]	39 w	98.6	86.5	96.7	86.4	96.6	88.0
	50	90.1	79.4	93.9	78.9	84.8	80.8
	72	86.8	77.1	83.7	75.2	86.9	73.6
Albumen DM, %	39 w	12.3	12.5	12.4	12.3	12.0	12.2
	50	12.0	11.6	12.0	12.2	12.2	11.5
	72	11.5	11.3	11.7	11.3	10.9	11.1
Shelll deformation, 10^{-2} mm	39 w	68.0	68.7	68.1	71.1	64.2	68.8
	50	73.7	75.5	78.5	79.4	70.0	84.0
	72	82.6	83.4	77.3	86.1	83.4	104.3
Shell percentage	39 w	9.2	9.1	9.4	8.9	9.5	9.2
	50	8.7	8.6	8.6	8.3	9.0	8.1
	72	8.2	8.1	8.5	8.0	8.5	8.0
Yolk colour, scores[2]	39 w	5.1	5.2	5.0	5.6	5.3	5.6
	50	6.5	6.7	6.3	7.1	6.3	7.4
	72	5.5	6.2	6.1	6.4	6.4	6.8

[1] Measure of albumen height corrected for egg weight (Haugh, 1937)
[2] La Roche 15-scores scale

Figure 1. Plumage condition at 58 weeks of age.



Experiment 2

Production performance

Hyline, like LSL, generally had a better production than SH (Table 5). However, on C- feed the two genotypes had the same egg mass production. Unexpectedly, SH had a higher laying percentage than Hyline except for groups on A feed. Diet did not seem to affect laying percentage but egg weight was reduced on C- feed. SH had a higher rate of misplaced eggs than Hyline, but performed better better than in Expt. 1.

Some mortality occurred during the very last weeks of the experiment in the Hyline group on C- feed. This was mainly caused by peritonitis and salpingitis, but starved hens and cannibalism were also observed. Hyline fed on C- feed had also lost much weight at the end of the experiment.

Table 5. Production performance 20-80 weeks of age

Diet	**A**		**B**		**C+**		**C-**		**Stat analys, p<**		
Genotype	**Hyl**	**SH**	**Hyl**	**SH**	**Hyl**	**SH**	**Hyl**	**SH**	**Diet**	**Gen**	**Int**
Mortality, %	3.5	7.4	5.0	5.4	4.0	8.9	17.8	3.0	0.27	0.60	*0.03*
Live weight at 80 w	1750	1770	1730	1680	1790	1640	1540	1680	0.06	0.74	0.08
Feed consump., g/hd	110	109	111	106	112	109	110	112	0.41	0.21	0.21
FCR, kg/kg	2.22	2.31	2.22	2.26	2.30	2.28	2.43	2.48	*0.01*	0.06	0.28
Laying percentage	79.9	78.7	81.9	82.8	80.0	85.1	78.5	82.3	0.07	*0.05*	0.11
Egg weight, g	62.3	59.9	61.3	57.0	60.7	56.3	57.6	55.0	*0.001*	*0.001*	*0.03*
Egg mass prod., g/h/d	49.8	47.1	50.2	47.1	48.6	47.9	45.2	45.3	*0.02*	*0.02*	0.13
Misplaced eggs, %	0.8	3.9	0.9	2.8	1.1	2.2	1.3	2.4	0.73	*0.02*	0.50

Egg quality

Egg weight, albumen H-units and DM were significantly higher in Hyline ($p<0.001$), which in contrary to the LSL in Expt. 1 showed a higher yolk pigmentation than SH ($p<0.005$). Diet significantly affected egg weight ($p<0.002$) and yolk colour. ($p<0.001$).

Table 6. Egg quality parameters at 35, 50 and 70 weeks of age

Diet		**A**		**B**		**C+**		**C-**	
Genotype		**Hyl**	**SH**	**Hyl**	**SH**	**Hyl**	**SH**	**Hyl**	**SH**
Egg weight, g	35 w	62.6	56.2	60.7	56.7	61.5	55.2	58.9	55.2
	50	66.3	63.7	67.4	58.8	65.6	60.9	62.6	57.7
	70	68.1	65.1	69.1	60.9	66.9	62.4	69.9	59.7
Albumen quality, H-units[1]	35 w	95.2	88.9	96.4	89.0	97.0	88.0	95.0	86.7
	50	88.6	77.7	88.0	82.2	87.8	73.2	94.5	80.4
	70	84.3	69.6	82.6	73.3	79.8	71.8	84.3	72.4
Albumen DM, %	35 w	13.2	12.6	13.5	12.4	13.3	12.6	13.4	12.4
	50	12.8	12.2	13.2	12.2	12.9	12.0	12.5	11.1
	70	12.4	10.7	12.1	11.1	12.4	11.2	12.0	10.8
Shell deformation, 10^{-2} mm	35 w	70.8	74.1	70.4	74.1	73.2	67.7	62.9	75.2
	50	69.8	69.6	70.6	74.8	74.6	72.4	70.0	76.1
	70	92.3	87.1	80.3	82.2	73.1	74.7	73.9	88.6
Shell percentage	35 w	8.3	9.0	8.8	8.8	8.5	9.0	9.0	8.8
	50	8.7	8.9	8.6	8.5	8.4	9.0	8.8	8.5
	70	7.6	7.9	8.0	8.1	8.3	8.3	8.2	7.9
Yolk colour, scores[2]	35 w	6.4	6.3	9.0	8.8	7.1	6.9	7.1	6.7
	50	6.1	5.6	8.1	7.8	7.0	6.8	7.1	6.9
	70	7.6	6.4	8.8	8.4	7.1	7.1	7.2	7.3

[1] Measure of albumen height corrected for egg weight (Haugh, 1937)
[2] La Roche 15-scores scale

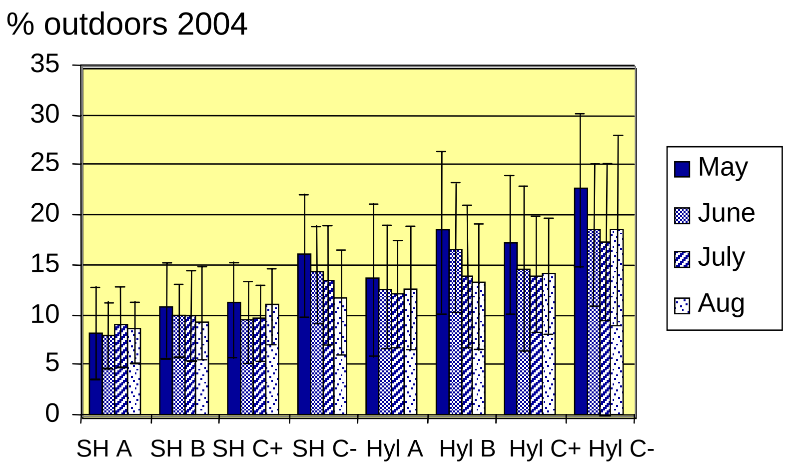
Significant differences in shell characteristics were not observed, neither between genotypes or diets. The period (35, 50 and 70 w) had highly significant effects on all parameters ($p<0.001$). No significant interaction effects were found between diet, genotype and period.

Use of open air run and nightly activity

Hyline used the outdoor-area about twice as much as SH (Figure 2). More birds of both genotypes were observed outdoors in the afternoon than in the morning. Most of them stayed within 5 meters from the opening. However, especially Hyline on C- feed used the whole outdoor-area, which had almost no grass cover at the end of the summer, while some other outdoor runs were completely covered by grass, except for near the opening. In this experiment feathering was almost complete throughout the whole cycle, but both genotypes were inferior at the end when fed the C-diet.

From 9 pm, at sun set, until 4 am, at sun rise close to 100% of the birds were seated on a perch. At 5 am only 40 % remained on a perch.

Figure 2. Percentage of SH and Hyline in the outdoor runs.



DISCUSSION

In Expt. 1 the birds seemed to try to compensate a low protein diet by increasing feed intake but in Expt. 2 feed intake was not influenced by diet. Diet did not affect laying percentage, but egg weight was markedly reduced on low protein/methionine diets. Total egg mass production seemed to be less influenced by diet in SH. Variation in production capacity is probably less expressed on a low protein diet. Most LSL eggs were laid in the nests whereas the rate of misplaced eggs was very high in SH. Some egg eating behaviour was observed in SH hens in Expt.1, which might have influenced records of production and feed intake. Also compared to Hyline in Expt. 1 SH had a higher rate of misplaced eggs.

Regardless of diet LSL had a higher frequency of feather pecking and peck injuries than SH hens, which agree with Wahlström *et al.* (1998) who studied the same hybrids.

Arvidsson (2002) investigated factors affecting the use of the outdoor runs in Expt. 1. A rather small proportion of the birds used the outdoor-area (4-17%). This corresponds with findings by Keeling *et al* (1988) and Bubier & Bradshaw (1998).

Keeling *et al* (1988) also showed that it is the same birds that use the outdoor-area daily. SH birds used the open air run significantly more than LSL and birds fed the low protein diet used the outdoor-area significantly more than hens fed the conventional feeds. Yolk colour scores tended to follow the rate of hens spending time outdoors.

On the contrary to LSL in Expt. 1, Hyline in Expt. 2 used the outdoor-area twice as much as SH, but also here the groups fed the low C- diet used the outdoor runs more frequently than the same genotype on other diets. This might be explained by an increased feed scavenging, in order to fulfil the protein requirements or an increase in activity due to hunger. Yolk pigmentation was also higher in Hyline eggs, the genotype spending the most time outdoors, but although diet significantly influenced yolk colour higher yolk scores were not observed in birds fed the C- diet. The higher pigmentation of B eggs was attributed to maize gluten, incorporated in this diet.

In conclusion it appears that birds favour production (number of eggs) and egg quality before feathering when fed low protein/methionine diets. There are important differences between genotypes in disposition to feather pecking. The use of outdoor area is influenced by diet protein/methionine content and responses may differ between genotypes.

REFERENCES

Abrahamsson, P. & Tauson, R. 1995. Aviary systems and conventional cages for laying hens. Effects on production, egg quality, health and birds location in three hybrids. Acta Agric. Scand. 45:192-203.

Arvidsson, Sara. 2002. Faktorer som påverkar utevistelsen hos värphöns. MSc Thesis no168. Department of animal nutrition and management, SLU. 34 p

Bubier, N. E. & Bradshaw, R. H. 1998. Movements of flocks of laying hens in and out of the hen house in four free-range systems. Br. Poultry Sci. 39:5-18.

Hughes, B.O. & Duncan, I.J.H. 1972. The influence of strain and environmental factors upon feather pecking and cannibalism in fowls. Br. Poultry Sci. 13:525-547.

Keeling, L., Hughes, B.O. & Dun P. 1988. Performance of free-range laying hens in a polythene house and their behaviour on range. Farm Building Progress. October 1988. 94:21-28.

KRAV standards January 2005. http://arkiv.krav.se/arkiv/regler/Standards2005EditionJanuary.pdf

Liljedahl, L.-E., & Weide, C. 1980. Scandinavian selection and crossbreeding experiment with laying hens. Results from the Swedish part of the experiment. Acta Agric. Scand. 30:237-260.

Odén, K., Keeling L., & Algers, B. 2002. Behaviour of laying hens in two types of aviary systems on 25 commercial farms in Sweden. Br. Poultry Sci. 43:169-181.

SAS Institute Inc.,1989. SAS/STAT User´s Guide. Version 6. 4th edition. Volume 2, Cary N.C., USDA, 846 pp.

Schutte, J.B., De Jong, B., & Bertram, H-L. 1994. Requirement of the laying hen for sulphur amino acids. Poultry Sci. 73:274-280.

Tauson, R., Ambrosen, T. & Elwinger, K. 1984. Evaluation of procedures for scoring the integument of laying hens – independent scoring of plumage condition. Acta Agric. Scand. 34:400-408.

Tiller, H. 2001. Nutrition and animal welfare in egg production systems. In: Proceedings of 13th European Symposium on Poultry Nutrition, WPSA, Blankenberge, Belgium. pp 226-232.

Wahlström, A., Tauson, R. & Elwinger, K. 1998. Effects on plumage condition, health and mortality of dietary oats/wheat ratios to three hybrids of laying hens in different housing systems. Acta Agric. Scand Sect. A – Animal Science 48:250-259.