**Diet x genotype interactions in different housing systems**

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**Abstract**

Some recent research of nutrition of laying hens in different housing systems is discussed. Causes of variation in productivity, mortality rate and cannibalism rate in aviaries revealed a strong effect of genotype and in brown birds differences may occur between beak-trimmed and intact hens. Diet x genotype interactions seem preferably to influence health criteria, whereas genotypes tend to react similar what concerns production characteristics. The content of insoluble fibre in the diet may influence feather-pecking behaviour, and oats has been shown to decrease the risk of feather-pecking whereas wheat had the opposite effect. In a "semi"-organic environment genotypes was found to behave significant differently to variations in the diet's methionine content and methionine supplementation preferably improved health criteria and less production in number of eggs.

**Introduction**

Housing of laying hens in Europe, as well as in many other parts of the world, is facing a tremendous change from being dominated by traditional cages to a variety of more animal kindly alternatives. This includes also so called furnished cages (Tauson, 2002).

For years white and brown genotypes have been selected and adapted to produce in cage systems, where they have very limited possibilities to express behaviours performed in the wild. During the cage era such characteristics may have developed out of control and differently in different genotypes. Therefore bird genotypes may rank differently in different housing environments what regards many important performance criteria such as social competence, aggressiveness and willingness to lay in nests. Also nutritional requirements may interact between the genotype and its environment. There are quite many recent investigations comparing genotypes in different housing systems, but data on research also considering nutrition effects are limited.

The aim of this presentation is to review some recent information discussing these matters. A special attention is given to some experiments carried out at "semi"-organic conditions.

**Genotypes and housing conditions**

It is well known that many brown genotypes are predisposed to feather pecking and cannibalism, especially if kept in floor systems and not beak-trimmed. This was for instance demonstrated by Abrahamsson et al. (1996) comparing a non beak-trimmed white and a brown genotype in different housing systems, and recently by Lücke et al. (2004) using a brown egg genotype. Damme (2004) tested six different brown genotypes in a conventional floor system and found, in all of them, huge differences in feathering condition between beak-trimmed and intact birds. Mortality was twice as high in intact birds (7.7 vs. 3.5) and there was a cannibalistic behaviour observed in two genotypes. The diets fed were not specified in these presentations. Differences in cannibalistic and feather pecking behaviour between brown and white egg layers have further been shown in the Swedish new technique testing programme (Odén et al., 2002). In a systematic review of mortality of laying hens in aviaries Aerni et al. (2005) concluded that causes of variation in productivity, mortality rate and cannibalism rate in aviaries revealed a strong effect of strain. They did not make any statement concerning white or brown genotypes, however. Further information about performance of genotypes in different production systems is available in the Danish efficiency control in poultry production (Fig 1. Det danske fjerkraeraad, 2005).

**Diets and housing conditions**

There is a lack of systematic studies of nutrition requirements of layers in different housing systems. Research seems mainly have been carried out with the ambition to control feather pecking and cannibalistic incidences in barn and free range hens.

In this context interest has been focused to feed structure. But feed structure is difficult to isolate and study independently due to interactions and confounding with other factors. For instance comparing mash and pelleted feeds involves also factors such as, raw materials (fibre composition), pelleting conditions (steam, temperature, dye size, cooling) and grade of fineness.

With this in mind Wahlstrom et al. (1999a, 1999b, 2001) investigated effects of feeding a crumbled diet compared with a mash diet using two genotypes (LSL and an experimental White Leghorn x Rhode Island Red genotype, SH) of laying hens kept in an aviary system. Birds fed the mash diet compared with those fed the crumbled diet had a significantly higher proportion of misplaced eggs and inferior FCR. The crumbled diet gave higher body and egg weight, higher egg mass production and a more intensive yolk colour. However, genotype affected production and egg quality traits the most. Interactions between diets and hybrids were found regarding the proportion of misplaced eggs, dirty eggs, egg weight, and FCR. SH hens had more misplaced and dirty eggs when feeding mash compared with crumbled pellets, whereas these parameters in LSL hens were little affected by diet. Egg weight of SH birds was not affected by diet but in LSL the egg weight increased when fed the crumbled diet. Higher concentration of lactic and acetic acid was observed in crops from crumble fed birds. In this experiment diet generally had little effect on plumage condition, health, and tonic immobility. However, birds fed the crumbled diet had significantly fewer problems with bumble foot than those fed the mash diet. Genotypes differed in most traits studied.

Aerni et al. (2000) recommended that laying hens should be provided with foraging material (they used long-cut straw) and be fed on mash in order to avoid problems with feather pecking.

Dietary fibre is commonly looked upon as water soluble - or water insoluble non-starch polysaccharides (NSP:s). Water soluble NSP:s have been studied extensively (Bedford, 1995; Bedford & Morgan, 1996; Iji, 1999; Montagne et al., 2003) and their anti nutritional effects on young birds are comparable well-known and today routinely neutralised by the use of feed enzyme supplements. The insoluble fraction has traditionally been regarded as a nutrient dilutant in feeds for monogastric animals. However, recent work carried out in Scandinavia and Australia indicates that insoluble fibre may have beneficial effects on nutrient digestion and intestinal functions, and also prevents outbreaks of cannibalism and feather pecking in laying hens (Hetland et al., 2004).

Oats contain more insoluble fibre than most other cereals used for poultry. Traditionally, in Scandinavia oats have been regarded as a valuable cereal for poultry. However, prize differences and the low ME content of oats will in feed optimisation processes favour incorporation of wheat, which today dominate the cereal part of poultry diets in Sweden. In Norway, on the contrary, the government economic regulation system favour incorporation of high quantities of oats, and a typical layer ration may contain ca 25 % of oats.

Valuating oats by ME content only will risk underestimating of its nutritional advantages. Al-bustany & Elwinger (1988) compared feeding of whole oats, barley, wheat and mixed cereal based diets to two genotypes housed in traditionally cages. They found that for both genotypes diets based on oats were superior to the other three diets with respect to egg production and feather condition, and there was no difference in FCR despite lower energy and protein content in the oats based diet.

Wahlstrom et al. (1998a) investigated the effects of different dietary oats/wheat ratios on production and egg quality. Two non-beak-trimmed genotypes were used, Lohmann Selected Leghorn (LSL) and an experimental WLxRIR (SH). The birds were housed in multi-floor aviary pens. Energy and protein content varied depending on feed ingredients but requirements of essential amino acids were in accordance with recommendations. Increased oats/wheat ratios caused increased feed consumption, egg mass production, egg weight, enhanced yolk pigmentation and increased dry matter in the excreta. A higher oats/wheat ratio also lowered the ME intake per kg egg produced as well as bird live weight. Production performance and egg quality characteristics were superior for LSL than the experimental genotype. However, for egg production, the hybrids reacted similarly to variations in the oats/wheat ratio. The feather condition, on the contrary, was not influenced (constantly good) what concerned the SH hens, but deteriorated in LSL hens as the oats/wheat ratio was decreased (Fig 1. Wahlstrom et al., 1998b). In an other experiment with two diets with smaller oats/wheat/barley variations there were no diet x genotype interaction effects, but non-beak-trimmed Lohmann Brown birds housed in conventional cages showed better plumage condition compared with those housed in aviaries, whereas LSL birds showed the opposite trend (Wahlstrom et al., 1998b).

Studies by Wahlstrom (1999) and Hetland & Svihus (2001) indicate that positive effects on health (feather-pecking, cannibalism) and production (starch digestibility) may be related to the hull fraction of oats.

**Diet x genotype interactions in organic production**

Organic farming continue to increase worldwide, being about 2% of agricultural land in Europe (Willer & Yussefi, 2004). More than 170,000 farms are run organically. In the EU organic egg production increased by about 7 % over the last decade (Windhorst, 2004). Today, in Denmark about 14 % of the egg production is organic (Det danske fjerkraerad, 2005), Sweden counts ca 6 % (Eurobusiness homepage, 2005). Currently in most countries (April 2005) the use of up to 20 % of non-organic components is allowed in the feed ration of organically certified poultry. The local Swedish KRAV-standards say 15 %. This derogation was supposed to be removed in August 2005, but a step-wise phasing out to 2011 was discussed in the EU-expert committee in the end of April 2005. It is important that the certification requirement only relates to feedstuffs of agricultural origin, meaning that unlimited quantities of fish meal may be used as long as harvesting and processing do not infringe to the basic organic standards. Formulating certified balanced diets without access to fishmeal or to certified maize gluten/and or potato protein is today very difficult.

In the organic standards synthetic methionine is classified as a feed supplement for stimulation of growth and production (NOSB, 2001). However, studies carried out by Elwinger and Wahlström (2000) with LSL hens showed that methionine supplementation primarily stimulated bird health, not production (Table 2), which was further shown in two following experiments with two genotypes in each. The same experimental genotype (SH) as mentioned earlier had been selected for over 25 generations on a low protein/methionine diet and was compared with LSL (Expt. 1) and Hyline (Expt. 2). Due to the selection history of SH she was supposed to be god in organic production. The hens were kept in 12 groups in a three-floor Marielund aviary system, each with access to an out run. The compositions of the experimental diets are shown in Table 3. The nutrient content of diet D in Expt. 1 corresponded to the diet in the genetic selection programme of SH. The level of sulphur aa in Diet C- Expt. 2 were similar to Diet D Expt. 1.

In both experiments (Tables 4 and 6) there were significant differences between genotypes in most criteria. Diet predominately affected egg weight, whereas number of eggs was less influenced. Low sulphur aa levels increased feed intake in Expt. 1, but not in Expt. 2, but FCR was worse in both. Mortality was not influenced neither by Diet or Genotype in Expt. 1. In Expt. 2, however, incidences of peritonitis, salpingitis and some cannibalism suddenly occurred during the last experimental period in Hyline receiving the methionine deficient diet.

Concerning integument, feather condition in Expt.1 was influenced both by Genotype and Diet, LSL was more feather pecked and showed more peck injuries than SH, and birds given the C/D feed concept was more feather pecked than the others (Table 5). Integument of birds in Expt. 2 was close to complete throughout the whole experimental period, but deteriorated slowly with time in C- birds (not shown in Table).

In both experiments there were significant differences between genotypes in most egg quality characteristics (Tables 5 and 7). Albumen dry matter content was lower in eggs from hens fed low protein/methionine diets. Albumen H-units and egg shell quality was not influenced by diet.

There were significant differences in the use of out runs between genotypes and between diets in both experiments, SH being more outdoors than LSL in Expt.1 (Figure 2) and Hyline more than SH in Expt. 2. Low protein/methionine diet implied more hens outside. This was special obvious in Expt. 2 where figure 3 shows the appearance of the pasture when used by different genotypes fed different diets. In general birds spent more time outside in Expt. 2 than in Expt. 1, but never more than 50 % of all birds in a group were found outside at any time in both experiments. On the C- diet Hyline birds in Expt. 2 completely grazed down the pasture. Similar differences between SH birds fed the different diets were found, but not as clear as shown by Hyline.

An important difference between genotypes is willingness to nest visits. This was clearly shown by differences in misplaced eggs, SH laying more eggs on the litter bed and in the net floors than both WL-genotypes. This implies the importance of the location of the laying nests to be attractive also to “lazy” birds. Misplaced eggs can easily end up in egg-eating, which was noticed in Expt. 1 in SH, which in turn may have influenced production and consumption records.

**Conclusions**

- Feather pecking and cannibalism is a problem preferably in brown genotypes housed in free range and barn systems, and beak-trimming is frequently practised in prevention when permitted.
- There is a lack of systematic studies of nutrition of hens kept in different housing systems.
- Differences between genotypes are often greater than differences caused by housing and nutrition.
- Diet x Genotype interactions seem to affect birds health and behaviour more than production performance.
- Use of oats may prevent feather pecking.
- Location of laying nests may attract genotypes differently.
- Laying hens seem to favour production of number of eggs before health criteria, and methionine supplementation primarily improves health criteria.

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Table 1. Danish efficiency control Dec. 2003 to April 15th 2005

| | White cage | Brown barn | Brown range | Brown organic | White organic |
|---|---|---|---|---|---|
| Period, days | 385 | 350 | 329 | 339 | 350 |
| Mortality; % | 5.4 | 12.1 | 8.4 | 12.3 | 9.5 |
| Laying % | 86.3 | 82.7 | 78.1 | 79.6 | 78.1 |
| Egg weight, g | 62.5 | 63.7 | 62.8 | 62.9 | 62.5 |
| FCR | 2.11 | 2.47 | 2.55 | 2.65 | 2.70 |
| Returns DKR/h and y | 37.2 | 62.5 | 74.1 | 102 | 98.7 |

Table 2. Mortality, production, FCR and live weight of hens fed a methionine deficient (-) 3.1 g/kg, and a methionine supplemented (+) diet, 4.3, g/kg.

| | - | + | p< |
|---|---|---|---|
| Mortality, % | 7.2 | 7.0 | 0.8 |
| Laying percentage | 84.2 | 83.2 | 0.50 |
| Egg weight, g | 62.5 | 62.4 | 0.7 |
| Egg mass, g/h/d | 52.7 | 51.9 | 0.3 |
| Kg egg per started hen | 21.2 | 20.8 | 0.3 |
| Feed intake, g/h/d | 114 | 109 | *0.001* |
| FCR, kg/kg | 2.17 | 2.09 | *0.005* |
| Live weight 35 w, g | 1635 | 1679 | 0.23 |
| 55 w, g | 1731 | 1763 | 0.47 |
| Plumage condition[a], 35 w, % | 64 | 82 | *0.001* |
| 55 w | 36 | 51 | *0.05* |
| Peck injuries[b], 35 w | 3.43 | 3.92 | *0.01* |
| 55 w | 3.22 | 3.62 | *0.01* |

[a] Percentage left of original plumage.
[b] According to a 4 point scoring system where score 1= serious injuries and score 4= without remark

Table 3. Diets composition

| Diet…. | | Expt. 1 A | B | C | D[1] | Expt. 2 A | B | C+/C- [2] |
|---|---|---|---|---|---|---|---|---|
| Oats | ,% | 15 | 24 | 21 | 18.7 | 15 | 20 | 10 |
| Other ingredients | | 70.26 | 67 | 56.5 | 63.8 | 65.76 | 57.5 | 39.8 |
| Soybean meal | | 14.5 | 0 | 0 | 0 | 19 | 0 | 0 |
| Fish meal | | 0 | 5 | 0 | 0 | 0 | 0 | 0 |
| Maize gluten meal | | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| Potato prot conc. | | 0 | 4 | 5 | 0 | 0 | 2.5 | 0 |
| Rapeseed cake | | 0 | 0 | 7.5 | 7.5 | 0 | 15 | 15 |
| Peas | | 0 | 0 | 10 | 10 | 0 | 0 | 35 |
| DL-Methionine | | 0.18 | 0 | 0 | 0 | 0.16 | 0 | (0.2) |
| L-Lysine_HCl | | 0.06 | 0 | 0 | 0 | 0.08 | 0 | 0 |
| Calc. nutrient contents | | | | | | | | |
| MJ ME/ kg | | 10.8 | 10.8 | 10.6 | 10.5 | 11.1 | 11.0 | 10.5 |
| Protein, | g/kg | 160 | 169 | 169 | 135 | 158 | 156 | 150 |
| Lysine | | 8 | 8.7 | 8.8 | 5.9 | 8.3 | 6.4 | 8.7 |
| Methionine | | 4.3 | 3.7 | 3.1 | 2.3 | 3.9 | 3 | 4.0/2.0 |
| Met+cys | | 7 | 6.7 | 6.5 | 5.1 | 6.8 | 6.5 | 6.9/4.9 |
| Fat | | 66 | 31 | 37 | 35 | 68.1 | 67.5 | 60.5 |

[1] Fed to C birds from 25 weeks of age

[2] Diet C+ supplemented with methionine C- not supplemented. C+ was fed from start to end of one group of each genotype and to 37 weeks of age to the other two groups, hereafter diet C- was fed was to these groups.

Table 4**.** Production performance 20-76 weeks of age (Expt. 1).

| Genotype | LSL | SH | LSL | SH | LSL | SH | Stat analys, p< | | |
|---|---|---|---|---|---|---|---|---|---|
| Diet | A | A | B | B | C/D | C/D | Diet | Gen | Int |
| Mortality. % | 4.1 | 10 | 7.4 | 5.6 | 4.0 | 6.0 | 0.76 | 0.28 | 0.26 |
| Feed intake. g/hd | 107 | 103 | 113 | 107 | 118 | 114 | *0.003* | *0.02* | 0.75 |
| FCR. kg/kg | 1.97 | 2.12 | 2.00 | 2.19 | 2.57 | 2.44 | *0.001* | *0.002* | 0.30 |
| Laying. % | 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 | 0.08 |
| Henday prod. g | 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 |

Table 5. Birds integument appearance 58 weeks of age and egg quality characteristics average off estimates at 39, 50 and 72 weeks of age Expt. 1.

| Genotype | LSL | SH | LSL | SH | LSL | SH | Stat. analysis p< | | |
|---|---|---|---|---|---|---|---|---|---|
| Diet | A | A | B | B | C/D | C/D | Diet | Gen | Int |
| Live weight, g | 1736 | 1946 | 1697 | 1946 | 1554 | 1891 | *0.04* | *0.001* | 0.29 |
| Plumage[1] | 12.8 | 21.2 | 14.1 | 21.7 | 10.6 | 15.8 | *0.01* | *0.001* | 0.35 |
| Peck injuries comb[2] | 3.4 | 3.5 | 3.2 | 3.6 | 3.1 | 3.7 | 0.83 | *0.008* | 0.24 |
| Peck injuries cloaqua[2] | 3.5 | 4.0 | 3.7 | 4.0 | 3.2 | 3.4 | *0.05* | 0.07 | 0.63 |
| Egg quality. | | | | | | | | | |
| Egg weight. g | 66.8 | 67.0 | 65.6 | 66.2 | 62.4 | 63.6 | *0.001* | 0.25 | 0.73 |
| Proportion of yolk. %[3] | 28.5 | 27.3 | 27.7 | 28.5 | 28.3 | 28.7 | 0.21 | 0.97 | *0.04* |
| Albumen height. H units[4] | 91.8 | 81.0 | 91.4 | 79.8 | 89.4 | 80.8 | 0.47 | *0.001* | 0.36 |
| Albumen dry matter. % | 11.9 | 11.8 | 12.1 | 12.0 | 11.7 | 11.6 | *0.02* | 0.28 | 0.99 |
| Shell deform. $10^{-2}$ mm | 74.8 | 75.9 | 78.5 | 78.9 | 71.1 | 80.1 | 0.70 | *0.002* | 0.09 |
| Shell weight. % | 8.7 | 8.6 | 8.6 | 8.3 | 9.0 | 8.1 | 0.73 | *0.002* | 0.10 |
| Yolk colour. Points[4] | 5.7 | 6.0 | 5.8 | 6.3 | 6.0 | 6.6 | *0.003* | *0.001* | 0.48 |

[1] Scale 6-24. where 24 is best preformance
[2] Scale 1-4. where 4=no ramarks.
[3] 50 weeks of age
[4] According to Haugh (1937)
[5] La Roche 15 point scale

Table 6. Production performance 20-80 weeks of age Expt 2.

| Genotype | Hyl | SH | Hyl | SH | Hyl | SH | Hyl | SH | Stat analysis p< | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diet | A | A | B | B | C+ | C+ | C- | C- | 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* |
| Slaughter lw., g | 1745 | 1770 | 1730 | 1680 | 1790 | 1640 | 1540 | 1680 | 0.06 | 0.74 | 0.08 |
| Feed intake. 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 % | 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* |
| Henday prod.. g | 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 |

Table 7 Egg quality characteristics, average of estimates at 35, 50 and 70 weeks of age Expt 2.

| Genotype | Hyl | SH | Hyl | SH | Hyl | SH | Hyl | SH | Stat analysis p< | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Diet | A | A | B | B | C+ | C+ | C- | C- | Diet | Gen | Int |
| Egg weight. g | 65.7 | 61.7 | 65.7 | 58.8 | 64.7 | 59.5 | 61.8 | 57.5 | *0.002* | *0.001* | 0.20 |
| Albumen H units[3] | 89.4 | 78.7 | 89.0 | 81.5 | 88.2 | 77.7 | 91.3 | 79.8 | 0.25 | *0.001* | 0.32 |
| Albumen d.m. % | 12..8 | 11.8 | 12.9 | 11.9 | 12.9 | 11.9 | 12.6 | 11.4 | *0.02* | *0.001* | 0.75 |
| Shell def. $10^{-2}$ mm | 77.6 | 76.9 | 73.8 | 77.0 | 73.6 | 71.6 | 71.0 | 79.9 | 0.37 | 0.21 | 0.24 |
| Shell weight. % | 8.4 | 8.6 | 8.5 | 8.4 | 8.4 | 8.8 | 8.7 | 8.4 | 0.61 | 0.30 | 0.12 |
| Yolk colour, points | 6.7 | 6.2 | 8.6 | 8.3 | 7.1 | 6.8 | 7.1 | 7.0 | *0.001* | *0.005* | *0.03* |

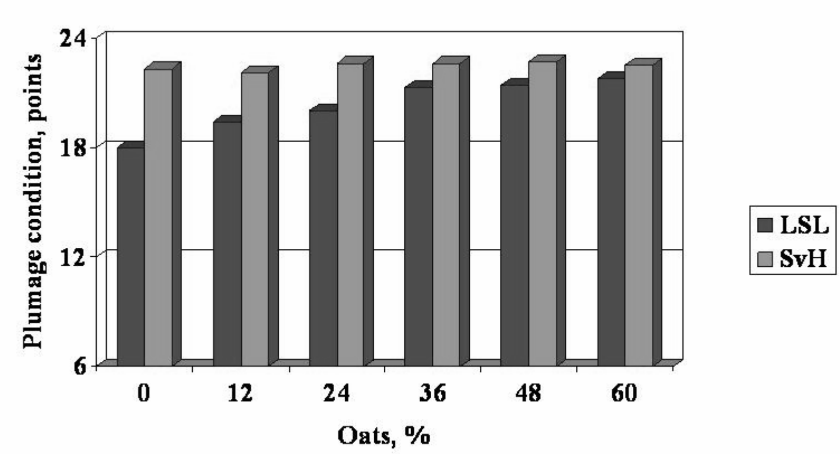

Figure 1. Effects of oats on plumage condition of two genotypes of laying hens, 6 points almost naked hens, 24 points complete feathering. (Wahlstrom et al., 1998b)

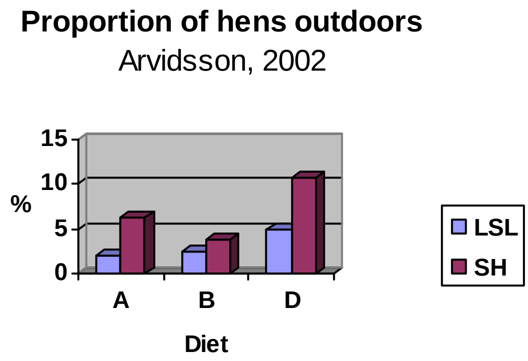


Fig.2 Use of outdoor area in Expt. 1

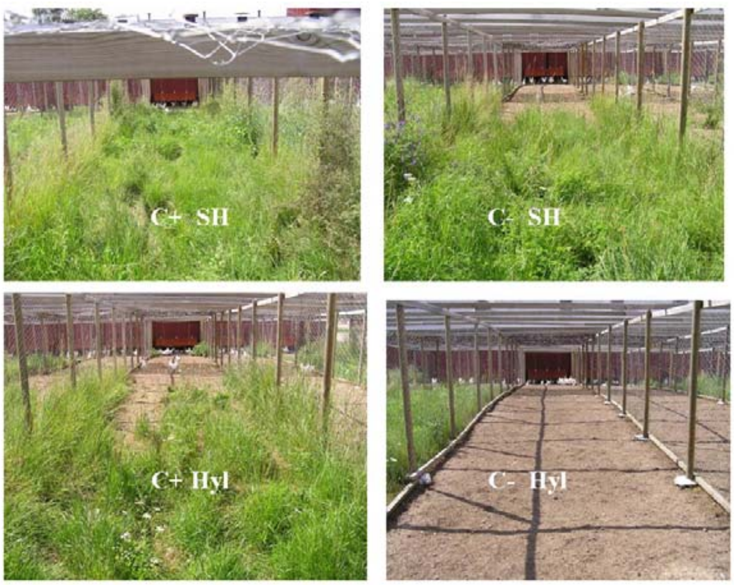


Fig. 3 Use of pasture in Expt. 2. Upper left: Diet C +, hen SH; Upper right: C-, SH; Down left: C+, Hyline; Down right: C-, Hyline