

# Alternatives for the battery cage system: a comparison of economic, environmental and societal performance

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The ban on the battery cage system in the European Union after 2012, mainly due to impaired hen welfare, forces farmers to change to alternative housing systems for laying hens. Large-scale introduction of more hen-friendly systems, however, requires a comparison of these systems on their economic, ecological and societal (EES) performance, i.e., on their contribution to sustainable development. The aim of this paper is to assess the EES performance of the battery cage system, and of the three most prevalent alternative housing systems in the Netherlands (i.e., the deep litter system with and without outdoor run, and the aviary system with outdoor run). To assess the EES performance of different egg production systems, the following indicators were quantified: labour income per full time equivalent; land and fossil energy use per kg egg produced; acidification, eutrophication and global warming per kg egg produced; animal needs index; mortality rate (21-68 wks); medicine use; deviations from the production curve; % farmers with physical complaints; % of second quality of eggs; and the *Salmonella enteritidis* status of the flock. In 2004, data were collected by visiting 16 farms with battery cages, 15 with a deep litter system without outdoor run, 17 with a deep litter system with outdoor run and 13 with an aviary system with outdoor run. Data were analysed statistically to reveal significant differences among production systems. Economic performance was best in the aviary system, whereas the battery cage system resulted in the best environmental performance. As expected, prerequisites to express natural behaviour were better in alternative systems, especially if hens had access to an outdoor run. On the other hand, alternative systems seem to run a risk for a higher mortality rate due to, e.g., cannibalism or a higher disease incidence. Between farm variation in mortality rate was high, consequently differences among systems were not significant. This large variation, however, also implies potential for improvement. Physical complaints of farmers and egg quality did not differ among production systems. Overall, it can be concluded that within the boundary of this study, the aviary system with outdoor run appeared the best alternative for the battery cage system.

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**Keywords:** animal welfare; laying hen; economy; environment; sustainability indicators

## Introduction

The ban on the battery cage system in the European Union after 2012, mainly due to impaired hen welfare, forces farmers to change to alternative housing systems for laying hens. A major issue in discussions about future animal production systems in the Netherlands, however, is the concern about sustainable development (LNV, 2005). Sustainable development is defined in many ways (Bell and Morse, 2003). In literature, it is agreed generally that sustainable development encompasses economic, ecological and societal issues. Large-scale introduction of more hen-friendly systems, therefore,

requires a comparison of these systems on their economic, ecological and societal (EES) performance, i.e., on their contribution to sustainable development. The aim of this paper is to use sustainability indicators to assess the EES performance of the battery cage system, and of the three most prevalent alternative housing systems in the Netherlands, i.e., the deep litter system with and without outdoor run, and the aviary system with outdoor run.

## Materials and methods

Mollenhorst and de Boer (2004) concluded that in order to assess the contribution of egg production systems to sustainable development, animal health and welfare, economics, environmental impact, ergonomics, product quality, consumer concerns and knowledge and innovation should be taken into account. The aim of this study was to assess the EES performance of various housing systems, by quantifying sustainability indicators (SIs) on a large number of farms for each system. Therefore, we did not incorporate consumer concerns, and knowledge and innovation in this study.

For each EES issue, we defined possible SI and subsequently selected final SI. Selection of SI was based on the following criteria (Mollenhorst et al., 2005b). Indicators have to be a) relevant, i.e., they have to express something about the issue, b) simple, i.e., they have to be understandable for users, and c) sensitive and reliable, i.e., they have to react to changes in the system, and different measurements must lead to the same outcome. Furthermore, d) it must be possible to determine a target value or trend, and e) data have to be accessible. In this study, we gathered data from finished flocks.

Table 1 shows such a qualitative assessment for all possible SI for the issue animal health and welfare, based on the ‘five freedoms’ that cover the animal’s basic welfare needs as defined by the Farm Animal Welfare Council (1992). These freedoms are 1) the freedom from hunger and thirst, 2) the freedom from discomfort, 3) the freedom from pain, injury or disease, 4) the freedom to express normal behaviour, and 5) the freedom from fear and distress. In accordance with these five freedoms, we considered animal health as an integral part of animal welfare.

**Table 1 Selection of sustainability indicators (SIs) for animal welfare.**

Possible SI	Relevant	Simple	Sens./ reliable	Trend/ target	Data	Final SI
Behavioural observations	+	-	+	-	-	-
Animal Needs Index	+	+	0	+	+	Y
Feather condition score	+	+	+	+	-	-
Disease incidence	+	+	+	+	-	-
Clinical observations	+	+	+	+	-	-
Mortality rate	0	+	0	+	+	Y
Deviations from the egg production curve	0	0	+	+	+	Y
Medicine use	0	+	0	+	+	Y

+ suitable; 0 moderately suitable; - not suitable; Y = Yes

Results from behavioural observations are the most relevant SI for freedom to express normal behaviour, but also for elements like freedom from discomfort, fear, and distress. Specialist, however, have to observe the hens during repetitive visits, which hampers data accessibility. Furthermore, wished and unwished behaviour are difficult to define, which hampers simplicity and the ability to define a target. An alternative SI is a scoring system, like the Animal Needs Index (ANI, Striessel, 1994). The ANI scores prerequisites for animal welfare by means of mainly environment-based and some animal-based parameters. Data on environment-based parameters, e.g., dimensions of the stable and facilities, like nests and perches, are easily accessible. Mollenhorst et al. (2005b) compared the ANI with behavioural observations to test its relevance and sensitivity. They concluded that ANI is an appropriate method for assessment of the between-system variation in laying hen welfare on a large number of farms. The ANI covers especially freedom to express normal behaviour, and only partly freedom from hunger and thirst, injury, and discomfort. The ANI divides the needs of an animal in eight categories: locomotion, feeding and drinking, social, resting, comfort and nesting behaviour, supplemented with management with respect to hygiene and care. In all categories different aspects

are scored and summed (Mollenhorst et al., 2005b). Many parameters, like available space, are expressed per hen. In this study, we used the maximum number of hens present at a time. Furthermore, all ANI-scores were based on information provided by the farmer.

The third possible SI for animal welfare is the feather condition score. Feather pecking and cannibalism are considerable problems in laying hens (Savory, 1995; Koene, 1997; Green et al., 2000; McAdie and Keeling, 2000; Pötzsch et al., 2001). They can lead to bald (featherless) patches and injuries, sometimes resulting in death. The feather condition score of Bilcik and Keeling (1999) scores damage to feathers and skin injuries and is, therefore, a good SI for freedom from discomfort, pain, injury, fear, and distress. Data accessibility, however, again is a problem, because it requires observations by specialists in the house.

Other possible SI for animal welfare are disease incidence and results from clinical observations. They are the most relevant SI related to freedom from diseases, but are difficult to measure. Disease incidence was not registered regularly on farm, and clinical observations have to be done by a specialist during repetitive visits, which hampers data accessibility. Immunological and pathological assessments, which could replace clinical observations, are not routinely performed and are, therefore, also not relevant as SI in this study. Van de Ven (2002) searched for general illness symptoms for poultry diseases. These, however, are hard to define, because different diseases show different symptoms. The only general symptoms are behaviour and zootechnical parameters. Zootechnical parameters are, e.g., mortality rate, egg production, and feed intake. Behaviour has been discussed earlier and was not selected as final SI. Relevance and sensitivity for the zootechnical parameters are moderate, because they only indicate severe stages of illness or other problems, like cannibalism. On the other criteria, however, they score well. Therefore, we selected mortality rate, a simple indicator for seriously impaired welfare, and 'deviations from the egg production curve', a more sensitive, but less simple indicator, as SI. We used cumulative mortality rates from 21 to 68 weeks of age to make a fair comparison of mortality rates for all flocks. In order to assess 'deviations from the egg production curve', we fitted a curve through the weekly production data of each flock. The last possible SI for animal welfare is medicine use, which also relates to freedom from diseases. Relevance and sensitivity of this SI are moderate, as it strongly depends on farmer's management how quickly he uses medicine. On individual farms, it is, therefore, not a good SI, as using no medicine in case of disease can hamper animal welfare. For assessment among housing systems, as in this study, however, medicine use is a useful SI, as higher average medicine use points at a (conceived) health risk. We only inventoried of the type of medicines used, because data on amount of medicines used were not always available.

Similarly, labour income per full time equivalent (FTE) was selected as SI to assess the economic performance of a farm. The environmental performance of a farm was assessed based on several SI deduced from a life cycle analysis of egg production, i.e., land and fossil energy use per kg egg produced; acidification, eutrophication and global warming potential per kg egg produced.

Besides animal health and welfare, egg quality and ergonomics were relevant societal issues with respect to sustainable development. Egg quality was measured using the % of second quality of eggs; and the *Salmonella enteritidis* status of the flock, whereas ergonomics was assessed by asking the farmers whether they had complaints during the last year (especially with respect to limbs and the respiratory system).

From February until August 2004, data were collected by visiting 16 farms with battery cages (BC), 15 with a deep litter system without outdoor run (DL), 17 with a deep litter system with outdoor run (DLO) and 13 with an aviary system with outdoor run (AO). Data were analysed statistically to reveal significant differences among production systems.

## Results and discussion

For each production system, the mean and standard deviation of SIs quantified are given in Table 2.

**Table 2 Mean and standard deviation (in brackets) of sustainability indicators (SI) quantified for battery cage (BC), deep litter (DL), deep litter with outdoor run (DLO), and aviary with outdoor run (AO).**

SI	BC	DL	DLO	AO
Animal Needs Index	36.9 <sup>A</sup> (4.5)	59.7 <sup>B</sup> (9.3)	96.7 <sup>C</sup> (9.4)	114.4 <sup>D</sup> (8.9)
Mortality rate (21-68 wks) <sup>1</sup>	5.5 <sup>a</sup>	9.3 <sup>ab</sup>	10.6 <sup>b</sup>	8.7 <sup>ab</sup>
Deviations production curve (% flocks)	14	25	73	27
No medicine use (% flocks)	81	73	41	31
Labour income/Full Time Equivalent	2855 <sup>a</sup> (32596)	15576 <sup>a</sup> (22600)	22828 <sup>a</sup> (19149)	86041 <sup>b</sup> (54016)
Acidification (SO <sub>2</sub> -eq/kg egg)	0.032 <sup>a</sup> (0.013)	0.057 <sup>c</sup> (0.012)	0.065 <sup>c</sup> (0.003)	0.042 <sup>b</sup> (0.006)
Eutrophication (NO <sub>2</sub> <sup>-</sup> -eq/kg egg)	0.25 <sup>a</sup> (0.04)	0.31 <sup>b</sup> (0.04)	0.41 <sup>c</sup> (0.03)	0.35 <sup>b</sup> (0.02)
Global warming (CO <sub>2</sub> -eq/kg egg)	3.9 <sup>a</sup> (0.3)	4.3 <sup>bc</sup> (0.5)	4.6 <sup>c</sup> (0.3)	4.2 <sup>ab</sup> (0.3)
Land use (m <sup>2</sup> /kg egg)	4.5 <sup>a</sup> (0.3)	4.8 <sup>ab</sup> (0.5)	5.7 <sup>c</sup> (0.6)	5.1 <sup>b</sup> (0.4)
Fossil energy use (kJ/kg egg)	1.3 (0.14)	1.34 (0.19)	1.39 (0.15)	1.37 (0.11)
Complaints related to poultry (% farmers)	6	20	6	15
Coughing and sneezing fits (%)	13	13	24	8
% flocks > 10% 2 <sup>nd</sup> quality eggs	33	17	6	0
% Flocks contaminated S.E.	0	0	6	0

<sup>1</sup> Geometric means instead of arithmetic means.

<sup>A,B,C,D</sup> different superscripts in the same row differ significantly ( $P < 0.001$ ; Bonferroni)

<sup>a,b,c,d</sup> different superscripts in the same row differ significantly ( $P < 0.05$ ; Bonferroni)

### *Animal health and welfare*

Average ANI scores ranged from 37 points for BC to 114 points for AO, with all mutual differences among housing systems being significant (Table 2;  $P < 0.001$ ). Higher scores for DLO and AO were determined mainly by the availability of an outdoor run. Other important determinants for differences among housing systems were the number of hens per square meter, and availability of facilities like litter, perches and nestboxes.

Mortality rates differed considerably within and among housing systems (Table 2). They were log-transformed before analysis to approach a distribution with equal variances. The geometric mean of mortality rates ranged from 5.5% for BC to 10.6% for DLO. Because the variation within housing systems was high, only BC and DLO differed significantly ( $P < 0.05$ ). Extremely high mortality rates are caused mostly by cannibalism, which was also the case for the three highest values in DL in this study. Lower mortality rates in systems with outdoor runs could be caused by better opportunities to escape from attacks. This was not supported by our data.

Concerning 'deviations from the egg production curve', DLO performed worse than the other systems, with 73% of the flocks having deviations in DLO and 27% or less in all other systems (Table 2). Herewith, the influence of housing system on the percentage of flocks with deviations from the production curve was significant (Fisher's exact test:  $P < 0.05$ ).

No medicines were used in BC and DL in respectively 81% and 73% of the flocks, compared to 41%, respectively 31% in DLO and AO (Table 2). Anthelmintics (used in more than 50% of all flocks that had access to an outdoor run) caused the differences in medicine use, whereas other medicines were used in similar amounts. The relationship between housing system and 'using no medicine' was significant (Fisher's exact test:  $P < 0.05$ ).

The results on animal welfare, which were confirmed by literature, showed that prerequisites for performing behaviour were better in non-BC systems and in systems with access to an outdoor run. On the other hand, these systems could implicate some extra risks, e.g., increased mortality due to cannibalism or higher diseases incidence. The better farms, however, showed that there are possibilities to reduce these risks effectively.

### *Economic performance*

Labour income per FTE differed considerably among housing systems, as shown by the differences in averages, as well as within housing systems, as shown by the high standard deviations (Table 2). Results of AO (86 thousand euros per FTE per year) were significantly better than of all other housing systems ( $P < 0.001$ ). Most important determinants were higher revenues, due to higher (standard) sales prices of eggs from systems with outdoor run, higher numbers of hens per FTE in AO compared to DL and DLO, and lower housing costs per hen compared to DL and DLO. Feeding costs, as well as almost all other costs were lowest for BC. These low costs, however, could not compensate for the lower revenues due to lower egg prices (difference BC vs. AO was 1.75 eurocent per egg, i.e., 39%).

### *Environmental performance*

Table 2 shows life cycle analysis results of environmental problems considered for all housing systems. Acidification was highest for DL and DLO, and intermediate for AO, due to higher ammonia emission from manure, present in the house, storage facility, or outdoor run. Eutrophication was highest for DLO, and intermediate for DL and AO. DL and DLO had a higher eutrophication due to higher ammonia emission, whereas systems with outdoor run had a higher eutrophication due to leaching from the manure in the outdoor run. Global warming was highest for DLO and lowest for BC. Differences, however, were small. The main contributor was N<sub>2</sub>O-emission during the growing of concentrate ingredients and from manure on the farm. Differences in contribution of concentrate production to the total impact, mainly determined by differences in feed conversion ratio, were most clearly shown on this impact category, but were present in all impact categories. Land use was highest for DLO and AO, mainly caused by the outdoor run, which was the only contributor to on-farm land used. Differences in fossil energy use were not significant, because differences in the contribution of concentrate production were counteracted by differences in direct energy use. DL and DLO use less direct energy, because, usually, they do not have manure drying facilities.

### *Ergonomics*

The number of farmers with complaints ascribed to working in the laying hen house did not differ significantly among housing systems (Table 2). In the questionnaire we asked specifically for complaints at neck or shoulders, arm or hand, lower back, and leg or foot. Neck or shoulders and lower back contributed mostly to the total number of complaints. These specified complaints, however, also did not differ significantly among housing systems.

The average percentage of farmers with coughing and sneezing fits ranged from 8% to 24%, and also did not differ significantly among housing systems (Table 2). Concentrations of dust and endotoxins, however, are higher in non-cage systems (Seedorf et al., 1998; Takai et al., 1998; Drost et al., 2002; Whyte, 2002; Fiks-van Niekerk et al., 2003). That this was not reflected in our results could be due to the overall low incidence of complaints about coughing and sneezing fits, or was due to too low levels or short durations of exposure to cause complaints.

### *Product quality*

The number of flocks exceeding 10% second grade eggs did not differ significantly among housing systems (Fisher's exact test,  $P = 0.08$ ; Table 2). There was only one SE contaminated flock in this study, which resulted also in no significant differences among housing systems (Table 2). Only 31% of the flocks in BC was vaccinated, while more than 75% was vaccinated in all other systems. This resulted in a significant ( $P < 0.01$ ) difference among housing systems. Whether this preventive measure was really necessary is doubtful, because Mollenhorst et al. (2005a) showed that the risk of contamination with SE is only higher in DL compared to BC when there are hens of different ages on a farm.

### *Conclusion*

A clear set of criteria for indicators is necessary when selecting SI for on-farm assessment of SusD. Although some SI have practical constraints or are not yet developed, selection of available SI and subsequently quantifying them, gives a good indication of the strengths and weaknesses of different systems. From this analysis it appears that AO is a good alternative for BC, with better scores for AO on animal welfare and economics, but with worse scores on environmental impact. DL and DLO perform equally or worse than AO on all SI.

## **References**

- BELL, S. and MORSE, S.** (2003) *Measuring sustainability: learning by doing*. Earthscan Publications, London.
- BILCÍK, B. and KEELING, L.J.** (1999) Changes in feather condition in relation to feather pecking and aggressive behaviour in laying hens. *British Poultry Science* **40**: 444-451.

- DROST, H., MEIJS, C.H.A. and ELLEN, H.H.** (2002) Kwaliteit van de arbeid in pluimveehouderijsystemen als alternatief voor de legbatterij. IMAG Rapport 2002-04. IMAG, Wageningen, The Netherlands.
- FARM ANIMAL WELFARE COUNCIL** (1992) FAWC updates the five freedoms. *Veterinary Record* **17**: 357.
- FIKS-VAN NIEKERK, T.G.C.M., REUVEKAMP, B.F.J., VAN EMOUS, R.A. and RUIS, M.A.W.** (2003) Systeem van de toekomst voor leghennen. Praktijkrapport Pluimvee 6. Praktijkonderzoek Veehouderij, Lelystad, The Netherlands.
- GREEN, L.E., LEWIS, K., KIMPTON, A. and NICOL, C.J.** (2000) Cross-sectional study of the prevalence of feather pecking in laying hens in alternative systems and its associations with management and disease. *Veterinary Record* **147**: 233-238.
- KOENE, P.** (1997) Cannibalism in extensive poultry keeping in the Netherlands: an inventory, in: *Proceedings of the Fifth European Symposium on Poultry Welfare* (P., Koene, and H.J. Blokhuis, eds), pp 147-148, Wageningen Agricultural University, Wageningen, and Institute for Animal Science and Health, Lelystad, The Netherlands.
- LNV** (2005) Brief aan de Tweede Kamer betreffende 'Toekomst van de intensieve veehouderij' (met 2 bijlagen). Minister van Landbouw, Natuur en Voedselkwaliteit.
- McADIE, T.M. and KEELING, L.J.** (2000) Effect of manipulating feathers of laying hens on the incidence of feather pecking and cannibalism. *Applied Animal Behaviour Science* **68**: 215-229.
- MOLLENHORST, H. and DE BOER, I.J.M.** (2004) Identifying sustainability issues using participatory SWOT analysis - A case study of egg production in the Netherlands. *Outlook on Agriculture* **33**: 267-276.
- MOLLENHORST, H., VAN WOUDEBERGH, C.J., BOKKERS, E.G.M. and DE BOER, I.J.M.** (2005a) Risk factors for Salmonella enteritidis infections in laying hens. *Poultry Science* **84**: 1308-1313.
- MOLLENHORST, H., RODENBURG, T.B., BOKKERS, E.A.M., KOENE, P., and DE BOER, I.J.M.** (2005b) On-farm assessment of laying hen welfare: a comparison of one environment-based and two animal-based methods. *Applied Animal Behaviour Science* **90**: 277-291.
- PÓTZSCH, C.J., LEWIS, K., NICOL, C.J. and GREEN, L.E.** (2001) A cross-sectional study of the prevalence of vent pecking in laying hens in alternative systems and its associations with feather pecking, management and disease. *Applied Animal Behaviour Science* **74**: 259-272.
- RIGBY, D., WOODHOUSE, P., YOUNG, T. and BURTON, M.** (2001) Constructing a farm level indicator of sustainable agricultural practice. *Ecological Economics* **39**: 463-478.
- SAVORY, C.J.** (1995) Feather pecking and cannibalism. *World's Poultry Science Journal* **51**: 215-219.
- SEEDORF, J., HARTUNG, J., SCHRÖDER, M., LINKERT, K.H., PHILLIPS, V.R., HOLDEN, M.R., SNEATH, R.W., SHORT, J.L., WHITE, R.P., PEDERSEN, S., TAKAI, H., JOHNSEN, J.O., METZ, J.H.M., GROOT KOERKAMP, P.W.G., UENK, G.H. and WATHES, C.M.** (1998) Concentrations and emissions of airborne endotoxins and microorganisms in livestock buildings in Northern Europe. *Journal of Agricultural Engineering Research* **70**: 97-109.
- STRIEZEL, A.** (1994) Tiergerechtheitsindex für Legehennen, in: *Tiergerechtheitsindex - 200: ein Leitfaden zur Beurteilung von Haltungssystemen* (A., Sundrum, R., Andersson, R., and G., Postler, eds.), pp. 73-88, Koellen, Bonn, Germany.
- TAKAI, H., PEDERSEN, S., JOHNSEN, J.O., METZ, J.H.M., GROOT KOERKAMP, P.W.G., UENK, G.H., PHILLIPS, V.R., HOLDEN, M.R., SNEATH, R.W., SHORT, J.L., WHITE, R.P., HARTUNG, J., SEEDORF, J., SCHRÖDER, M., LINKERT, K.H. and WATHES, C.M.** (1998) Concentrations and emissions of airborne dust in livestock buildings in Northern Europe. *Journal of Agricultural Engineering Research* **70**: 59-77.
- VAN DE VEN, L.** (2002) Ontwikkeling van een gezondheidsparameter voor leghennen. MSc Thesis, Wageningen University, Wageningen, The Netherlands.
- WHYTE, R.T.** (2002) Occupational exposure of poultry stockmen in current barn systems for egg production in the United Kingdom. *British Poultry Science* **43**: 364-373.