



## Effects of two different rearing systems (organic and barn) on production performance, animal welfare traits and egg quality characteristics in laying hens

Valentina Ferrante, Susanna Lolli, Giuseppe Vezzoli & Luigi Guidobono Cavalchini

To cite this article: Valentina Ferrante, Susanna Lolli, Giuseppe Vezzoli & Luigi Guidobono Cavalchini (2009) Effects of two different rearing systems (organic and barn) on production performance, animal welfare traits and egg quality characteristics in laying hens, Italian Journal of Animal Science, 8:2, 165-174, DOI: [10.4081/ijas.2009.165](https://doi.org/10.4081/ijas.2009.165)

To link to this article: <http://dx.doi.org/10.4081/ijas.2009.165>



Copyright 2009 Taylor & Francis Group LLC



Published online: 01 Mar 2016.



Submit your article to this journal [↗](#)



Article views: 105



View related articles [↗](#)



# Effects of two different rearing systems (organic and barn) on production performance, animal welfare traits and egg quality characteristics in laying hens

Valentina Ferrante<sup>1</sup>, Susanna Lolli<sup>1</sup>, Giuseppe Vezzoli<sup>2</sup>,  
Luigi Guidobono Cavalchini<sup>1</sup>

<sup>1</sup>Dipartimento di Scienze Animali. Università di Milano, Italy

<sup>2</sup>Department of Animal Science. University of California, Davis, USA

*Corresponding author:* Dr. Valentina Ferrante. Dipartimento di Scienze Animali, Sezione di Zootecnica Veterinaria. Università degli Studi di Milano. Via Celoria 10, 20133 Milano, Italy - Tel. +39 02 50318044 Fax: +39 02 50318030 - Email: valentina.ferrante@unimi.it

---

*Received June 12, 2008; accepted December 6, 2008*

---

## ABSTRACT

Alternative housing systems for hen eggs production represents clear evidence of the trend in animal housing and husbandry towards extensive rearing methods. Consumer demand is oriented towards healthy foods controlled not only under a safety point of view, but also under a welfare assessment of the animals' living conditions. Among the different alternative systems deep litter and organic production in recent years have been improved in Italy. The aim of this study was to evaluate whether different housing systems (barn B and organic O) for laying hens may influence productive performance, fear responses and egg quality characteristics. A total of 4,745 birds were housed in the B system and 2,016 in the O system, both of which were commercial facilities. In each system the same strain (Hy-Line Brown) was housed and layer performance, external and internal egg characteristics, mortality and feed consumption were recorded weekly. Animal reactivity was recorded monthly with the approaching test. Moreover, the Tonic Immobility test was conducted at 70 weeks of age; feather and foot pad conditions were also investigated at the same time. The peak of laying was reached in both housing systems at 25 weeks of age and was higher in organic hens (94.5%) than in barn hens (93.0%). Feed conversion rate during the overall laying period was 2.36 vs 2.20, respectively, in O and B housing systems. There was a significant difference concerning the eggs classified as very dirty, dirty and cracked between the two systems. The dirty eggs were higher in O system probably due to laying eggs in a free range area, while the higher number of cracked eggs in B system may be due to a significantly less shell thickness in this system. Egg weight increased with layer age in both housing systems. Animals reared in O system showed less fearfulness than in B emphasised by the approaching and Tonic Immobility test results. Feather scoring did not evidence any severe plumage damage; statistical analysis showed some significant differences in comb and back areas between O and B systems. The hens reared on litter showed more aggressive pecking than the organic hens probably due to difference both in light intensity and in density.

*Key words:* Alternative housing systems, Welfare, Performance, Reactivity.

## RIASSUNTO

## EFFETTO DI DUE DIFFERENTI SISTEMI DI ALLEVAMENTO DELLA GALLINA OVAIOLE (BIOLOGICO E A TERRA) SU PERFORMANCES PRODUTTIVE, BENESSERE ANIMALE E CARATTERISTICHE QUALITATIVE DELLE UOVA

*I sistemi alternativi alla gabbia per l'allevamento di galline per la produzione di uova rappresentano una chiara tendenza ad orientarsi verso sistemi estensivi di allevamento. La domanda dei consumatori è oggi orientata sempre più verso alimenti sani e controllati non solo dal punto di vista della sicurezza alimentare, ma anche nell'ambito di una valutazione del benessere degli animali. Negli ultimi anni, in Italia, gli allevamenti a terra e biologico sono tra i sistemi alternativi quelli maggiormente impiegati per sostituire le gabbie.*

*L'obiettivo di questo studio è stato quello di valutare se il diverso sistema di allevamento (terra e biologico) per le galline ovaiole potesse influenzare le performance produttive, il benessere delle galline e le caratteristiche qualitative delle uova. Nel sistema a terra sono state accasate 4745 galline, 2016 nel biologico. Entrambi gli allevamenti erano commerciali. Il ceppo genetico utilizzato era il medesimo in entrambe le tipologie di allevamento (Hy-Line Brown).*

*Le variabili considerate sono state la produttività, le caratteristiche interne ed esterne delle uova, la mortalità e il consumo settimanale di mangime. Mensilmente è stata testata la reattività degli animali nei due sistemi di allevamento, mediante il test di avvicinamento. Il test dell'immobilità tonica è stato effettuato a fine ciclo (70 settimane di età) insieme alla valutazione dello stato del piumaggio e delle lesioni alle zampe.*

*Dall'analisi dei dati sono emerse alcune differenze tra i sistemi di allevamento. Il picco di deposizione, registrato in entrambi gli allevamenti alla settimana 25, è stato più elevato nel sistema biologico rispetto all'allevamento a terra (94,5% vs 93,0%). L'indice di conversione alimentare di tutto il ciclo di allevamento è stato 2,36 vs 2,20, rispettivamente, nel sistema biologico e a terra. Per quanto riguarda le caratteristiche qualitative delle uova è riscontrata una differenza significativa tra le uova classificate come molto sporche, sporche e rotte tra i due sistemi. In particolare le uova provenienti dall'allevamento biologico sono risultate più sporche a causa di una maggior deposizione di uova nel parchetto esterno, mentre le uova provenienti dalle galline allevate a terra su lettiera hanno presentato gusci significativamente più sottili e, di conseguenza, un maggior numero di uova rotte. Il peso delle uova è aumentato in entrambi i sistemi con l'aumentare delle settimane di età degli animali. Le galline allevate con metodo biologico hanno mostrato una minor paura nei confronti dell'uomo, dato confermato sia dal test di avvicinamento sia dal test di immobilità tonica. Anche se complessivamente in entrambe le tipologie di allevamento lo stato del piumaggio è risultato in buone condizioni, dall'analisi statistica dei dati è emersa una differenza significativa per quanto riguarda il punteggio attribuito alla cresta e al dorso degli animali. Infatti nelle galline allevate a terra si è notata una maggior aggressività tra gli animali probabilmente da collegare alla differente intensità luminosa e densità tra i due sistemi.*

Parole chiave: *Sistemi alternativi, Benessere degli animali, Performance, Reattività.*

**Introduction**

Continuous selection for egg production traits has led to highly performing laying hens, selected on the basis of their performance in a defined environment. The change in housing systems which is imposed by welfare regulations, 1999/74 EU-directive, has created a new challenge for breeders.

Poultry production has a relevant role

in Italian animal production due to its economic impact and to its ability to adapt to the market and consumers demands. In recent years food safety and "naturalness" are becoming increasingly important consumer demands. This has resulted in the development of different production methods able to satisfy consumer requests regarding product quality, while also taking into consideration animal welfare and environmental

protection in the whole production chain.

Alternative housing systems for hen egg production represent clear evidence of the animal housing and husbandry trend towards extensive rearing methods. Consumer demand is oriented towards healthy foods controlled not only under a safety point of view but also under a welfare assessment of the animals' living conditions. In recent years in Italy alternative systems for laying hens such as barn and organic farming with free range management systems have been improved.

In the middle of the last century organic farming developed as a serious way of keeping animals and growing crops. In 1991 Council Regulation (EEC) no. 2092/91 was implemented thereby setting the outlines for organic production of agricultural products as well as the means of identifying such agricultural products and foodstuffs. Recently this regulation has been supplemented for livestock production through Council Regulation (EC) no. 1804/1999, implemented in 1999. For a long period consumers were not very interested and organic products had the reputation of being less consistent and not so attractive. Consequently the market share was small (Ficks-van Nierkerk, 2001).

The EU regulation pointed out the importance of animal welfare in organic production; nevertheless the production system and associated standards do not automatically provide for good animal welfare. Consequently, the organic standards have often been developed under the influence of consumer concerns rather than being based on animal needs. The welfare evaluation of egg layers in organic egg production is complex. On one hand the birds are offered conditions to fully develop their "natural" behaviours, at least when making use of the outdoor facilities. Thus, they get natural light, are able to use litter, nests, perches and have plenty of space. On the

other hand, the potential for some diseases is clearly greater. Hence, the possibility to use medication against parasites without withdrawal time for eggs can be crucial. Several recent studies report on increasing problems that were not present in battery cages and litter floors before but are now turning up at high mortality rates especially in the free range production (Hafez *et al.*, 2001; Permin *et al.*, 2002; Eriksson *et al.*, 2003). Kreienbrock *et al.* (2004) reported average mortality in outdoor keeping to be higher compared to conventional cages in Germany. Ficks-van Nierkerk (2001) reported cannibalism and feather pecking being major problems in Dutch organic farming, mainly because beak trimming is not allowed in this form of production.

Behavioural problems encountered with adaptation of high performing layers to new management systems (enriched cages, floor systems) have been reviewed by Kjaer and Mench (2003). They involved feather pecking and cannibalism, fear and stress, nesting behaviour, feeding behaviour. Genetics and management are complementary approaches to be used in order to decrease these problems or to prevent their occurrence. The genetic approach offers the possibility to have cumulative effects, to make predictions about the breeding value and future performance and to really change the potential for adaptability of birds. The feasibility of a genetic approach requires a good knowledge of the genetic variability of behavioural traits. This can be done either between or within lines. Many studies have been undertaken in this field and have been reviewed by Faure *et al.* (2003) and Muir (2003).

The aim of this paper was to describe two different housing systems, litter floor and organic, that could replace conventional cages in 2012, and to make suggestions for future work. We investigated the effects of these

two systems on productive performances, reactivity and behaviour of laying hens as well as egg quality characteristics.

## Material and methods

The study was carried out in one litter floor housing system and one organic housing system located in Northern Italy. In each system the same strain of laying hens (Hy-Line Brown®) was housed in agreement with Council Directive 1999/74 and the Directive 1804/99 regarding organic production.

The study involved a total of 6,761 laying hens reared using two methods: 2,016 hens in organic (O) and 4,745 in barn (B) housing systems, both of which were commercial facilities. In each system the same strain of laying hens (Hy-Line Brown®) was housed in agreement with Council Directive 1999/74 and the Directive CE 1804/99 regarding organic production. Birds were beak-trimmed at one day old and transferred to the laying systems at 18 weeks old and they were slaughtered at 70 weeks of age.

In the organic farm a free-range area (9000m<sup>2</sup>) was accessible through 16 doors (35cm x 100cm, in agreement with the Directive CE 1804/99). The indoor poultry farm (5m x 75m) was divided in three parts: litter (1/3 of whole area), slat with drinking and feeding areas, and nests. The stocking density was 5.4 birds/m<sup>2</sup>.

The second farm was a typical barn (12m x 42m) with 1/3 of litter and 2/3 of slat. The stocking density was 9.4 birds/m<sup>2</sup>. Sixteen hours of light/day was provided through lateral windows located along the two longest walls and an artificial lighting program.

In both the organic and barn systems water and food were available *ad libitum*.

Total number of eggs, mortality and feed consumption were recorded weekly. We analysed the external egg characteris-

tic of downgraded eggs (laid on the floor) on a monthly basis. These eggs were classified as very dirty (the shell surface was >1cm<sup>2</sup> dirty), dirty (the shell surface was <1cm<sup>2</sup> dirty), clean, cracked, or giant (double yolk).

At 27, 30, 35, 43, and 53 weeks of layers' age, we investigated the internal characteristic of 30 eggs for each system. The eggs were weighed and the yolk colour was determined using the Roche yolk colour fan (1979). Thereafter, the yolk was separated from the albumen and weighed; then the albumen was removed from the shell and the shell plus the membranes were weighed. Thickness of the shells (with inner and outer shell membranes) was measured at three places (top, middle, bottom), using a digital micrometer (Mitutoyo, Miyazaki, Japan). The weight of albumen was calculated as the difference between the egg weight and the weight of the shell and yolk.

Animal reactivity was recorded monthly with the approaching test or birds' fear reaction to the tester or observer according to the method described by Hegelund and Sørensen (2007) modified. The observer walked inside the farm and stood 2 m from the door. The reaction of the birds was scored for 5 minutes on a scale ranging from 0 to 3. Zero meant panic among the birds and 3 indicated that there was no noticeable reaction or change in behaviour.

At the end of the production cycle at 70 weeks of age, the Tonic Immobility test was performed on 50 hens in each system. The Tonic Immobility test (TI) was used to investigate a fear response to manual restraint of the animal, which can be observed when the bird is set on its back in a U-shaped cradle, and held down for 10s in a quiet environment. Upon release the bird will stay more or less time on its back until self-righting. The measurement of the time needed before self-righting has been

used to select divergent hen lines, showing either Short or Long TI (Mills and Faure, 1991). Selection for short TI has been accompanied by reductions in fearfulness, without changes in growth. In the present study TI test duration was 180 seconds and the maximum number of inductions was 3 (Ferrante *et al.*, 2005).

Immediately after the TI test, 5 body areas of each animal (comb, neck, wings, back, and cloaca) were scored for the feather condition; the scale ranged from 1 (plumage very damaged) to 4 (plumage not damaged), in agreement with the "Tauson method" (Tauson *et al.*, 2006). The foot pad status was classified according to a protocol designed by Extrand *et al.* (1998).

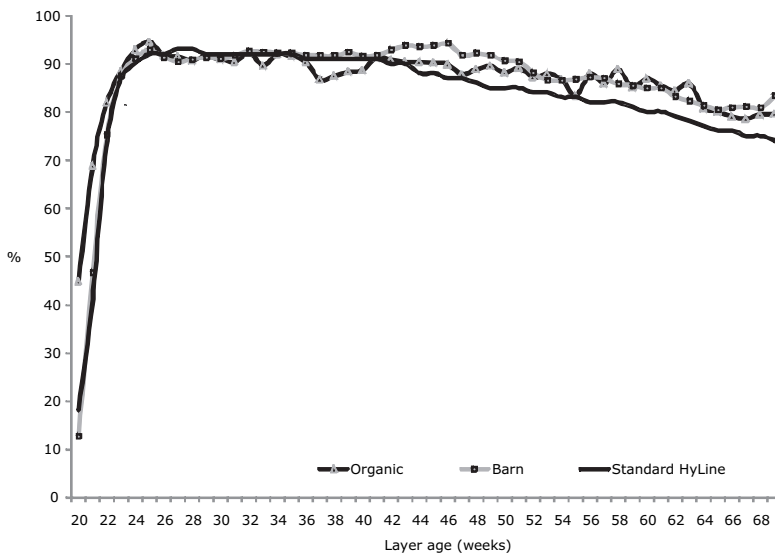
The data related to the characteristics of eggs laid on floor at the different ages and the TI results were analyzed using the non parametric analysis of variance of SPSS vers. 14.0 (test Wilcoxon) with housing system as the main effects. The data related to

the internal egg characteristics were analysed using the GLM procedure with age and housing system as main effect and the two-way interaction between these factors.

## Results and discussion

Several effects due to layer age and housing system were found. Hens began to lay at 20 weeks of age. The peak of laying attained was higher in organic hens (94.5%) than in barn hens (93.0%) in week 25 (Figure 1). From 25 to 58 weeks of age, the laying rate was always higher in barn hens than in the organic ones, while after week 25 the laying rates were similar. As expected, however, globally over the laying period, the laying rate was identical in organic and barn housing systems (86.40% vs 86.35%). In comparison to the standard production of Hy-Line (Hy-Line, 2007) at the same week of deposition, the percentage of deposition was generally higher. These findings are

Figure 1. Deposition in relation to layer age and housing system.



quite different from those of Tauson and Holm (2001) who found a 3% lower egg mass in barn hens compared to caged hens. This difference may be due to the high level of management in the two farms of this study. The mortality of the whole laying period was lower in the organic system than in the barn housing system (4.24% B vs 2.43% O).

Feed conversion rate was 2.36 vs 2.20, respectively, in the organic and barn systems. In agreement with Tauson *et al.* (1999) and with Michel and Huonnic (2003) feed conversion rate increases due to more movement by birds in systems with more activity (organic), but also due to the degree of heat losses in relation to feather cover and environmental temperature (Peguri and Coon, 1993).

As expected, egg weight increased with layer age in both housing systems. B layers had lower egg weight than O layers at the beginning of the experiment, but egg weight increased faster and was greater at a layer age of 35 (Figure 2). The eggs collected and the albumen weight were signif-

icantly higher in laying hens reared in barn systems than layers in the organic system (Table 1). Our results do not confirm the data of Van den Brand *et al.* (2004), who found an inversely proportional increase in eggs and albumen weight with increasing age of layers. Air cell diameter was not significant: 2.24mm in organic eggs and 2.00mm in litter eggs. No differences were found in yolk colour.

There was a significant difference between hen housing systems concerning the incidence of very dirty, dirty and cracked eggs laid on the floor (Table 2). In the organic system downgraded eggs were especially dirty and very dirty, probably due to laying eggs in the free range area while in litter system eggs were more cracked (29.74% B vs 8.57% O), probably due to less shell thickness, which was significantly higher in the organic system than in the litter floor housing system (0.44mm vs 0.42mm,  $P < 0,001$ ). Also in free range several authors found a positive effect of out run on shell strength (Pavloski *et al.*, 1981; Hughes *et al.*, 1985; Leyendecker, 2001).

Figure 2. Fresh egg weight in relation to layer age and housing system.

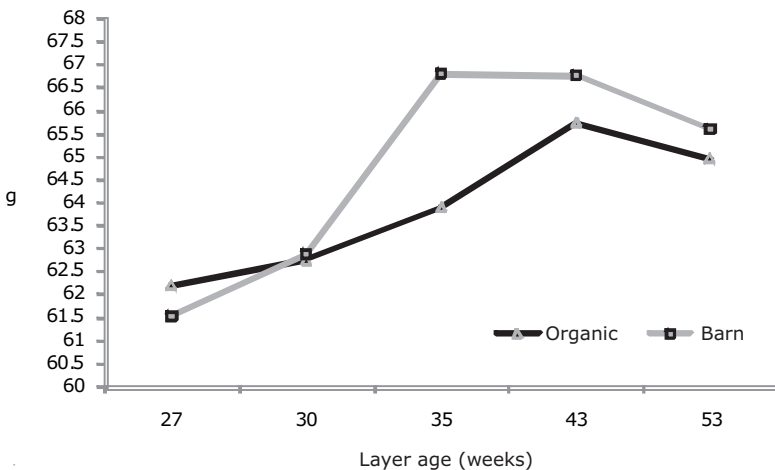




Table 1. Effects of age, housing systems and their interaction on egg quality characteristics.

	Egg weight (g)	Yolk weight (g)	Shell weight (g)	Albumen weight (g)
Age of layers (weeks):				
27	61.87 <sup>b</sup>	13.22 <sup>d</sup>	6.41 <sup>d</sup>	42.24 <sup>ab</sup>
30	62.82 <sup>b</sup>	14.23 <sup>c</sup>	6.92 <sup>c</sup>	41.68 <sup>ab</sup>
35	65.35 <sup>a</sup>	15.34 <sup>b</sup>	7.01 <sup>c</sup>	43.01 <sup>a</sup>
43	66.27 <sup>a</sup>	16.59 <sup>a</sup>	7.85 <sup>a</sup>	41.83 <sup>ab</sup>
53	65.28 <sup>a</sup>	16.74 <sup>a</sup>	7.58 <sup>b</sup>	40.83 <sup>b</sup>
68	65.18 <sup>a</sup>	16.37 <sup>a</sup>	6.86 <sup>c</sup>	41.95 <sup>ab</sup>
SEM	0.63	0.26	0.07	0.58
Housing:				
Organic	63.44 <sup>b</sup>	15.49	7.04 <sup>b</sup>	40.91 <sup>b</sup>
Barn	65.49 <sup>a</sup>	15.34	7.17 <sup>a</sup>	42.98 <sup>a</sup>
SEM	0.36	0.15	0.04	0.34
Source of variation:				
Age	<0.0001	<0.0001	<0.0001	<0.0001
Housing	<0.0001	ns	<0.05	<0.0001
Age x housing	<0.0001	<0.05	<0.05	<0.05

<sup>a, b, c</sup>: Values within columns with different superscripts are significantly different ( $P < 0.05$ ).

ns: not significant.

Test data showed some differences in behaviour between the organic and barn systems. In every session animals reared in the organic system showed less fearfulness than those in the barn system, as they registered more curiosity (Figure 3). This approach to the human was underlined by Tonic Immobility test results. Although the test did not show significant differences between rearing methods, organic hens had longer immobility (52.82 vs 41.26 sec) and higher inductions (2.48 vs 2.40) than hens in the barn system. Feather scoring did not evidence severe plumage damage; this is probably the best indirect selection criteria to be used in order to modify feather peck-

ing as it is relatively simple to measure and is heritable. Plumage score was found to be correlated with the feather pecking behaviour in some selection experiments (Kjaer *et al.*, 2001; Chapuis *et al.*, 2003). Moreover, statistical analysis showed some significant differences in comb and back areas between organic and litter systems. Comb and back area scores were worse in the barn system than in the organic system (Table 3). This result agrees with the correlation found by other authors between fearfulness and aggressive behaviour (Hughes and Duncan, 1972; Ouart and Adams, 1972). No differences regarding foot pad conditions between systems were found (Table 3).



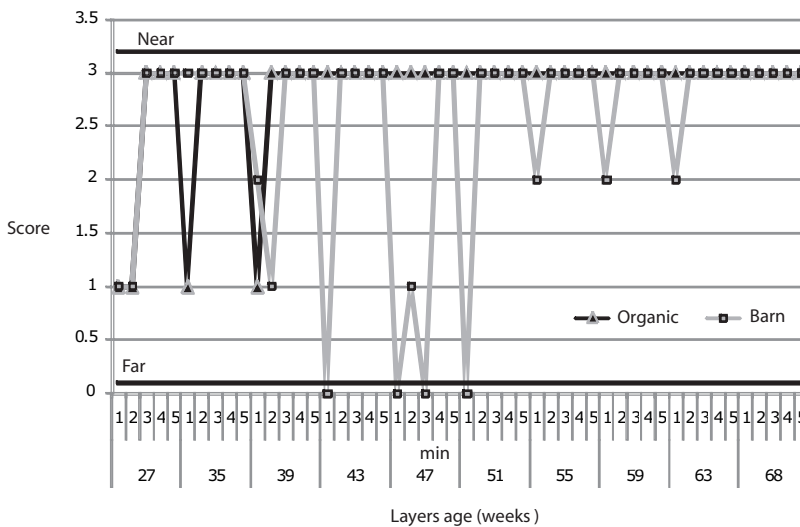
Table 2. Eggs laid on the floor (mean±standard error).

Parameters		Organic	Barn	P value
Very dirty	%	36.07 ± 2.37	23.91 ± 2.77	<0.05
Dirty	"	41.97 ± 5.25	20.81 ± 3.6	<0.05
Cracked	"	8.57 ± 1.58	29.74 ± 2.91	<0.0001
Clean	"	21.96 ± 4.53	55.29 ± 3.75	<0.0001
Giant	"	15.20 ± 4.51	23.13 ± 3.27	ns

Table 3. Plumage and foot pad conditions (means ±SD).

	Organic	Barn	SEM	P
Comb	3.94 ± 0.24	3.72 ± 0.49	0.055	<0.05
Neck	2.92 ± 0.9	2.92 ± 0.8	0.121	ns
Wings	3.68 ± 0.51	3.72 ± 0.54	0.074	ns
Back	3.64 ± 0.78	3.36 ± 0.59	0.098	<0.05
Cloaca	3.86 ± 0.41	3.76 ± 0.43	0.059	ns
Foot pad	3.9 ± 0.3	3.9 ± 0.3	0.04	ns

Figure 3. Approaching test in Organic and Barn housing systems.



## Conclusions

The results presented here lead to the conclusion that alternative housing systems (organic or barn) generally did not negatively influence the performance of the layers. From an animal welfare point of view, layers reared in organic and in barn systems did not show stress and aggressiveness and the performances were optimal in both rearing conditions. Both the TI results and the approaching test showed that organic hens are less fearful to humans than barn hens because of the more natural environment. From the productive point of view the good results of this experiment demonstrate the importance of high professional skills among the farmers in al-

ternative non cage systems. In fact, it is most likely that successful organic farming will depend on the right combination of layout and management of the henhouse and free range on the one hand, and on the choice of the right breed of hen on the other. Apart from areas for improvement, the balance between the two aspects will probably be of major importance.

*The authors are grateful to "Azienda Agricola Castello", "Allevamenti Avicoli Boccola" and "Azienda Agricola Lucchi" for their support in this research.*

Research funded by Lombardia Region, project ECCEOVO.

## REFERENCES

- Chapuis, H., Boulay, M., Retailleau, J.P., Arnould, C., Migon-Grasteau, S., Berri, C., Besnard, J., Coudurier, B., Faure, J.M., 2003. Sélection d'une souche de poulet label contre le picage : bilan après trois générations de sélection au "picomètre". pp 363-366 in Proc. 5<sup>th</sup> Journées de la Recherche Avicole, Tours, France.
- Eriksson, H., Fossum, O., Chirico, J., Gunnarsson, A., Jansson, D.S., 2003. Erysipelas-a growing problem in aviary and organic housing systems. Page 130 (abstr.) in Proc. 5<sup>th</sup> World Congr. Veterinary Poultry Association, Denver, CO, USA.
- Extrand, C., Carpenter, T.E., Andersson, I., Algers, B., 1998. Prevalence and control of foot-pad dermatitis. *Brit. Poultry Sci.* 39:318-324.
- Faure, J.M., Bessei, W., Jones, R.B., 2003. Direct selection for improvement of animal well-being. In: W.M. Muir and S.E. Aggrey (eds.) *Poultry genetics, breeding and biotechnology*. CAB Publishing, Wallingford, UK, pp 221-245.
- Ferrante, V., Marelli, S., Pignattelli, P., Baroli, D., Cavalchini, L., 2005. Performance and reactivity in three Italian chicken breeds for organic production. pp 23-29 in Proc. 7<sup>th</sup> Eur. Symp. on Poultry Welfare, Lublin, Poland.
- Fiks-van Nierkerk, T.G.C.M., 2001. Organic poultry farming: a small but growing concept. In: H. Oester and C. Wyss (eds.) Proc. 6<sup>th</sup> Eur. Symp. on Poultry Welfare, Zollikofen, Switzerland, pp 35-37.
- Hafez, H.M., Mazaheri, A., Prusas, C., Böhland, K., Pöppel, M., Schulze, D., 2001. Aktuelle Geflügelkrankheiten bei Legehennen im Zusammenhang mit alternative Haltungssystemen. *Tierärztl. Prax.* 29:168-174.
- Hegelund, L., Sørensen, J.T., 2007. Measuring fearfulness of hens in commercial organic egg production. *Anim. Welfare* 16:169-171.
- Hughes, B.O., Dun, P., McCorquodale, C.C., 1985. Shell strength of eggs from medium-bodied hybrid hens housed in cages or on range in outside pen. *Brit. Poultry Sci.* 26:129-136.
- Hughes, B.O., Duncan, I.J.K., 1972. The influence of strain and environmental factors upon feather pecking and cannibalism in fowls. *Brit. Poultry Sci.* 13:525-547.
- Hy-Line Brown Plus, 2007. A publication of Hy-Line International P.O. Box 65190. West Des Moines

- Iowa, IA, USA.
- Kjaer, J.B., Mench, J.A., 2003. Behaviour problems associated with selection for increased production. In: W.M. Muir and S.E. Aggrey (eds.) Poultry genetics, breeding and biotechnology. CAB publishing, Wallingford, UK, pp 67-82.
- Kjaer, J.B., Sorensen, P., Su, G., 2001. Divergent selection on feather pecking behaviour in laying hens (*Gallus gallus domesticus*). Appl. Anim. Behav. Sci. 71:229-239.
- Kreinbrock, L., Schäl, J., Beyerbach, M., Rohn, K., Glaser, S., Schneider, B., 2004. Epileg. Orientierende epidemiologische Untersuchung zum Leistungsniveau und Gesundheitsstatus in Legehennhaltungen verschiedener Haltungssysteme. Tierärztliche Hochschule Hannover Publ., Hannover, Germany.
- Leyendecker, M., Hamman, H., Hartung, J., Kamphues, J., Ring, C., Glunder, G., 2001. Analysis of genotype-environment interactions between layer lines and hen housing systems for performance traits, egg quality and bone breaking strength. 2<sup>nd</sup> comm.: Egg quality traits. Zuchtungskunde 73:308-323.
- Michel, V., Huonnic, D., 2003. A comparison of welfare, health and production performance of laying hens reared in cages or in aviaries. Brit. Poultry Sci. 44:775-776.
- Mills, A.D., Faure, J.M., 1991. Divergent selection for duration of tonic immobility and social reinstatement behaviour in Japanese quail (*Coturnix coturnix japonica*) chicks. J. Comp. Physiol. 105:25-38.
- Muir, W.M., 2003. Indirect selection for improvement of animal well-being. In: W. M. Muir and S. E. Aggrey (eds.) Poultry genetics, breeding and biotechnology. CAB publishing, Wallingford, UK, pp 247-255.
- Ouart, M.D., Adam, A.W., 1982. Effects of cage design and birds density on layers. 1. Productivity, fearfulness and nervousness. Poultry Sci. 61:1606-1613.
- Pavlovski, Z., Masic, B., Apostolov, N., 1981. Quality of eggs laid by hens on free range and in cages. In: G. Beuving, C.W. Sheele and P.M.C. Simons (eds.). Proc. 1<sup>st</sup> Eur. Symp. on Quality of Eggs, Apeldoorn, The Netherlands, pp 231-235.
- Peguri, A., Coon, C., 1993. Effect of feather coverage and temperature on layer performance. Poultry Sci. 72:1318-1329.
- Permin, A., Ambrosen, T., Maag Eigaard, N., Folden Flensburg, M., Bojensen, M., Christensen, J.P., Bisgaard, M., 2002. Sygdomme og velfaerd. Danks Veterinaertidskrift 85(6):12-16.
- SPSS, 2003. Base System User's Guide. Version 5.0. SPSS Inc., Chicago, IL, USA.
- Tauson, R., Holm, K.E., 2001. First furnished small group cages for laying hens in evaluation program on commercial farms in Sweden. In: H. Oester and C. Wyss (eds.) Proc. 6<sup>th</sup> Eur. Symp. on Poultry Welfare, Zollikofen, Switzerland, pp 26-32.
- Tauson, R., Kjaer, J., Maria, G.A., Cepero, R., Holm, K.E., 2006. Applied scoring of integument and health in laying hens. LayWel Project – deliverables 3.1. Home page address: <http://www.laywell.eu>
- Tauson, R., Wahlstrom, A., Abrahamsson, P., 1999. Effect of two floor housing systems and cages on health, production, and fear response in layers. J. Appl. Poultry Res. 8:152-159.
- Van den Brand, H., Parmentier, H.K., Kemp, B., 2004. Effects of housing system (outdoor vs cages) and age of laying hens on egg characteristics. Brit. Poultry Sci. 45:745-752.