Welfare of organic poultry

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Summary
Organic poultry production has substantially increased in the last few years. On organic farms, welfare of poultry is enhanced due to enriched housing conditions as access to a free range area. This may reduce feather pecking and keep the health status at least on the same level as on conventional farms. However, welfare of organic poultry may be further improved if: **(a)** laying hens are already reared in enriched systems that are close to the systems in the layer house, **(b)** a frequent and even use of the run, **(c)** selection of suitable genotypes especially in relation to digestive ability, and **(d)** effective prevention and control of parasites.

Keywords: organic poultry; welfare; feather pecking; breeding; parasites

In Europe, organic poultry production has increased in the last few years. Over 8 million organic laying hens (mainly in the UK, France, Germany, the Netherlands and Italy), over 9 million organic broilers (mainly in France and the UK) and around half a million other poultry (geese, ducks, turkeys mainly in Germany and the UK; Eurostat, 2006) are kept. In organic agriculture, poultry is traditionally kept in free range systems with lower stocking densities than in conventional systems and with littered floor inside the poultry house. Health should be maintained or achieved without preventive allopathic treatments and zootechnic measures (e.g. beak trimming). Feed contains mostly organically grown components and a 100% organic feed composition should be achieved in Europe from 2012 on. Even though these general guide-lines exist for organic farming, the diversity in production systems in the different countries is large as for instance with respect to the maximum flock and farm size.
The differences to conventional farming may increase welfare but, on the other hand, also aggravate welfare problems. Whereas some housing aspects are specific to organic farming and therefore only influence organic poultry welfare (e.g. feeding regulations and limited treatments), other aspects are also relevant for conventional 'low input' farms (e.g. free range systems).

Organic poultry production standards require **free range systems** for layers and broilers. In a free range system, laying hens may show beneficial behavioural elements which are not possible in the poultry house. Therefore, access to free range can improve welfare. For instance, the complete sunbathing behaviour is only shown in direct sunlight and not in artificial light (Huber, 1987). Ruis *et al.* (2004) concluded from their study that an outdoor run potentially also improves welfare of broilers. They found that natural light as such does not guarantee a better welfare, but that it is likely that the quality and intensity of lighting is of importance. Thus it appears that access to a free range area is very important for poultry.

However, infrequent and uneven **use of the hen run** is one of the main problems not only in organic but in all free range systems for laying hens. This indicates that the animals do not feel safe in the non roofed run area. In flocks of free range hens, generally only a small proportion of the flock is outside at the same time. Hirt *et al.* (2000) have shown that laying hens in larger groups (over 1000 animals) did not use the run as often as laying hens in smaller groups (up to 500 animals) and that the hens in the run mostly remained close to the poultry house. Therefore, limitation of the flock size in organic agriculture seems to be important.

Fürmetz *et al.* (2005) observed an average of 75% of the hens within 20m from the poultry house. This leads to **destroyed vegetation** in these areas. Menzi *et al.* (1997) found a nutrient and heavy metal overload on the frequently used parts of the run. According to these authors, 15 to 25% of daily droppings are excreted in the hen run. This corresponds to the calculations of Elbe *et al.* (2005), where the amount of nitrogen in the soil reached a very high level in the area close to the poultry house. Additionally, Berk *et al.* (2002) found that the activity of turkeys was related to the spatial distribution of phosphorus supplied by faeces. As accumulation of P was highest in the roofed part of the free range they suggested that further enrichment of the non roofed area with bushes or trees should promote activities in this area and thus improve animal health and welfare and favour an even distribution of nutrients. It is therefore recommended to structure the outdoor area with trees and installations providing shade and protection to the hens. While Hegelund *et al.* (2002) observed in their study in Denmark that weather conditions have a higher influence on the number of hens in the run than tents, several other studies demonstrate the importance of a structured free range area. Zeltner and Hirt (2003) found that a simple artificial structure like a roofed box with sand in the hen run improved the distribution of the hens, whereas scattering grains on the range area had no effect on the number of hens in the run (Hauser *et al.* 2003). Nicol *et al.* (2003) and Bestman and Wagenaar (2003) both found that the use of the hen run is associated with cover, trees or hedges in the range area. Zeltner and Hirt (2008) found that hens were more evenly distributed in the hen run when structuring elements are provided. Every type of structure provided was used by the hens and variety of structures was more important than the number of structuring elements to fulfil requirements of individual hens.

In the case-control study of Nicol *et al.* (2003), risk of **feather pecking** was reduced, when the hens used the free range more frequently. These results correspond with Bestman and Wagenaar (2003) who detected low levels of feather pecking damage when the use of the outdoor run was stimulated by means of vegetative and artificial cover. However, Winckler *et al.* (2004) found no significant differences in body weight and feather condition (which may be an indirect indicator for feather pecking) between groups with different use of the hen run.

Even though feather pecking is reduced when the hens use the free range frequently, feather pecking remains a problem on organic farms. On organic farms beak trimming is forbidden and feather pecking is therefore considered to be an even more severe problem than on conventional farms. For instance, in the Netherlands feather pecking is seen in 70% of the organic laying flocks (Bestman and Wagenaar, 2003) and in 54% of the organic rearing flocks (Bestman and Wagenaar, 2006). Feather pecking is an indicator for reduced welfare of both, victim and performer, and is associated with stress (El Lethey *et al.*, 2000).

Bestman and Wagenaar (2003) concluded from their study that less feather pecking is seen on organic farms if farmers do their own **rearing**. They therefore tried to identify risk factors for feather pecking on rearing farms and the persistence of feather pecking throughout life. They found that 82% of flocks which started feather pecking during the rearing period, continued to do so during the laying period. Additionally, in rearing farms feather pecking is correlated with high densities of chicks, combined with poor environments, especially the first weeks, when they are confined on grid floors without litter and perches (Bestman and Wagenaar, 2006). In the study of Knierim *et al.* (2008) risk factors for poor plumage were: little elevated perch space, few drinking places and no regular scattering of grain during rearing period and poor litter quality during the laying period. The plumage condition in this study did not differ between organic and conventional farms.

Animal health is an important aspect when evaluating animal welfare. Mortality rates of organic poultry vary substantially between and within countries in Europe. For example, Fiks *et al.* (2002) found mean mortalities of 11% (0-21%) in organic layers in the Netherlands. Main mortality causes were *E. coli*, infectious bronchitis, coccidiosis and brachyspira. In Switzerland, mortality in organic layer flocks was estimated to 8% (3-25%; Bio Suisse, 2006). A cautious general conclusion drawn from a literature survey by Lund and Algers (2003) was that parasite problems tend to be worse and other health traits tend to be similar or better in organic than in conventional farming.
The most important **parasites** of laying hens include the poultry red mite (*Dermanyssus gallinae*), coccidia (*Eimeria* spp.) and gastro-intestinal helminths (mainly the roundworms *Ascaridia galli* and *Heterakis gallinarum*).
Studies in Switzerland (Maurer *et al.*, 1993), Sweden (Höglund *et al.*, 1995), and England (Fiddes *et al.*, 2005) have revealed that *D. gallinae* presents a major problem in laying hen husbandry and that its prevalence is higher in free range and barn or aviary systems than in battery systems. Control of *D. gallinae* on organic farms presents an intermediate situation between the ban and admission of synthetic acaricides: *D. gallinae* control should primarily be achieved by preventive measures and acaricides of natural origin according to national and international regulations (e.g. the Council Regulation (EC) No 834/2007; EC, 2007), but synthetic acaricides may be used as a last resort. A three-stage control system including management practices between flocks (e.g. cleaning and disinfection of the empty house after each cycle), physically acting substances during flocks (e.g oil and desiccant dusts), and the selective application of acaricides of natural origin to highly affected places is successfully applied on Swiss organic farms (Maurer *et al.*, 2009a)
Häne (1999) found that a higher percentage of hens with access to a free range area (73%) excreted oocysts of *Eimeria* spp. than hens without free range area (58%). However, presence or absence of litter was a more important factor in this study. In both, layers and broilers, vaccination against the relevant *Eimeria* spp. is available and widely used in organic flocks; the importance of coccidiosis has therefore decreased in the last few years (Shirley *et al.*, 2005).
In their prevalence studies Permin *et al.* (1999) and Häne (1999) revealed a higher risk of helminth infections in free range systems. According to Häne (1999) twice as many anthelmintic treatments were performed in free range systems than in systems without an outdoor area. Helminth parasites of poultry are usually controlled by repeated anthelmintic treatments of the flock. However, the regular and preventive use of such

chemically synthesised drugs is not compatible with organic regulations and therefore preventive management and alternative control strategies need to be developed. Preventive management strategies against gastro-intestinal helminths are less effective in poultry than in ruminants (Maurer *et al.*, 2007) due to epidemiological differences of the helminth species involved. For instance, Heckendorn *et al.* (2009) have recently shown that both, a lower stocking rate (10 *vs.* 5m^2/hen) and a simple run management measure (mowing) significantly improved run quality, but had no effect on helminth infections in the hens. Similarly, helminth infections were not impaired by different litter management regimes (Maurer *et al.*, 2009b). Alternative treatments for gastro-intestinal helminths in poultry (e.g. anthelmintic plants) have been investigated in several studies (e.g. Javed *et al.*, 1994; Lal *et al.*, 1976; Singh and Nagaich 1999; 2000; 2002). However, scientifically validated data on the efficacy of herbal treatments against *A. galli* or *H. gallinarum* remain scarce and often limited to *in vitro* studies.

The risk of **zoonotic disease** is not strictly an animal welfare issue. However, this problem is often related to organic poultry production due to increased contact of free range poultry with external vectors such as wild birds. While the incidence of *Salmonella* infections has decreased, *Campylobacter* infections associated with the consumption of poultry products have increased in northern Europe (Lee and Newell, 2005). In a Danish prevalence study, Heuer *et al.* (2001) isolated *Campylobacter* from 100% of organic broiler flocks, but only from 37% of conventional indoor broiler flocks. These findings are supported by Swedish (Engvall, 2001) and Dutch (Rodenburg *et al.*, 2004) studies. Approximately 80% of the cases of pasteurellosis in Danish poultry occurred in free range flocks (Christensen *et al.*, 1998). Prevalence of *Salmonella* in broilers was recently found to be similar (approximately 13%) in organic and in conventional systems in the Netherlands (Rodenburg *et al.* 2004).

Organic egg and broiler production are mainly based on the same **genetics** as conventional production because the use of traditional pure breeds is currently not feasible for the vast majority of organic poultry producers for economic reasons. Although genotype by environment interactions for laying hen performance in organic and other free range systems were shown to exist (Kjaer *et al.*, 2001, Sørensen, 2001), the needs of organic poultry farmers are only marginally considered by poultry breeders due to the small market share of organic poultry products (Boelling *et al.*, 2003) An issue of particular concern for the organic sector is the discarding of spent layers and the fact that male chicks are killed after hatching. This is considered to seriously undermine consumer confidence in the ethics of organic egg production.
In a review, Castellini *et al.* (2008) conclude that only **slow-growing broiler** strains can fully benefit from an organic rearing system because the weight of fast-growing strains is excessive and therefore results in welfare problems such as leg weakness, need for high culling and high mortality rates. In the EU regulation on organic farming (EC, 2007) a minimal age at slaughter is given for poultry, and the use of fast-growing strains is therefore virtually prohibited. The use of slow growing hybrids has reduced skeletal lesions in organic broilers. If hybrids with a fattening period of more than two months are used on organic farms, animals usually remain mobile during the whole fattening period (Castellini *et al.*, 2008). Predators (e.g. hawk, fox, martens) are a cause of broiler losses in free-range systems. However, more broilers use the free range when artificial

shelters are provided (Gordon, 2002), and predation is expected to be reduced as broilers may hide.
A further welfare and health problem in organic broiler production as supposed by organic producers may be the occurrence of breast blisters which is associated with perching. However, Nielsen (2003) found that in some broiler strains access to perches may increase the occurrence of breast blisters, but significant strain differences in the occurrence are also found independent of perch use. Ferrante *et al.* (2008) compared organic and conventional broiler farms and found that organic broilers had a lower reactivity towards human. They concluded that a better adaptation to the environment and to humans increase broiler welfare.

The main problem to meet the **nutrient requirements** for organic poultry is the ban on synthetic amino acids and other restrictions in feed supplements. Due to the limited availability and high cost of organically produced and non-GM soya, particularly organic producers face difficulties in supplying diets with balanced amino acid patterns. This situation could worsen since organic poultry feed must be composed of 100% organic components from 2012 onwards. Feather pecking to some extent is influenced by the amino acid contents and composition of the diet (Kjaer and Sorensen 2002). However, there is evidence that some genotypes are more tolerant to imbalanced diets and other feeding deficiencies. For example, Sørensen (2001) suggests that it is possible to select laying hens that maintain high performance and low levels of feather pecking on diets with lower crude protein supply and imbalanced amino acid composition.
Elwinger *et al.* (2008) selected a genotype over 25 generations on low protein diets based on home grown feedstuffs. This experimental genotype was compared with two commercial hybrids on different diets. Cannibalism and feather pecking occurred mostly in the low protein diet in commercial hybrids. These results indicate that the reliance on soya could be reduced and production could be based on diets with a higher proportion of home-grown protein crops (e.g. beans, peas, lupins and/or protein cake from oil crop) throughout Europe if another genotype or breed would be used. .
It is easier to supply broilers with adequate essential amino acids than laying hens because the slow-growing broiler genotypes used in organic farming have lower requirements for proteins than fast growing broilers (Zollitsch and Baumung, 2004). Accordingly, Bellof and Schmidt (2007) found that feed mixtures with clearly reduced energy contents as well as lowered contents of essential amino acids can be successfully used in organic broilers and turkeys. O'Brien *et al.* (2006) could not point to overall health, growth, behaviour or welfare concerns or increases in production costs when comparing 80% and 100% organic rations for broilers. This is in contrast to the assumption that nutritional inadequacy would result on the 100% ration.

In summary, some aspects of organic farming are predestined to increase welfare of organic poultry. However, welfare may be further improved when attention is paid to **(a)** rearing of laying hens in enriched systems that are close to the systems in the layer house, **(b)** a frequent and even use of the run, **(c)** selection of suitable genotypes especially in relation to digestive ability, and **(d)** effective prevention and control of parasites.

References

- BELLOF, G. and SCHMIDT, E. (2007). Ökologische Geflügelmast - Lösungsmöglichkeiten für eine 100 % Bio-Fütterung. In Wiesinger, K. (Ed.) Angewandte Forschung und Beratung für den ökologischen Landbau in Bayern, Schriftenreihe der Bayerischen Landesanstalt für Landwirtschaft, Freising 3/2007: 23-33.
- BERK, J., HANEKLAUS, S. and SCHNUG, E. (2002). Free range behaviour of male turkeys and its effect on the spatial variability of phosphorous in soil. In: Koene, P. (Ed) Proceedings of the 36th international congress of the ISAE, the Netherlands, p. 133.
- BESTMAN, M.W.P. and WAGENAAR, J.P. (2006). Feather pecking in organic rearing hens. Joint Organic Congress, Odense, 30-31 May 2006.
- BESTMAN, M.W.P. and WAGENAAR, J.P. (2003). Farm level factors associated with feather pecking in organic laying hens. Livestock Production Science 80: 133-140.
- BIO SUISSE (2006). Calculation of production costs (internal document).
- BOELLING, D., GROEN, A.F., SØRENSEN, P., MADSEN, P. and JENSEN, J. (2003). Genetic improvement of livestock for organic farming systems. Livestock Production Science 80: 79–88.
- CASTELLINI, C., BERRI, C., LE BIHAN-DUVAL, E. and MARTINO, G. (2008). Quality attributes and consumer perception of organic and free range poultry meat. World's Poultry Science Journal 64: 500-512.
- CHRISTENSEN, J.P., DIETZ, H. H. and BISGAARD, M. (1998). Phenotypic and genotypic characters of isolates of Pasteurella multocida obtained from back-yard poultry and from two outbreaks of avian cholera in avifauna in Denmark. Avian Pathology 27(4): 373-381.
- EC (2007). Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing. Regulation (EEC) No 2092/91. Official Journal of the European Communities, L189/1 (20.7.2007)**,** 1-23.
- ELBE, U., ROSS, A., STEFFENS, G., VAN DEN WEGHE, H. and WINCKLER, C. (2005). Organic layers in large flocks: use of the outdoor run and accumulation of nutrients in the soil. In: Hess, J., Rahmann, G. (Eds) Ende der Nische, Beiträge zur 8. Wissenschaftstagung Ökologischer Landbau, Kassel, p. 307.
- EL LETHEY, H., AERNI, V., JUNGI, T.W. and WECHSLER, B. (2000). Stress and feather pecking in laying hens in relation to housing conditions. British Poultry Science 41: 22-28.
- ELWINGER, K., TUFVESSON, M., LAGERKVIST, G. and TAUSON, R. (2008). Feeding layers of different genotypes in organic feed environments. British Poultry Science 49: 654-665.
- ENGVALL, A. (2001). May organically farmed animals pose a risk for *Campylobacter* infections in humans? Acta Vet. Scand. Suppl. 95: 85-87.
- EUROSTAT (2006). http://www.organic-europe.net/europe_eu/statistics-eurostat.asp#tables; Search performed in January 2009.
- FERRANTE, V., BAROLI, D., LOLLI, S. and DI MAURO, F. (2008). Broilers welfare, health and production in organic and conventional systems. 16th IFOAM Organic World Congress, Modena, Italy, June 16-20, 2008. Archived at http;//orgprints.org/view/projects/conference.html.

- FIDDES, M.D., LE GRESLEY, S., PARSONS, D.G., EPE, C., COLES, G.C. and STAFFORD, K.A. (2005). Prevalence of the poultry red mite (*Dermanyssus gallinae*) in England. Veterinary Record 157: 233-235.
- FIKS, T.G.C.M., REUVEKAMP, B.F.J. and LANDMAN, W.J.M. (2002). Pluimveehouderij 33(2): 10-11.
- FÜRMETZ, A., KEPPLER, C., KNIERIM, U., DEERBERG, F. and HESS, J. (2005). Laying hens in a mobile housing system – Use and condition of the free-range area. In: Hess, J., Rahmann, G. (Eds) Ende der Nische, Beiträge zur 8. Wissenschaftstagung Ökologischer Landbau, Kassel, p. 313.
- GORDON, S. (2002). Effect of breed suitability, system design and management on welfare and performance of traditional and organic table birds. http://orgprints.org/8104/.
- HÄNE, M. (1999). Legehennenhaltung in der Schweiz. Schlussbericht BVET Forschungsprojekt 2.97.1. 164pp.
- HAUSER, J., ZELTNER, E. and HIRT H. (2003). Rearing of Laying Hens in Free Range Systems: Can the Use of the Hen Run be Improved by Scattering Grains Outside? In: Aktuelle Arbeiten zur artgemässen Tierhaltung 2002, KTBL-Schrift 418: 37-44.
- HECKENDORN, F., HAERING, D.A., AMSLER, Z. and MAURER, V. (2009). Do stocking rate and a simple run management practice influence the infection of laying hens with gastrointestinal helminths? Veterinary Parasitology 159: 60-68.
- HEGELUND, L., KJAER, J., KRISTENSEN, I.S. and SØRENSEN, J.T. (2002). Use of the outdoor area by hens in commercial organic egg production systems. Effect of climate factors and cover In: 11th European Poultry Conference – Abstracts. Archiv für Geflügelkunde 66: 141-142.
- HEUER, O.E., PEDERSEN, K., ANDERSEN, J.S and MADSEN, M. (2001). Prevalence and antimicrobial susceptibility of thermophilic Campylobacter in organic and conventional broiler flocks. Letters in Applied Microbiology 33: 269-274.
- HIRT, H., HÖRDEGEN, P. and ZELTNER, E. (2000). Laying hen husbandry: group size and use of hen-runs. In: Alföldi, T. Lockeretz, W. & Niggli, U. (Eds) Proceedings 13th International IFOAM Scientific Conference, Basel, 363.
- HÖGLUND, J., NORDENFORS, H., and UGGLA, A. (1995). Prevalence of the poultry red mite, *Dermanyssus gallinae*, in different types of production systems for egg layers in Sweden. Poultry Science 74: 1793-1798.
- HUBER, H.U. (1987). Untersuchungen zum Einfluss von Tages- und Kunstlicht auf das Verhalten von Hühnern. Ph. D. Thesis, ETH Zürich.
- JAVED, I. AKHTAR, M. S., RAHMAN, Z. U., KHALIQ, T. and AHMAD, M. (1994). Comparative anthelminthic efficacy and safety of Caesalpinia crista seed and piperazine adipate in chickens with artificially induced Ascaridia galli infection. Acta Veterinaria Hungarica 42(1): 103-109
- KJAER, J., SØRENSEN, P.and SU, G. (2001). Divergent selection on feather pecking behaviour in laying hens. Applied Animal Behaviour Science 71: 229–239.
- KJAER, J. and SØRENSEN, P. (2002). Feather pecking and cannibalism in free-range laying hens as affected by genotype, dietary level of methionine + cystine, light intensity during rearing and age at first access to the range area. Applied Animal Behaviour Science 76: 21-39.

- KNIERIM, U., STAACK, M., GRUBER, B., KEPPLER, C., ZALUDIK, K. and NIEBUHR, K. (2008). Risk factors for feather pecking in organic laying hens – starting points for prevention in the housing environment. 16th IFOAM Organic World Congress, Modena, Italy, June 16-20, 2008. Archived at http;//orgprints.org/view/projects/conference.html.
- LAL, J., CHANDRA, S., RAVIPRAKASH, V. and SABIR, M. (1976). In vitro anthelmintic action of some indigenous medicinal plants on Ascardia galli worms. Indian J Physiol Pharmacol 20(2): 64-8.
- LEE, M:D. and NEWELL, D.G. (2005). Campylobacter in poultry: filling an ecological niche. Avian Diseases 50: 1-9.
- LUND, V. and ALGERS, B. (2003). Research on animal health and welfare in organic farming – a literature review. Livestock Production Science 80: 55-68.
- MAURER, V., BAUMGÄRTNER, J., BIERI, M. and FÖLSCH, D.W. (1993). The occurrence of the chicken mite *Dermanyssus gallinae* (Acari: Dermanyssidae) in Swiss poultry houses. Mitteilungen der Schweizerischen Entomologischen Gesellschaft 66: 87-97.
- MAURER, V., HOERDEGEN, P. and HERTZBERG, H. (2007). Reducing anthelmintic use for the control of internal parasites in organic livestock systems. In: Cooper, J., Niggli, U. and Leifert, C. (eds.). Handbook of Organic Food Safety and Quality. Woodhead Publishing Limited, Cambridge, England. Pp. 221-240.
- MAURER, V., PERLER, E. and HECKENDORN, F. (2009a) *In vitro* efficacies of oils, silicas and plant preparations against the poultry red mite *Dermanyssus gallinae*. Experimental and Applied Acarology, in press. doi: 10.1007/s10493-009-9254-2
- MAURER, V., AMSLER, Z., PERLER, E. and HECKENDORN, F. (2009b). Poultry litter as a source of gastrointestinal helminth infections. Veterinary Parasitology, in press. doi:10.1016/j.vetpar.2009.01.020
- MENZI, H., SHARIATMADARI, H., MEIERHANS, D. and WIEDMER, H. (1997). Nähr- und Schadstoffbelastung von Geflügelausläufen. Agrarforschung 4: 361-364.
- NICOL, C.J., PÖTZSCH, C., LEWIS, K. and GREEN L.E. (2003). Matched concurrent case-control study of risk factors for feather pecking in hens on free-range commercial farms in the UK. British Poultry Science 44: 515-523.
- NIELSEN, B.L. (2003). The relationship between breast blisters and the availability and use of perches by organic broilers. In Ferrante, Valentina, (Ed.) Proceedings of the 37th International Congress of the ISAE (International Society for Applied Ethology), Abano Terme, Italy, June 24-28, 2003, pp. 122-122.
- O'BRIEN, J., ASPRAY, C. and PHILIPPS, L. (2006). Research and development into the viability of a one hundred per cent organic ration for organic table birds within a silvo-poultry system . Joint Organic Concgress, Odense May 2006. Archived at http;//orgprints.org/view/projects/conference.html.
- PERMIN, A., BISGAARD, M., FRANDSEN, F., PEARMAN, M., KOLD, J. and NANSEN, P. (1999). Prevalence of gastrointestinal helminths in different poultry production systems. British Poultry Science 40: 439-443.
- RODENBURG, T.B., VAN DER HULST-VAN ARKEL, M.C. and KWAKKEL, R.P. (2004).Campylobacter and Salmonella infections on organic broiler farms. Netherlands Journal of Agricultural Science 52: 101-108.

- RUIS, M.A.W., COENEN, E., VAN HARN, J., LENSKENS, P. and RODENBURG, T.B. (2004). Effect of an outdoor run and natural light on welfare of fast growing broilers. In: Hänninen, L., Valros, A. (Eds), Proceedings of the 38th international congress of the ISAE, Helsinki, p.255.
- SHIRLEY, M.W., SMITH, A.L. and TOMLEY, F.M. (2005)..The biology of avian Eimeria with an emphasis on their control by vaccination. Advances in Parasitology 60: 285-330.
- SINGH, K. and NAGAICH, S. (1999). "Efficacy of aqueous seed extract of Carica papaya against common poultry worms Ascaridia galli and Heterakis gallinae." Journal of Parasitic Diseases 23(2): 113-116.
- SINGH, K. and NAGAICH, S. (2000). Studies on the anthelmintic activity of Allium sativum (Garlic) oil on common poultry worms Ascaridia galli and Heterakis gallinae. Journal of Parasitology and Applied Animal Biology 9 (1): 47-52.
- SINGH, K. and NAGAICH, S. (2002). Anthelmintic efficacy of the alcoholic extract of Ocimum sanctum against common poultry worms Ascaridia galli and Heterakis gallinae. Journal of Parasitic Diseases 26(1): 42-45.
- SØRENSEN, P. (2001). Breeding strategies in poultry for genetic adaptation to the organic environment. In: The 4th NAHWOA Workshop, Wageningen, 24–27 March.
- WINCKLER, C., TECHNOW, H.J. and ELBE, U. (2004). Outdoor range use of individual laying hens. In: Hänninen, L., Valros, A. (Eds), Proceedings of the 38th international congress of the ISAE, Helsinki, p.210.
- ZELTNER, E. and HIRT, H. (2008). Factors involved in the improvement of the use of hen runs. Applied Animal Behaviour Science 114: 395-408.
- ZELTNER, E. and HIRT, H. (2003). Effect of artificial structuring on the use of laying hen runs in a free-range system. British Poultry Science 44: 533-537.
- ZOLLITSCH, W. and BAUMUNG, R. (2004). Protein supply for organic poultry: options and shortcomings. In Hovi, S., Sundrum, A. and Padel, S. Diversity of Livestock Systems and Definition of Animal Welfare, Proceedings of the 2nd SAFO Workshop 25-27 March 2004, Witzenhausen, Germany. University of Reading.