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Economic, ecological, and social performance of conventional and organic broiler production in the Netherlands — Source link

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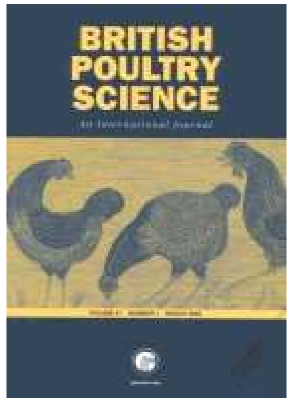

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Economic, ecological, and social performance of conventional and organic broiler production in the Netherlands

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Abstract

1. In this study, we compared a conventional broiler production system keeping fast growing broilers with an organic broiler production system keeping slow growing broilers in the Netherlands, both managed by one person working a full time year (Full Time Equivalent, FTE). This comparison was based on a quantification of economic, ecological and social indicators. Indicators were quantified using scientific literature and national data sets.

2. The organic system performed better for the economic indicator net farm income per FTE than the conventional system.

3. Regarding ecological indicators, calculations showed a higher on-farm emission of ammonia per kg live weight for the organic system. Moreover, an organic system includes a higher risk for eutrophication per ha due to outdoor access. Emission of green house gasses, use of fossil fuels and use of land required for the production of one kg of live weight is higher for an organic than for a conventional system. This is mainly due to a lower feed conversion in organic production and use of organic feed.

4. The organic system performed better than the conventional system for the social indicators related to animal welfare time spent on walking, footpad lesions, mortality, and sound legs. Regarding the social indicator food safety was found that meat from an organic system contained less antibiotic residues and Salmonella contaminations but more Campylobacter contaminations than meat from a conventional system.

5. Changing from a conventional to an organic broiler production system, therefore, not only affects animal welfare, but also affects economic, ecological and other social issues. In this study, we ran into the situation that some information needed was lacking in literature and quantifications had to be based upon several sources. Therefore, an integrated on-farm assessment is needed, which can be used to develop a broiler production system that is economically profitable, ecologically sound, and acceptable for society.

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5. INTRODUCTION

Selective breeding for high growth rate and low feed conversion in broilers has been succesful, but selection impairs animal welfare due to health problems and behavioural changes (Savory, 2002; Bokkers and Koene, 2003; Turner *et al.*, 2003). A modern broiler grows on average from 40 g to 2100 g in about 6 weeks. This high growth rate is different for different body parts (Nestor *et al.*, 1985; Havenstein *et al.*, 2003), which creates skeletal-biomechanical imbalances (Lilburn, 1994; Corr *et al.*, 2003a, 2003b) and increases susceptibility to metabolic disorders (Scheele, 1996; Gonzales *et al.*, 1999; Havenstein *et al.*, 2003).

Time spent on different behaviours has changed in fast growing broilers compared with other lines (Bokkers *et al.*, 2000; Bokkers and Koene, 2003), while the normal behavioural repertoire of a chicken has maintained. Incidence of several behaviour patterns decreases with increasing age and body weight. In addition, many behaviour patterns are performed increasingly in a sitting posture instead of a standing posture with increasing age (Weeks *et al.*, 1994; Reiter and Kutritz, 2001; Bokkers and Koene, 2003).

Fast growing broilers are the most common lines kept for chicken meat production. There are, however, slow growing lines that are also kept for chicken meat production. Roughly, there are two types of slow growing broilers: “medium” and “normal”. Medium-slow growers grow to a slaughter weight of 2100 g in about 8 weeks whereas normal slow growers need 12 weeks to reach the same slaughter weight. Because of their lower growth rate, slow growing broilers are presumed to have fewer health and physical problems than fast growing broilers. In the Netherlands, slow growing broilers are kept mainly for organic chicken meat production. In organic broiler production, birds are kept at a lower stocking density than in conventional broiler production. Stocking density is seen, in addition to high growth rate of the used lines, as one of the factors for welfare problems in conventional broiler production (EU, 2000;

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Regarding behaviour of fast growing broilers was found that not the behavioural repertoire, but time spent on different behaviours has changed compared to other genotype chicks

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Hall, 2001). A high stocking density reduces freedom of movement, and affects litter and air quality negatively (Bessei, 2006).

A decision to introduce an organic broiler production system that includes keeping slow growing broilers at a low stocking density is expected to affect the welfare status positively. Such a decision in favour of welfare, however, also has economic, ecological, and other social consequences, as shown, e.g., in egg production systems (Mollenhorst *et al*., 2006). Organic regulations, for example, determine that animals should have outdoor access for a certain period of their life or of the year. In addition to improved animal welfare, such regulations may have negative environmental consequences, such as, higher ammonia volatilisation or nitrogen leaching (Hermansen *et al*., 2004). Making a well-reasoned, holistic consideration whether one production system contributes more to sustainable development than another, therefore, requires comparison of the economic, ecological, and social performance of both production systems. In our case, the contribution to sustainable development of a conventional broiler production system and an organic broiler production system should be assessed. In this study, we compared the combined economic, ecological, and social performance of a defined conventional broiler production system with a defined organic broiler production system.

METHODOLOGY

The four step methodology used in this study was based on ideas of Bell and Morse (1999) and was developed further by Mollenhorst and De Boer (1999). This methodology has been used to evaluate the economic, ecological, and social (EES) performance of different egg production systems (Mollenhorst *et al*., 2006) and seems suitable to evaluate the EES performance of broiler production systems. The methodology consists of four steps: 1) description of the problem situation and definition of the systems, 2) identification of relevant economic, ecological, and social

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Fast growing broilers are the most common genotypes that are kept for poultry meat production. There are, however, broilers selected especially to grow slower. Slow growing broilers are presumed to have less health and physical problems than fast growing broilers. Roughly, there are two types of slow growing broilers. Medium slow growers grow to slaughter weight in about 8 weeks while "normal" slow growers grow to slaughter weight in 12 weeks. In the Netherlands, slow growing broilers are kept mainly for organic poultry meat production. In organic broiler production birds are kept at a much lower stocking density than in conventional broiler production. Stocking density is seen as an important cause of welfare problems in conventional broiler production, besides the unilateral genetic selection

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A decision to introduce slow growing broilers in a production system and keeping them at a low stocking density is expected to affect the welfare status positively. Such a measure in favour of welfare, however, also has economic, ecological and other societal consequences as shown by Mollenhorst et al.

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issues, 3) selection and quantification of indicators for each issue, and 4) final assessment of the contribution of production systems to sustainable development.

Step (1): Description of the problem situation and defining the systems

The first step requires a description of the problem situation and definition of the systems. The problem situation was described in the introduction. The systems were a defined conventional broiler production system and a defined organic broiler production system, each managed by one person working a full-time year (Full Time Equivalent, FTE). Both systems were characterised by production, housing, and management, with related inputs and outputs (see below the section on definition of production systems).

Step (2): Identification and definition of economic, ecological and social issues

The second step implies the selection of EES issues relevant for sustainable development of a broiler production system. Based on recent assessment studies (Mollenhorst and de Boer, 2004; van Calker *et al.*, 2004), we selected nine EES issues: profitability of the farm, acidification of the soil, eutrophication of terrestrial and aquatic ecosystems, use of fossil fuels, land use, animal welfare (including animal health), food safety, product quality and working conditions. These nine EES issues will be discussed in this study.

Step (3): Selection and quantification of indicators

The third step involves the selection and quantification of indicators for the selected EES issues. An indicator, which is a parameter that quantifies the status of an issue, is needed for each EES issue. For the comparison of production systems, we selected the best available indicators using six criteria: relevance, simplicity, sensitivity, reliability, trend/target, accessibility of data (Mitchell *et al.*, 1995; de Boer and Cornelissen, 2002; Mollenhorst *et al.*, 2006). The selected indicators for the comparison of the conventional and the organic broiler production system were quantified based on scientific literature and data bases of Dutch institutes: the

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Agricultural Economic Research Institute, the Ministry of Agriculture, Nature and Food Quality, the Product Boards of Livestock, Meat and Eggs, and Statistics Netherlands.

For social issues, we selected comparative studies for conventional and organic broiler production. In some cases, however, studies were used that compared fast and slow growing broilers where the slow growing broilers were not kept within the organic constraints. For economic and ecological performance, we used average values from handbooks for animal production (KWIN, 2003-2004, 2006) and data from literature to derive new computations for the indicators. Selection and quantification of indicators is described for each issue (see below).

Step (4): Final assessment of the contribution to sustainable development

In the fourth step, information from all indicators is combined to determine the final outcome of the contribution of the system to sustainable development. This step is considered in the general discussion section.

ECONOMIC PERFORMANCE

Net farm income is the best indicator for economic performance of a farm (van Calker *et al*., 2005). Net farm income is defined as the difference between revenues and costs, excluding costs of family labour (van den Tempel and Giesen, 1992). To estimate economic performance, we must first describe the system and the year in which the computations were based. A conventional broiler production system (further called conventional system) was compared with an organic broiler production system (further called organic system), both managed by one FTE in 2003. For this study, it was assumed that both systems use an all-in all-out procedure to start and finish a production round. An all-in all-out procedure means all birds within a production round at a farm arrive and leave the farm at the same day.

Definition of the production systems

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In the conventional system, one FTE can manage 70,000 birds (KWIN, 2003-2004). Stocking density is 22 birds per m^2. A production round takes 53 days (43 days growing birds, 10 days empty), which means about seven production rounds per year (365/53). Houses are lighted artificially and the climate is controlled with heaters and mechanical ventilation. Water is provided by drinking nipples and feed by automatically filled open feeders. The floor is covered with wood shavings (Rodenburg and van Harn, 2004).

In the organic system, one FTE can manage a maximum of 16,000 birds, which have to be kept in several houses. Stocking density is a maximum of 10 birds per m^2 on a total useful floor area of 1,600 m^2 (EU, 1999). The maximum number of birds per house is 4,800 (EU, 1999). According to the Council Regulation 1804/1999, it is not allowed to slaughter organic broilers before 81 days of age, unless slow growing lines are used (EU, 1999). Because only slow growing lines are used in practice, organic broilers are slaughtered around 70 days of age. Organic broilers are kept in houses with natural ventilation and natural daylight, supplemented by artificial light (Rodenburg and van Harn, 2004). In the beginning of the growing period, houses are heated according to a similar temperature schedule as used in a conventional system. Throughout the growing period, water is provided in open drinkers and feed is available in open feeders that are filled by hand. The floor is covered with chopped straw (Rodenburg and van Harn, 2004). Feed for organic broilers must be GMO-free, and finisher feed should contain at least 65% cereals. Furthermore, 85% of the dry matter of the feed must be of organic origin, and antimicrobial growth promoters and anticoccidials are not allowed. An overview of technical data for both systems that is used for the economic computations is in Table 1.

INSERT TABLE 1

Data and assumptions for economic calculations

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For the conventional system, calculation of net farm income was based on intensive animal production in the Netherlands (KWIN, 2003-2004; 2006), whereas for the organic system calculation of net farm income was based on data of Vermeij (2004) (Table 2). Vermeij (2004) made several assumptions for the organic system because data were lacking. These assumptions are summarised. Water intake is related to feed in a ration of 1.8:1. Water intake of a broiler was 7 l in 43 days, so water intake was assumed to be 11.5 l in 70 days. Costs for health care were expected to be higher for an organic system than for a conventional system because extra vaccinations are necessary due to outdoor access. Costs per bird for electricity were expected to be lower than in a conventional system due to natural ventilation and natural daylight. a Although a similar amount of energy is used in both systems to heat one m^3 of air, heating costs per bird were expected to be higher in an organic system than in a conventional system. This difference was expected because in an organic system fewer birds are kept per m^2, which makes it more expensive to heat the building when expressing the costs per bird. Costs per bird for bedding were higher in an organic than in a conventional system, because more litter is used per square meter and birds are kept in a lower stocking density. Costs for catching and loading the birds for slaughter were higher for an organic system due to smaller flocks. Costs for legal animal health levies collection service for dead animals were similar for both systems. Manure transport for the conventional system was based upon a farm with no land. Because there is a manure surplus in the Netherlands, the removal of manure from the farm involves costs. This situation is different for an organic system. There was enough demand for organic poultry manure that no costs for manure removal and transport needed to be taken into account.

INSERT TABLE 2

Final economic calculations

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Final economic calculations are summarised in Table 3. Regarding the variable and fixed costs, some additional comments are needed. Feed costs were calculated according to the formula: FC x (BS+0.5BD), whereas FC is feed consumption per bird, BS is the number of birds that reached the slaughterhouse alive, and BD is the number of birds that died during the production round. Feed consumption of BD is multiplied by a half to estimate the amount of feed consumed by birds that died at different moments of the production round.

For the conventional system, investment costs were estimated 180 EUR per m^2 for the building and 70 EUR per m^2 for the inventory (KWIN, 2003-2004). For the organic system, investment costs were estimated 160 EUR per m^2 for the building and 30 EUR per m^2 for the inventory (Vermeij, 2004).

For the conventional system, depreciation for the building was 3.5% and for the organic system, it was 3%. Maintenance costs for the building were 1% for both systems. Costs for depreciation (6.5%) and maintenance (2%) for the inventory were similar for both systems (KWIN, 2003-2004).

Investments for the outdoor run in the organic system were 37,400 EUR per ha. Costs for the outdoor run were based on interest (0.09 EUR per m^2), costs for fencing and furniture (0.025 EUR per m^2), and maintenance (0.02 EUR per m^2) (Vermeij, 2004). Organic production has to answer to special regulations that are controlled by the independent organisation “Skal” in the Netherlands. Levies for Skal were based on an annual fee of 260 EUR and an additional 0.05 EUR per bird (Skal, 2004). Finally, costs for accounting, insurances, telephone, clothing, contributions, etc, were expected to be similar for both systems.

INSERT TABLE 3

Discussion on the economic calculations

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Although price per kg of meat was lower for the conventional system than for the organic system, total revenues were higher because of more birds per production round (70,000 vs 16,000) and more production rounds per year (6.9 vs 4.6). More birds and production rounds, however, also meant more total costs (689 vs 265 kEUR). The main contributors to the higher costs in the conventional system were feed (399 vs 165 kEUR) depreciation (45 vs 14 kEUR), and manure transport (12 vs 0 kEUR). As a result, net farm income was higher in the organic system (73 kEUR) than in the conventional system (7 kEUR). Economic results, however, depend heavily on market prices and feed costs. In the future, for example, when the consumer market for organic broiler meat increases, production will increase as well. The whole production chain will get more professional and therefore more efficient. Consequently, prices and costs will decrease. It is difficult to predict whether an organic broiler farmer can make a profit in that case.

Economic calculations were based on several assumptions. One assumption was that all parts of the organic birds were sold as organic meat. In reality, however, it is hard to sell all parts as organic meat, especially in the Netherlands, where many consumers buy only specific fresh chicken parts, such as breasts and legs instead of a whole chicken. The market for other fresh chicken parts is variable in the Netherlands. Unsold parts will be processed by the food industry or exported, in many cases as conventional meat, which reduces profits for the farmer. Furthermore, the market for organic products is small. High prices for organic meat compared with conventional meat and limited availability in supermarkets account for the limited demand by consumers for organic products (Tacken *et al.*, 2007).

In addition, the farm size for the organic system is large compared with the average farm size, which is around 3,200 birds per farm. Consequently, most farmers with an organic system need to have a second source of income. The low net farm income of the conventional system corresponded to reality, because conventional

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broiler production has not been very profitable in the Netherlands recent years (Bolhuis and Wisman, 2007).

ECOLOGICAL PERFORMANCE

The environmental performance of a broiler production system can be quantified by assessing the impact of that system on acidification of the soil, eutrophication of terrestrial and aquatic ecosystems, and on climate change, and by measuring its use of land and fossil fuels (de Boer, 2003). There are more issues related to ecological performance, such as human toxicity, terrestrial and aquatic eco-toxicity, biodiversity, soil quality, and water use that are affect by a production system. These issues, however, were not addressed in this study, because there is no generally accepted and validated assessment method or because required data were not available (Thomassen, 2008).

Acidification and eutrophication

The computation in this section could not be based upon the technical data as given in Table 1, because relevant data were lacking. Computations were done for the conventional system and the organic system, in which broilers reach slaughter weight in 43 days and 81 days, respectively.

Ammonia (NH_3) emission from animal manure is a major contributor to acidification (Groot Koerkamp, 1994). The NH_3 emission per kg live weight, therefore, is a relevant indicator for acidification (Thomassen and de Boer, 2005). Conventional broilers on litter emitted on average 11.2 mg per h, which is 0.08 kg NH_3 per bird place per year (0.08 kg = 11.2 mg/h/bird x 24 h x (365/53) rounds x 43 days of life)/1,000,000) (Groot Koerkamp *et al.*, 1998). This value is used as the emission factor for broilers in the Netherlands (VROM, 2002). Assuming a live weight of 2.1 kg per bird, 5.5 g NH_3 volatilises per kg of live weight annually. For an organic system, the NH_3 emission per bird place per year is unknown. A conventional broiler, however,

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produces 1.275 kg manure in 43 days (Oenema *et al.*, 2000), whereas an organic broiler produces 3.4 kg per bird in 81 days (Gordon and Charles, 2002). Annually, therefore, a conventional broiler produces 8.8 kg of manure (1.275 x 365/53), whereas an organic broiler produces 13.6 kg (3.4 x 365/91). In addition, a conventional broiler excretes 0.543 kg N per bird place per year (Groenestein *et al.*, 2005), which converts to 6.1% of total manure production. An organic broiler excretes 0.843 kg N per year, assuming a similar N percentage in manure.

The NH_3 emission of a conventional broiler was 0.08 kg NH3 per bird place per year, or 0.066 kg N. Assuming a similar NH_3 emission factor of 12.1% (100 x 0.066/0.543), the NH_3 emission of an organic broiler is 0.10 kg N per bird place per year. Based on a live weight of 3.050 kg at 81 days, 8.3 g NH_3 volatilizes per kg of live weight annually. Hence, annual NH_3 emission per kg of live weight is 51% higher for an organic system than for a conventional system.

The previous computation was based on the assumption that the N content of manure, and its related NH_3 emission factor, were equivalent for conventional and organic systems. The N content of manure depends mainly on the composition of the feed, and composition of the feed does not need to be different between the conventional and the organic system. The NH_3 emission factor, however, depends on the housing system, stocking density, air temperature and velocity, and pH of manure (Groot Koerkamp, 1994). No information is available, however, to quantify the influence of these factors on NH_3 emission.

Organic broilers must have an outdoor run for at least one third of their life (EU, 1999), which might also influence the NH_3 emission factor. Emission of NH_3 in the outdoor run depends on the time broilers spend outside, which itself depends on conditions, such as weather, season, temperature, facilities, and experience of the broilers. The influence of an outdoor run on NH_3 emission is unknown, and requires further research. Besides its contribution to acidification, an outdoor run carries a risk to ecology regarding eutrophication through leaching of excess of nitrate and phosphate.

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It was found that 3,000 laying hens that could be outdoor from 11:00 h till sunset at an organic commercial farm produced on average 2,845 kg N per ha per year (Aarnink *et al.*, 2006), which is higher than the legal limit of 170 kg N per ha per year (EU, 1991). Furthermore, a large part of this manure was dropped close to the hen house, resulting in an even increased risk for eutrophication. No such data exist for broilers with an outdoor run, but it is clear that there is a risk for eutrophication in organic broilers.

Fossil-fuel use and climate change

Regarding use of fossil fuels, we distinguished between direct and indirect use. Direct use includes use of oil, gas, and electricity on the broiler farm, whereas indirect use includes use of fossil fuels for production and transport of farm inputs, such as concentrates. In a conventional system, 25% of the total use of fossil fuels is direct use of electricity and gas at the farm, whereas 70% is indirect use for cultivation and transport of concentrates (Spedding *et al.*, 1983; Vermeij, 2004). In a conventional system, direct use is electricity for mechanical ventilation and for lightning of the stable, on average about 0.15 kWh per bird per day (Dyer and Desjardins, 2006). In an organic system, natural ventilation is used and artificial light is used only in winter (Rodenburg and van Harn, 2004). Therefore, electricity use was estimated to be 50% lower for an organic compared with a conventional system (Vermeij, 2004). In addition to electricity, a conventional system uses on average 0.09 m^3 gas for heating during the first 3 weeks of production to maintain the body temperature of young chicks (Vermeij, 2004). In an organic system, however, the amount of fossil fuels required for heating is expected to double due to the lower stocking densities (Vermeij, 2004). Overall, the direct use of fossil fuels is expected to be 25% higher for an organic system compared with a conventional system (Vermeij, 2004).

Indirect use for fossil fuels required for the cultivation and transport of feed ingredients account for around 70% of the total use of fossil fuels. Concentrate composition and feed conversion, therefore, are useful measures for indirect use of

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fossil fuels. Feed conversion (kg feed/kg gain) is 1.76 for the conventional system and 2.45 for the organic system (KWIN, 2003-2004; Vermeij, 2004). Indirect use of fossil fuels is expected to be higher in an organic system compared with a conventional system, due to this higher feed conversion. This expected increase, however, might be partly compensated for with lower use of fossil fuels for transport of feed ingredients due to the use of locally grown feed. Overall, total energy use per kg of live weight varies in literature between 8.4–17 MJ for conventional production (Ellendorff, 2002; Williams *et al.*, 2006; Blonk *et al.*, 2007). For organic production, total energy use per kg of live weight is estimated to be 30-59% higher (Ellendorff, 2002; Williams *et al.*, 2006; Blonk *et al.*, 2007).

Worldwide, the main green houses gasses (i.e. gasses that contribute to climate change) related to animal production are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (de Boer, 2003). Emission of CO_2 is related to combustion of fossil fuels and deforestation. Methane emission in broiler production results from manure only. Enteric methane emission from poultry is assumed to be negligible (IPCC, 2006). Nitrous oxide emission results mainly from application of fertilizer during cultivation of feed ingredients. For conventional production, emission of green house gases per one kg of live weight of chicken is estimated at 2-3.2 kg expressed in CO_2 units (IPCC, 2006; Williams *et al.*, 2006). These estimates include green house gas emissions on the broiler farm and emissions during the production of transport of farm inputs, such as concentrates (i.e. off-farm emissions). For organic production, emission of green house gases is estimated to be 50% higher (Williams *et al.*, 2006). The lower feed conversion and use of organic feed explain the higher emission of green house gases in organic production.

Land use

Land use (on and off-farm) in broiler production is reported to be 5.0 m^2 per kg of meat in a conventional system (Blonk *et al.*, 2007). For organic production, land use is

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estimated to be 92-119% higher (Williams *et al.*, 2006; Blonk *et al.*, 2007). This difference between the conventional and organic system is because organic broilers were fed organic feed. The harvest per hectare of organically grown crops is generally lower than that of conventionally grown crops. Hence, more land is used to produce for 1 kg of feed in an organic system than in a conventional system. Another factor that might influence land use per kg of broiler meat is the feed conversion, which is higher in organic than in conventional broilers. The more feed that is needed to produce 1 kg of meat, the more land is needed for the production of feed.

SOCIAL PERFORMANCE

Animal welfare

The Farm Animal Welfare Council (1992) formulated five freedoms that define ideal states for animal welfare: 1) freedom from hunger and thirst; 2) freedom from discomfort; 3) freedom from pain, injury or disease; 4) freedom to express normal behavior; 5) freedom from fear and distress. Mollenhorst *et al.* (2006) showed that behavioural studies provide relevant indicators regarding not only freedom to express normal behaviour, but also freedom from discomfort, fear, and distress. In addition, to assess freedom from pain, injury or disease, indicators such as disease incidence or clinical observations appear relevant. From literature, we deduced the following five indicators for animal welfare in broilers: time spent on walking, percentage of birds with footpad lesions, gait score, percentage of birds with heart abnormalities, and mortality rate. Because behavioural and animal health studies with slow growing broilers are not always conducted within the constraints of organic production, it will be mentioned in this section whenever a study was done within the organic constraints.

Time spent on walking is used to judge physical abilities and capacities of a broiler. Slow growing broilers spent twice as much time on walking than fast growing

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broilers at 6 weeks of age (Weeks, 2002). At 5 weeks of age, slow growers walked 4.4% of their time, whereas fast growers walked 1.5% of the time, both housed with a stocking density of 20 birds per m^2 (Reiter and Kutritz, 2001). This finding is in accordance with results of Bokkers and Koene (2003), who kept broilers in a lower stocking density (4 birds per m^2) and found that slow growers walked 6.7% of the observed time at 6 weeks of age, whereas fast growers walked 2.0%. Percentage walking decreased to 5.8% in slow growers and to 1.2% in fast growers at 12 weeks of age. Time spent on walking is low in both fast and slow growers compared with chicks of a layer line (13.4% at 6 weeks of age) (Bokkers, not published).

Gait score is another way to study walking behaviour. Gait score has a six point scale: from 0 = no detectable walking abnormalities to 5 = incapable of sustained walking on its feet (Kestin *et al.*, 1992). A high gait score, therefore, means worse walking behaviour and consequently an indicator for impaired welfare. Average gait score was 0.25 for slow growering and 2.18 for fast growing female broilers at 78 days of age (Nielsen *et al.*, 2003). One percent of the slow growing line and 87% of the fast growing line had a gait score higher than 1 at that age (Nielsen *et al.*, 2003). Fast growing lines had a gait score of 2.9 at 54 days of age and 3.8 at 81 days, whereas slow growing lines had a gait score of 1.5 at 54 days of age and 2.0 at 81 days (Kestin *et al.*, 2001). Based on walking behaviour and gait scores, therefore, we concluded that walking performance was better in slow growing broilers than in fast growing broilers. Fast growing broilers seemed to be physically restricted but the motivation to walk was still present (Bokkers *et al.*, 2007), which can be interpreted as a situation of reduced welfare.

Footpad lesions affect welfare because they might cause pain. Unfavourable housing conditions, such as moisture and chemical irritants in the litter, were associated with footpad lesions (Ekstrand *et al.*, 1998). Stocking density, activity of the birds, and location in the house affected litter quality (Gordon, 1992; Su *et al.*, 2000; Tasistro *et al.*, 2004). Footpad lesions were found in 75.5% of fast growers and 1.5% in

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slow growers at 84 days of age (Nielsen et al., 2003). In addition, 78.3% of fast growers had footpad lesions at 40.5 days of age compared with 5.4% of medium-slow growers at 50 days (van Horne *et al.*, 2003). In the UK, 14.8% of conventional reared fast growing broilers had footpad lesions at 39 days of age, whereas 9.6% of medium-slow growing broilers had lesions at 49 days (Pagazaurtundua and Warriss, 2006). Rodenburg *et al.* (2004) found more footpad lesions in fast growing (88.5% at 41 days of age) and medium-slow growing (16% at 55 days of age) broilers with a roofed outdoor run than in fast growing (83.5% at 41 days of age) and medium-slow growing (11.5% at 55 days of age) broilers that were kept indoors. In both situations, the fast growing broilers had a higher prevalence than the medium-slow growing broilers.

In an organic broiler production system a prevalence of footpad lesions of 98.1% was found at 70 days of age (Pagazaurtundua and Warriss, 2006). A higher age and the outdoor run were associated with this high prevalence of footpad lesions. So, it appeared that results of different studies are contradictorily because footpad lesions appeared more frequently in fast growing broilers, but an outdoor run – as compelled in an organic broiler production system - also has negative consequences.

Heart abnormalities in broilers are associated with growth and, therefore, are a useful indicator for welfare. Heart abnormalities were found more frequently in fast growers (22.0%) than in slow growers (4.3%) at 12 weeks of age (Bokkers and Koene, 2003). Mortality due to cardiovascular disorders was higher in fast growers (2.1%) kept until 42 days of age than in medium-slow growers (0.4%) kept until 56 days of age (van Horne *et al.*, 2003).

In animal production, mortality is the ultimate consequence of a failing biological-adaptation mechanism. Mortality, therefore, is an indirect or cumulative animal welfare indicator. Mortality rate at commercial farms averages 4% for conventional systems after 43 days (KWIN, 2006) and 3% for organic systems after 70 days (Tacken *et al.*, 2003; Vermeij, 2004). In two experiments, mortality rate for fast growers averaged 4.8% at 42 days of age and for medium-slow growers averaged

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1.5% at 56 days of age (van Horne *et al.*, 2003). Cause of death, such as heart failure, is not well documented, in contrast to the number of deaths.

Food safety

Food safety refers to substances or organisms that unintentionally contaminate food and that are a health risk to the consumer. Broiler products mainly hold the risk of being contaminated with antibiotic residues, and the bacteria *Campylobacter* spp., and *Salmonella* spp.

Using antibiotics in animal production results in a high risk of organisms developing resistance to antibiotics, especially when these organisms are infectious for animals and humans. Resistance may occur when medicines such as tetracyclines and quinolones are used in animals and humans (Kramer *et al.*, 2003). In a Dutch study, residues of antibiotics were found in 8.3% broiler product samples of a conventional system, whereas there were found in 0% broiler products samples of an organic system (Kramer *et al.*, 2003). None of the samples exceeded the legal maximum residue level as laid down by the European Union (Kramer *et al.*, 2003). Samples of broiler products of both conventional and organic systems contained bacteria strains with resistance to several antibiotics (van der Zee *et al.*, 2005). Samples of conventional system broiler products, however, showed a higher resistance and a resistance to more antibiotics than samples of an organic system (van der Zee *et al.*, 2005). It seems, therefore, that meat from an organic system contains fewer residues of antibiotics and has less antibiotic resistant micro-organisms than from a conventional system.

Campylobacter spp. is a zoonotic pathogen of humans and an important cause of bacterial diarrhoeal disease worldwide (Humphrey, 2006). Broiler meat is considered one of the most important sources of *Campylobacter* spp. infection for humans (Altekruse *et al.*, 1994). Measurements to detect sources of risk can be conducted not only at farms, but also at broiler product outlets to assess the direct risk

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466 for consumers. The percentage of samples of fresh chicken products bought from
467 supermarkets, poulterers, and butchers across the Netherlands and over 2003-2004,
468 that were contaminated with *Campylobacter* spp. averaged 27.6% for a conventional
469 system and 40.1 for an organic system (van der Zee *et al.*, 2005). In another Dutch
470 study, there was no difference between Campylobacter presence in products of a
471 conventional system (43%) and an organic system (49%) (Kramer *et al.*, 2003).
472 Campylobacter presence at slaughter was 36.7% in birds of a conventional system and
473 100% in birds from an organic system (Heuer *et al.*, 2001), indicating a high risk for the
474 meat to be contaminated at slaughter, especially organic broiler meat.

475 *Salmonella* spp. are a second group of zoonotic pathogens for which broiler
476 meat is a major cause of infections (Humphrey, 2006), and meat from conventional
477 systems tend to be contaminated more often. The percentage of samples of fresh
478 broiler products taken over a whole year that were contaminated with *Salmonella* spp.
479 averaged 9.3% for a conventional system and 2.8% for an organic system (van der Zee
480 *et al.*, 2005). Salmonella contamination tended to be higher in conventional broiler
481 meat (8%) than in organic broiler meat (4%), although the difference was not significant
482 (Kramer *et al.*, 2003).

483 *Product quality*

484 There are many aspects of a food product that determine its quality, e.g., eating quality,
485 convenience, stability, wholesomeness, nutritive value (Erdtsieck, 1989). Because
486 eating quality is the most direct experience of a consumer, it is used often as a
487 measurement for product quality. Eating quality includes characteristics such as texture
488 (e.g., tenderness), appearance (e.g., colour), and flavour (taste and odour).

489 To be successful in an economic sense, a food product, in this case meat of a
490 broiler, should meet the preferences and expectations of the consumer. To test this,
491 consumers are asked to judge broiler products in blind tests. Farmer *et al.* (1997) used
492 8 trained panellists to compare breast and thigh meat from slow growing male broilers

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(4.25 birds per m^2, but birds were not kept according to organic regulations) at 83 days of age and fast growing male broilers (17 birds per m^2, conventionally kept) at 48 days of age. They found that the appearance of cooked breast meat from slow growers was more uniform in colour and had more visible moisture than from fast growers. They found also that the texture of breast meat from slow growers was less tough, fibrous, and resistant to the knife than that from fast growers. Results for the same indicators, however, were the opposite when judging the thigh meat. A consumer panel of 100 found that breast meat from medium-slow growers at 56 days of age was less juicy and tender, and tougher than breast meat of fast growers at 42 days of age (van Horne *et al.*, 2003). No difference was found for thigh meat. Another consumer panel of 90 found no difference for tenderness between breast meat of slow growing broilers with outdoor access and fast growing broilers kept indoor, both slaughtered at the same weight (Fanatico *et al.*, 2006). Juiciness of breast meat from fast growers kept indoors was judged better than from slow growers with access to outdoors.

Furthermore, breast meat from fast growers had a higher odour intensity than breast meat from slow growers (Farmer *et al.*, 1997). Breast meat of medium-slow growers, however, had a better odour and appearance than fast growers (van Horne *et al.*, 2003). In thigh meat the odour intensity, qualified as "chicken odour" and "abnormal odour", was higher in fast growers than in slow growers (Farmer *et al.*, 1997). Fast growers kept indoors scored a higher for flavour of thigh meat than slow growers with access to outdoors (Fanatico *et al.*, 2006), but Farmer et al. (1997) did not find such a difference for flavour.

In studies on product quality a large number of factors affect the outcome, such as age, genotype, sex and weight of the birds; feed, housing system, way of preparing the samples, and cultural background of the panellists. These factors were not similar between different studies, which makes a comparison between, and interpretation over studies hard. Product quality, nevertheless, can be a useful indicator when used carefully.

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Working conditions

Working conditions concern the farmer. Relevant indicators for working conditions include, for example, working hours, and number of physical and psychological complaints related to work (Dinten *et al.*, 2006; Mollenhorst *et al.*, 2006). Although there are a number of indicators regarding working conditions, there is little information on the effects of barn conditions on human health. No comparative studies were found regarding conventional and organic systems.

Several studies were conducted on the levels of dust and gaseous pollutants in broilers houses that might be detrimental for humans. Main sources of dust are from feed, litter, and the broilers themselves (Wathes, 2004). Dust can carry bacteria, viruses, and endotoxins (Takai *et al.*, 1998). Takai *et al.* (1998) discriminated between respirable dust (between 0.5 – 7 μm) and inhalable dust (between 7-20 μm). Amount of dust is dependent on time of day, time of production period, ventilation, moisture, animal activity, etc. In Dutch broiler houses, a mean concentration of 1.05 mg/m^3 respirable dust and of 10.4 mg/m^3 inhalable dust, and a mean concentration of 41 ng/m^3 respirable endotoxins and of 381 ng/m^3 inhalable endotoxins were found (Takai *et al.*, 1998). Dust and the attached endotoxins in the pig house caused disorders in the bronchi and lungs of the farmer (Donham *et al.*, 1984; Vogelzang, 1999; Von Essen *et al.*, 2005). Bongers *et al.* (1987) concluded that respiratory problems are found more frequently in farmers than in other professional groups.

Gaseous pollutants also affect working conditions. Ammonia, for example, irritates eyes and respiratory system. In the EU, the maximum acceptable concentration for ammonia is 50 ppm. For poultry houses, it is advised to keep ammonia concentration below 25 ppm, because above this level ammonia has a detrimental effect on the body weight gain of chickens (Miles *et al.*, 2004) and severity of clinical corneal lesions increased (Miles *et al.*, 2006). In the Netherlands, an ammonia concentration of 11.2 ppm was found in conventional broiler houses with

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peaks up to 40 ppm (Groot Koerkamp *et al.*, 1998), but no such studies were found for organic broiler production .

GENERAL DISCUSSION AND CONCLUSION

The objective of this study was to gain more insight into the contribution to sustainable development of two broiler production systems, conventional and organic, by quantifying issues related to economic, ecological, and social performance. Our results showed that economic performance was better for the organic system than for the conventional system, but that economic results depend on the market price for broiler meat and on feed costs. Data on economic performance, therefore, are valid for a specific time period and should be interpreted with care.

Regarding ecological performance, on-farm ammonia emission per kg live weight was higher in an organic system than in a conventional system. Because of the outdoor run, organic production has an increased risk for eutrophication. Moreover, emission of green house gasses, use of fossil fuels and land required for the production of one kg of live weight is higher for an organic than for a conventional system. This is mainly due to a lower feed conversion in an organic system and use of organic feed.

Regarding the social issue of animal welfare, many studies have been conducted that have lead to a variety of suitable indicators. Not all indicators are ready to use. Total mortality, e.g., is a good indicator, but detailed data are needed to be able to quantify causes of death properly. From these studies, we can conclude that slow growers in organic or extensive systems have better chances to maintain an acceptable level of welfare than fast growers in conventional systems.

Regarding the social issue of food safety, meat from an organic system was never found to be contaminated with antibiotics, in contrast to conventional system. In meat of both systems, however, antibiotic resistant organisms were found. The risk for Campylobacter contamination in broiler meat was higher in an organic system than in a

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conventional system, whereas the risk for Salmonella contamination was lower. In both systems, therefore, improvements can be made in relation to food safety.

Product quality has been found to be a difficult issue to quantify. Although several studies on product quality were found, results were difficult to compare and to interpret due to multi-factorial effects. In future studies more attention should be paid to these factors influencing product quality.

Finally, no data were found to quantify issues relating to working conditions. Indirect variables were described, and that could give an indication, but these variables were only available for a conventional system of broiler production.

Although assumptions had to be made for several issues, basically the methodology of Mollenhorst and De Boer (2004) was useful to assess sustainable development in these two defined broiler production systems. It has become clear now that the studied systems differ and what knowledge is lacking to make a good comparison for all issues. To increase our knowledge, a next step should be an integrated, on-farm assessment. By collecting data on farms, a quantification of all indicators should be possible. In that way, insight can be gained into how issues affect each other and thus into the trade-offs when taking measurements to innovate a broiler production system.

In conclusion, this study showed that changing to an organic broiler production system has consequences for more than only animal welfare. Although it is difficult to compare different indicators for each issue, it is necessary to study the contribution to sustainable development of all issues. An integrated on-farm assessment is needed to fill in the gaps. In this way a production system can be developed that is economically profitable, ecologically sound, and socially acceptable.

ACKNOWLEDGEMENT

We would like to thank Marieke Klaasen for her valuable help with collecting data and Mike Grossman for improving the English and the readability of this paper.

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Table 1: Technical data of a conventional and an organic broiler production system for 2003.

Technical data	Broiler production system	
	Conventional	Organic
Birds at the start of a round (number)	70,000	16,000
Duration of a round (days)	43	70
Empty for cleaning (days)	10	10
Rounds per year (number)	6.9	4.6
Space inside (birds per m^2)	22	10
Space outdoor (m^2 per bird)	0	4*
Mortality (%)	3.3	2.8
Birds slaughtered per round (number)	67,690	15,552
Slaughter weight (g)	2,100	2,600
Total delivered (kg per year)	980,828	186,002
Growth (g per day)	50.8	36.5
Feed conversion (kg feed per kg growth)	1.73	2.45
Feed intake per round (g per bird)	3,634	6,370
Water intake per round (l per bird)	7.0	11.5

*the outdoor run must be accessible at least ⅓ of their life

Source: conventional (KWIN, 2003-2004, 2006); organic (Vermeij, 2004)

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Table 2: Economic data of a conventional and an organic broiler production system for the year 2003.

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Economic data (EUR per bird)*	Broilers production system: Conventional	Broilers production system: Organic
Revenues	0.71	1.82
Purchase price chicks	0.27	0.50
Feed costs	23.15	35.75
Health care	0.045	0.120
Electricity	0.02	0.01
Heating	0.03	0.05
Water	0.010	0.016
Bedding	0.01	0.04
Catching and loading	0.04	0.05
Animal health levies	0.007	0.007
Carrion collecting service	0.002	0.002
Manure transport	0.0264	0.00
Interest livestock	0.0191	0.0191

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*Exept for EUR per kg meat for revenues and EUR per 100 kg for feed costs

Source: conventional (KWIN, 2003-2004, 2006); organic (Vermeij, 2004)

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842 Table 3: Annual economic performance of a conventional and an organic broiler
843 production system for 2003 in EUR per FTE.

Broiler production system	Conventional	Organic
Total revenues	**696387.95**	**338523.49**
Variable costs		
Feed	399,629.38	165,260.94
One-day-old chicks	130,410.00	36,800.00
Health care	21,735.00	8,832.00
Electricity	9,660.00	736.00
Heating	14,490.00	3,680.00
Water	4,830.00	1,209.14
Bedding	4,830.00	2,944.00
Catching and loading	19,320.00	3,680.00
Animal health levies	3,381.00	515.20
Carcass collecting service	966.00	147.20
Interest livestock	9,225.30	1,405.76
Total variable costs	**618,476.68**	**225,210.24**
Fixed costs		
Depreciation and maintenance of buildings	25,772.73	10,240.00
Depreciation and maintenance of inventory	18,931.82	4,080.00
Outdoor run	0.00	8,640.00
Manure transport	12,751.20	0.00
Control levies organic	0.00	3,940.00
Other fixed costs	13,000.00	13,000.00
Total fixed costs	**70,455.75**	**39,900.00**
Net farm income	**7,455.52**	**73,413.26**

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has much more consequences than

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. Although it is difficult to compare different indicators for each issue, it is necessary to

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the contribution to sustainable development of all relevant issues. An

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for that. In this way a production system

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English (U.S.), Do not check spelling or grammar

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, economic profitable and ecologically sound.

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in egg production systems. Organic regulations, for example, determine that animals should have outdoor access for a certain period of their life or of the year. This might have, next to improved animal welfare, negative environmental consequences such as a higher ammonia volatilisation or nitrogen leaching

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. Making a well reasoned holistic consideration whether one production system contributes more to sustainable development than another, therefore, requires a comparison of the economic, ecological and societal performance of both production systems. In other words, the contribution of a system with slow growing broilers and a system with fast growing broilers to sustainable development should be assessed. In this study, we compared the combined economic, ecological and societal performance of a defined organic production system with slow growing broilers with a defined conventional production system with fast growing broilers.

MATERIALS AND METHODS

The four step methodology used in this study is based on ideas of Bell and Morse

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and seems to be useful to apply for other production systems as well. It consists of the following steps: 1) description of the problem situation and of the system in study, 2) identification and definition of relevant economic, ecological en societal issues, 3) selection and quantification of indicators for each issue, and 4) final assessment of the contribution to sustainable development. These four steps are described in more detail.

Step (1): Description of the problem situation and the system in study

The first step requires a description of the problem situation and of the systems in study. The problem situation is described in the introduction. The systems in study are a defined conventional broiler production system with fast growing broilers and a defined organic broiler production system with slow growing broilers managed by one full time equivalent. The system boundary is therefore the farm with inputs such as feed, water, electricity, medicines, litter, one-day old chicks, etc., and with broilers for slaughter and manure as output.

Step (2): Identification and definition of economic, ecological and societal issues

The second step implies the selection of economic, ecological and societal (EES) issues relevant regarding sustainable development of a broiler production farm. Based on recent assessment studies (Mollenhorst and de Boer, 2004; van Calker et al., 2004), we selected the following EES issues: economic performance

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much

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In addition

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higher

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As far as we know no

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global warming

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energy use, we distinguish

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fossil energy

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fossil energy

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comprises

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energy

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comprises

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the

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like

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production

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energy use comprises

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energy

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of the total energy comprises

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fossil energy required for the production

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production

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energy comprises

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of

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and is

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production

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only

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, and, therefore,

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is

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to

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production

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. Besides

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farms use

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Due

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, energy required for heating in organic broiler production is expected to double

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energy

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organic production

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to

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production

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As mentioned above,

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energy

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production

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counts

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energy use

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parameters

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. In both genotypes percentage

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respectively of the observed time at

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Compared to chicks of a laying genotype time

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of their time on walking while fast growing broilers spent 2.7% of their time on walking

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experimental setting where birds had to walk on a treadmill to a feeder, slow growing broilers walked 35.1 m per h while fast growing broilers walked 9.3 m per h (Reiter and Bessei, 1995). Another

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capacities of broilers is by using the gait score. The gait

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The higher the score the more welfare is

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Kestin et al. (2001) found that when fed ad libitum fast

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Foot pad lesions are caused by unfavourable

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Foot pad lesions affect welfare because they are a health problem and may cause pain.

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and genotype affect the appearance of food pad lesions. Appearance of foot

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is therefore a useful indicator. Dermal lesions on foot pads

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an experiment

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the

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foot

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to

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growing broilers

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of age

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commercial

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foot pad dermatitis

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while

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genotypes

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foot pad dermatitis

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of age

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foot

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growing broilers

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inside

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Commercially grown

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broilers had

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appears

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food

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seemed to appear

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provided to

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broilers

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in relation to foot pad lesions

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problems

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seem to be

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in broilers

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observed

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growing broilers

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growing broilers

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can be considered

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as

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is on average 4.0% for fast growing broilers

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for slow growing broilers 3%

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was 3.9% and 5.6

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was 1.4% and

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. Samples of conventional broilers showed however resistance against more antibiotics. In case resistance against a antibiotic was found in samples of both production systems, samples of the conventional production method had a higher resistance than the organic samples

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. Although based upon only two studies, it seems that organic poultry meat contains fewer residues of antibiotics and has less antibiotic resistant micro-organisms. *Campylobacter* spp. is a zoonotic pathogen of humans and an important cause of bacterial diarrhoeal disease worldwide

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. Broiler meat is considered one of the most important sources of *Campylobacter* spp. infection for humans

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. Measurements can be conducted at farms to detect sources of risk but also at broiler product outlets to assess the direct risk for consumers. The percentage of samples of fresh chicken products bought in supermarkets, from poulterer and from butchers spread over the Netherlands and over a whole year which were contaminated with C*ampylobacter* spp. was for conventional broilers 25.9% in 2003 and 29.3% in 2004 and for organic broilers 36.3% in 2003 and 43.9% in 2004

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. Conventional poultry meat tends to be contaminated with Salmonella more often. The percentage of samples of fresh chicken products taken over a whole year that were contaminated with *Salmonella* spp. was for conventional broilers 11.2% in 2003 and 7.4% in 2004, and for organic broilers 3.4% in 2003 and 2.1% in 2004

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. Although in the study of Kramer et al.

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also no statistical difference was found, salmonella contamination on organic broiler meat (4%) tended to be lower than on conventional broiler meat (8%).

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Some aspects of eating quality can be measured objectively, but most aspects are subject to individual or cultural preferences and expectations.

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is, therefore, hard to define but it

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) which in studies are judged, e.g., a five or nine point Likert scale.

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Van Horne et al. (2003), however, found that breast

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Fanatico et al. (2006) found that fast

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, that have an affect on the outcome. This

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these confounding factors are taken into account

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less efficient than fast growing broilers, the contribution to global warming will be higher in slow growing broiler production systems; unless the extra energy needed is compensated with a high use of local grown feed which deceases energy use. Several issues were elaborated for societal performance.