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

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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 successful, 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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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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Deleted: 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 gr [... [10]

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95 issues. 3) selection and quantification of indicators for each issue, and 4) final
96 assessment of the contribution of production systems to sustainable development.
97 Step (1): Description of the problem situation and defining the systems
98 The first step requires a description of the problem situation and definition of the
99 systems. The problem situation was described in the introduction. The systems were a
100 defined conventional broiler production system and a defined organic broiler production
101 system, each managed by one person working a full-time year (Full Time Equivalent,
102 FTE). Both systems were characterised by production, housing, and management, with
103 related inputs and outputs (see below the section on definition of production systems).
104 Step (2): Identification and definition of economic, ecological and social issues
105 The second step implies the selection of EES issues relevant for sustainable
106 development of a broiler production system. Based on recent assessment studies
107 (Mollenhorst and de Boer, 2004; van Calker et al., 2004), we selected nine EES issues:
108 profitability of the farm, acidification of the soil, eutrophication of terrestrial and aquatic
109 ecosystems, use of fossil fuels, land use, animal welfare (including animal health), food
110 safety, product quality and working conditions. These nine EES issues will be
111 discussed in this study.
112 Step (3): Selection and quantification of indicators
113 The third step involves the selection and quantification of indicators for the selected
114 EES issues. An indicator, which is a parameter that quantifies the status of an issue, is
115 needed for each EES issue. For the comparison of production systems, we selected
116 the best available indicators using six criteria: relevance, simplicity, sensitivity,
117 reliability, trend/target, accessibility of data (Mitchell et al., 1995; de Boer and
118 Cornelissen, 2002; Mollenhorst et al., 2006). The selected indicators for the
119 comparison of the conventional and the organic broiler production system were
120 quantified based on scientific literature and data bases of Dutch institutes: the

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

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

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

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

134 ECONOMIC PERFORMANCE

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

145 Definition of the production systems

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146 In the conventional system, one FTE can manage 70,000 birds (KWIN, 2003-2004).
147 Stocking density is 22 birds per m². A production round takes 53 days (43 days growing
148 birds, 10 days empty), which means about seven production rounds per year (365/53).
149 Houses are lighted artificially and the climate is controlled with heaters and mechanical
150 ventilation. Water is provided by drinking nipples and feed by automatically filled open
151 feeders. The floor is covered with wood shavings (Rodenburg and van Harn, 2004).
152 In the organic system, one FTE can manage a maximum of 16,000 birds, which
153 have to be kept in several houses. Stocking density is a maximum of 10 birds per m²
154 on a total useful floor area of 1,600 m² (EU, 1999). The maximum number of birds per
155 house is 4,800 (EU, 1999). According to the Council Regulation 1804/1999, it is not
156 allowed to slaughter organic broilers before 81 days of age, unless slow growing lines
157 are used (EU, 1999). Because only slow growing lines are used in practice, organic
158 broilers are slaughtered around 70 days of age. Organic broilers are kept in houses
159 with natural ventilation and natural daylight, supplemented by artificial light (Rodenburg
160 and van Harn, 2004). In the beginning of the growing period, houses are heated
161 according to a similar temperature schedule as used in a conventional system.
162 Throughout the growing period, water is provided in open drinkers and feed is available
163 in open feeders that are filled by hand. The floor is covered with chopped straw
164 (Rodenburg and van Harn, 2004). Feed for organic broilers must be GMO-free, and
165 finisher feed should contain at least 65% cereals. Furthermore, 85% of the dry matter
166 of the feed must be of organic origin, and antimicrobial growth promoters and
167 anticoccidials are not allowed. An overview of technical data for both systems that is
168 used for the economic computations is in Table 1.

169 INSERT TABLE 1

170 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. Although a similar amount of energy is used in both systems to heat one m³ 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 m², 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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197 Final economic calculations are summarised in Table 3. Regarding the variable
198 and fixed costs, some additional comments are needed. Feed costs were calculated
199 according to the formula: $FC \times (BS + 0.5BD)$, whereas FC is feed consumption per bird,
200 BS is the number of birds that reached the slaughterhouse alive, and BD is the number
201 of birds that died during the production round. Feed consumption of BD is multiplied by
202 a half to estimate the amount of feed consumed by birds that died at different moments
203 of the production round.
204 For the conventional system, investment costs were estimated 180 EUR per m²
205 for the building and 70 EUR per m² for the inventory (KWIN, 2003-2004). For the
206 organic system, investment costs were estimated 160 EUR per m² for the building and
207 30 EUR per m² for the inventory (Vermeij, 2004).
208 For the conventional system, depreciation for the building was 3.5% and for the
209 organic system, it was 3%. Maintenance costs for the building were 1% for both
210 systems. Costs for depreciation (6.5%) and maintenance (2%) for the inventory were
211 similar for both systems (KWIN, 2003-2004).
212 Investments for the outdoor run in the organic system were 37,400 EUR per ha.
213 Costs for the outdoor run were based on interest (0.09 EUR per m²), costs for fencing
214 and furniture (0.025 EUR per m²), and maintenance (0.02 EUR per m²) (Vermeij,
215 2004). Organic production has to answer to special regulations that are controlled by
216 the independent organisation "Skal" in the Netherlands. Levies for Skal were based on
217 an annual fee of 260 EUR and an additional 0.05 EUR per bird (Skal, 2004). Finally,
218 costs for accounting, insurances, telephone, clothing, contributions, etc, were expected
219 to be similar for both systems.

220 INSERT TABLE 3

221 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.

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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).

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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).

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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 affected 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).

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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.

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Ammonia (NH₃) emission from animal manure is a major contributor to acidification (Groot Koerkamp, 1994). The NH₃ 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 NH₃ 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 NH₃ volatilises per kg of live weight annually. For an organic system, the NH₃ 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 ($1.275 \times 365/53$), whereas an organic broiler produces 13.6 kg ($3.4 \times 365/91$). 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 NH_3 per bird place per year, or 0.066 kg N. Assuming a similar NH_3 emission factor of 12.1% ($100 \times 0.066/0.543$), 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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303 It was found that 3,000 laying hens that could be outdoor from 11:00 h till sunset at an
304 organic commercial farm produced on average 2,845 kg N per ha per year (Aarnink et
305 al., 2006), which is higher than the legal limit of 170 kg N per ha per year (EU, 1991).
306 Furthermore, a large part of this manure was dropped close to the hen house, resulting
307 in an even increased risk for eutrophication. No such data exist for broilers with an
308 outdoor run, but it is clear that there is a risk for eutrophication in organic broilers.

309 Fossil-fuel use and climate change
310 Regarding use of fossil fuels, we distinguished between direct and indirect use. Direct
311 use includes use of oil, gas, and electricity on the broiler farm, whereas indirect use
312 includes use of fossil fuels for production and transport of farm inputs, such as
313 concentrates. In a conventional system, 25% of the total use of fossil fuels is direct use
314 of electricity and gas at the farm, whereas 70% is indirect use for cultivation, and
315 transport of concentrates (Spedding et al., 1983; Vermeij, 2004). In a conventional
316 system, direct use is electricity for mechanical ventilation and for lightning of the stable,
317 on average about 0.15 kWh per bird per day (Dyer and Desjardins, 2006). In an
318 organic system, natural ventilation is used and artificial light is used only in winter
319 (Rodenburg and van Harn, 2004). Therefore, electricity use was estimated to be 50%
320 lower for an organic compared with a conventional system (Vermeij, 2004). In addition
321 to electricity, a conventional system uses on average 0.09 m³ gas for heating during
322 the first 3 weeks of production to maintain the body temperature of young chicks
323 (Vermeij, 2004). In an organic system, however, the amount of fossil fuels required for
324 heating is expected to double due to the lower stocking densities (Vermeij, 2004).
325 Overall, the direct use of fossil fuels is expected to be 25% higher for an organic
326 system compared with a conventional system (Vermeij, 2004).

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

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330 fossil fuels. Feed conversion (kg feed/kg gain) is 1.76 for the conventional system and
 331 2.45 for the organic system (KWIN, 2003-2004; Vermeij, 2004). Indirect use of fossil
 332 fuels is expected to be higher in an organic system compared with a conventional
 333 system, due to this higher feed conversion. This expected increase, however, might be
 334 partly compensated for with lower use of fossil fuels for transport of feed ingredients
 335 due to the use of locally grown feed. Overall, total energy use per kg of live weight
 336 varies in literature between 8.4–17 MJ for conventional production (Ellendorff, 2002;
 337 Williams *et al.*, 2006; Blonk *et al.*, 2007). For organic production, total energy use per
 338 kg of live weight is estimated to be 30-59% higher (Ellendorff, 2002; Williams *et al.*,
 339 2006; Blonk *et al.*, 2007).

340 Worldwide, the main green houses gasses (i.e. gasses that contribute to
 341 climate change), related to animal production are carbon dioxide (CO₂), methane (CH₄),
 342 and nitrous oxide (N₂O) (de Boer, 2003). Emission of CO₂ is related to combustion of
 343 fossil fuels and deforestation. Methane emission in broiler production results from
 344 manure only. Enteric methane emission from poultry is assumed to be negligible
 345 (IPCC, 2006). Nitrous oxide emission results mainly from application of fertilizer during
 346 cultivation of feed ingredients. For conventional production, emission of green house
 347 gases per one kg of live weight of chicken is estimated at 2-3.2 kg expressed in CO₂
 348 units (IPCC, 2006; Williams *et al.*, 2006). These estimates include green house gas
 349 emissions on the broiler farm and emissions during the production of transport of farm
 350 inputs, such as concentrates (i.e. off-farm emissions). For organic production, emission
 351 of green house gases is estimated to be 50% higher (Williams *et al.*, 2006). The lower
 352 feed conversion and use of organic feed explain the higher emission of green house
 353 gases in organic production.

354 Land use

355 Land use (on and off-farm) in broiler production is reported to be 5.0 m² per kg of meat
 356 in a conventional system (Blonk *et al.*, 2007). For organic production, land use is

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357 estimated to be 92-119% higher (Williams *et al.*, 2006; Blonk *et al.*, 2007). This
358 difference between the conventional and organic system is because organic broilers
359 were fed organic feed. The harvest per hectare of organically grown crops is generally
360 lower than that of conventionally grown crops. Hence, more land is used to produce for
361 1 kg of feed in an organic system than in a conventional system. Another factor that
362 might influence land use per kg of broiler meat is the feed conversion, which is higher
363 in organic than in conventional broilers. The more feed that is needed to produce 1 kg
364 of meat, the more land is needed for the production of feed.

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SOCIAL PERFORMANCE

366
367 Animal welfare
368 The Farm Animal Welfare Council (1992) formulated five freedoms that define ideal
369 states for animal welfare: 1) freedom from hunger and thirst; 2) freedom from
370 discomfort; 3) freedom from pain, injury or disease; 4) freedom to express normal
371 behavior; 5) freedom from fear and distress. Mollenhorst *et al.* (2006) showed that
372 behavioural studies provide relevant indicators regarding not only freedom to express
373 normal behaviour, but also freedom from discomfort, fear, and distress. In addition, to
374 assess freedom from pain, injury or disease, indicators such as disease incidence or
375 clinical observations appear relevant. From literature, we deduced the following five
376 indicators for animal welfare in broilers: time spent on walking, percentage of birds with
377 footpad lesions, gait score, percentage of birds with heart abnormalities, and mortality
378 rate. Because behavioural and animal health studies with slow growing broilers are not
379 always conducted within the constraints of organic production, it will be mentioned in
380 this section whenever a study was done within the organic constraints.

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381 Time spent on walking is used to judge physical abilities and capacities of a
382 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 m² (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 m²) 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 growing 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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411 slow growers at 84 days of age (Nielsen et al., 2003). In addition, 78.3% of fast
412 growers had footpad lesions at 40.5 days of age compared with 5.4% of medium-slow
413 growers at 50 days (van Horne et al., 2003). In the UK, 14.8% of conventional reared
414 fast growing broilers had footpad lesions at 39 days of age, whereas 9.6% of medium-
415 slow growing broilers had lesions at 49 days (Pagazaurtundua and Warriss, 2006).
416 Rodenburg et al. (2004) found more footpad lesions in fast growing (88.5% at 41 days
417 of age) and medium-slow growing (16% at 55 days of age) broilers with a roofed
418 outdoor run than in fast growing (83.5% at 41 days of age) and medium-slow growing
419 (11.5% at 55 days of age) broilers that were kept indoors. In both situations, the fast
420 growing broilers had a higher prevalence than the medium-slow growing broilers.
421 In an organic broiler production system, a prevalence of footpad lesions of
422 98.1% was found at 70 days of age (Pagazaurtundua and Warriss, 2006). A higher age
423 and the outdoor run were associated with this high prevalence of footpad lesions. So, it
424 appeared that results of different studies are contradictorily because footpad lesions
425 appeared more frequently in fast growing broilers, but an outdoor run – as compelled in
426 an organic broiler production system – also has negative consequences.
427 Heart abnormalities in broilers are associated with growth and, therefore, are a
428 useful indicator for welfare. Heart abnormalities were found more frequently in fast
429 growers (22.0%) than in slow growers (4.3%) at 12 weeks of age (Bokkers and Koene,
430 2003). Mortality due to cardiovascular disorders was higher in fast growers (2.1%) kept
431 until 42 days of age than in medium-slow growers (0.4%) kept until 56 days of age (van
432 Horne et al., 2003).
433 In animal production, mortality is the ultimate consequence of a failing
434 biological adaptation mechanism. Mortality, therefore, is an indirect or cumulative
435 animal welfare indicator. Mortality rate at commercial farms averages 4% for
436 conventional systems after 43 days (KWIN, 2006) and 3% for organic systems after 70
437 days (Tacken et al., 2003; Vermeij, 2004). In two experiments, mortality rate for fast
438 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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for consumers. The percentage of samples of fresh chicken products bought from supermarkets, poulterers, and butchers across the Netherlands and over 2003-2004, that were contaminated with *Campylobacter* spp. averaged 27.6% for a conventional system and 40.1 for an organic system (van der Zee *et al.*, 2005). In another Dutch study, there was no difference between *Campylobacter* presence in products of a conventional system (43%) and an organic system (49%) (Kramer *et al.*, 2003). *Campylobacter* presence at slaughter was 36.7% in birds of a conventional system and 100% in birds from an organic system (Heuer *et al.*, 2001), indicating a high risk for the meat to be contaminated at slaughter, especially organic broiler meat.

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

Product quality

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

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

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(4.25 birds per m², but birds were not kept according to organic regulations) at 83 days of age and fast growing male broilers (17 birds per m², 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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521 *Working conditions*

522 Working conditions concern the farmer. Relevant indicators for working conditions

523 include, for example, working hours, and number of physical and psychological

524 complaints related to work (Dinten *et al.*, 2006; Mollenhorst *et al.*, 2006). Although

525 there are a number of indicators regarding working conditions, there is little information

526 on the effects of barn conditions on human health. No comparative studies were found

527 regarding conventional and organic systems.

528 Several studies were conducted on the levels of dust and gaseous pollutants in

529 broilers houses that might be detrimental for humans. Main sources of dust are from

530 feed, litter, and the broilers themselves (Wathes, 2004). Dust can carry bacteria,

531 viruses, and endotoxins (Takai *et al.*, 1998). Takai *et al.* (1998) discriminated between

532 respirable dust (between 0.5 – 7 µm) and inhalable dust (between 7-20 µm). Amount of

533 dust is dependent on time of day, time of production period, ventilation, moisture,

534 animal activity, etc. In Dutch broiler houses, a mean concentration of 1.05 mg/m³

535 respirable dust and of 10.4 mg/m³ inhalable dust, and a mean concentration of 41

536 ng/m³ respirable endotoxins and of 381 ng/m³ inhalable endotoxins were found (Takai

537 *et al.*, 1998). Dust and the attached endotoxins in the pig house caused disorders in

538 the bronchi and lungs of the farmer (Donham *et al.*, 1984; Vogelzang, 1999; Von Essen

539 *et al.*, 2005). Bongers *et al.* (1987) concluded that respiratory problems are found more

540 frequently in farmers than in other professional groups.

541 Gaseous pollutants also affect working conditions. Ammonia, for example,

542 irritates eyes and respiratory system. In the EU, the maximum acceptable

543 concentration for ammonia is 50 ppm. For poultry houses, it is advised to keep

544 ammonia concentration below 25 ppm, because above this level ammonia has a

545 detrimental effect on the body weight gain of chickens (Miles *et al.*, 2004) and severity

546 of clinical corneal lesions increased (Miles *et al.*, 2006). In the Netherlands, an

547 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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575 conventional system, whereas the risk for Salmonella contamination was lower. In both
576 systems, therefore, improvements can be made in relation to food safety.

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

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

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584 Although assumptions had to be made for several issues, basically the
585 methodology of Mollenhorst and De Boer (2004) was useful to assess sustainable

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586 development in these two defined broiler production systems. It has become clear now
587 that the studied systems differ and what knowledge is lacking to make a good
588 comparison for all issues. To increase our knowledge, a next step should be an
589 integrated, on-farm assessment. By collecting data on farms, a quantification of all
590 indicators should be possible. In that way, insight can be gained into how issues affect
591 each other and thus into the trade-offs when taking measurements to innovate a broiler
592 production system.

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

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599 ACKNOWLEDGEMENT

600 We would like to thank Marieke Klaasen for her valuable help with collecting data and
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Table 1: Technical data of a conventional and an organic broiler production system for 2003.

Broiler production system		
Technical data	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

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*the outdoor run must be accessible at least 1/3 of their life
Source: conventional (KWIN, 2003-2004, 2006); organic (Vermeij, 2004)

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

Broilers production system			Formatted Table
Economic data (EUR per bird)*	Conventional	Organic	Formatted: Superscript
Revenues	0.71	1.82	Deleted: (€/kg meat)
Purchase price chicks	0.27	0.50	Deleted: (€/bird)
Feed costs	23.15	35.75	Deleted: (€/100 kg)
Health care	0.045	0.120	Deleted: (€/bird)
Electricity	0.02	0.01	Deleted: (€/bird)
Heating	0.03	0.05	Deleted: (€/bird)
Water	0.010	0.016	Deleted: (€/bird)
Bedding	0.01	0.04	Deleted: (€/bird)
Catching and loading	0.04	0.05	Deleted: (€/bird)
Animal health levies	0.007	0.007	Deleted: (€/bird)
Carrion collecting service	0.002	0.002	Deleted: (€/bird)
Manure transport	0.0264	0.00	Deleted: (€/bird)
Interest livestock	0.0191	0.0191	Deleted: (€/bird)

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

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

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Table 3: Annual economic performance of a conventional and an organic broiler 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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, 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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, energy required for heating in organic broiler production is expected to double

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energy

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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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growing broilers

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commercial

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foot pad dermatitis

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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.		
<i>Campylobacter</i> 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 <i>Campylobacter</i>		
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 *Campylobacter* 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.

Page 19: [40] Deleted **bokke001** **12/23/2008 12:36:00 PM**

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

Page 19: [41] Deleted **bokke001** **12/23/2008 12:36:00 PM**

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

Page 19: [42] Deleted **bokke001** **12/23/2008 12:36:00 PM**

is, therefore, hard to define but it

Page 19: [43] Deleted **bokke001** **12/23/2008 12:36:00 PM**

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

Page 20: [44] Deleted **bokke001** **12/23/2008 12:36:00 PM**

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

Page 20: [45] Deleted **bokke001** **12/23/2008 12:36:00 PM**

Fanatico et al. (2006) found that fast

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Page 20: [46] Deleted	bokke001	12/23/2008 12:36:00 PM
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, that have an affect on the outcome. This

Page 20: [47] Deleted	bokke001	12/23/2008 12:36:00 PM
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these confounding factors are taken into account

Page 22: [48] Deleted	bokke001	12/23/2008 12:36:00 PM
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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.