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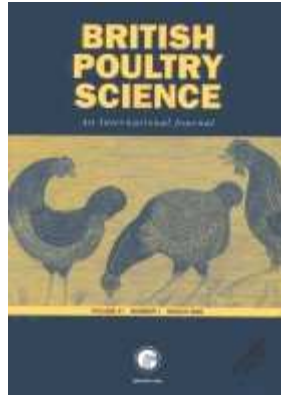
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Economic, ecological, and social performance of conventional and organic broiler production in the Netherlands

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15 **Abstract**

16 1. In this study, we compared a conventional broiler production system keeping fast
 17 growing broilers with an organic broiler production system keeping slow growing
 18 broilers in the Netherlands, both managed by one person working a full time year (Full
 19 Time Equivalent, FTE). This comparison was based on a quantification of economic,
 20 ecological and social indicators. Indicators were quantified using scientific literature and
 21 national data sets.
 22 2. The organic system performed better for the economic indicator net farm income per
 23 FTE than the conventional system.
 24 3. Regarding ecological indicators, calculations showed a higher on-farm emission of
 25 ammonia per kg live weight for the organic system. Moreover, an organic system
 26 includes a higher risk for eutrophication per ha due to outdoor access. Emission of
 27 green house gasses, use of fossil fuels and use of land required for the production of
 28 one kg of live weight is higher for an organic than for a conventional system. This is
 29 mainly due to a lower feed conversion in organic production and use of organic feed.
 30 4. The organic system performed better than the conventional system for the social
 31 indicators related to animal welfare, time spent on walking, footpad lesions, mortality,
 32 and sound legs. Regarding the social indicator, food safety was found that meat from an
 33 organic system contained less antibiotic residues and Salmonella contaminations but
 34 more Campylobacter contaminations than meat from a conventional system.
 35 5. Changing from a conventional, to an organic broiler production system, therefore, not
 36 only affects animal welfare, but also affects economic, ecological and other social
 37 issues. In this study, we ran into the situation that some information needed was
 38 lacking in literature and quantifications had to be based upon several sources.
 39 Therefore, an integrated on-farm assessment is needed, which can be used to develop
 40 a broiler production system that is economically profitable, ecologically sound, and
 41 acceptable for society.

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- Deleted: in organic broiler production, besides the fact that crop harvest per hectare is lower in general in
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5. INTRODUCTION

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Selective breeding for high growth rate and low feed conversion in broilers has been

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successful, but selection impairs animal welfare due to health problems and behavioural

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changes (Savory, 2002; Bokkers and Koene, 2003; Turner *et al.*, 2003). A modern

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broiler grows on average from 40 g to 2100 g in about 6 weeks. This high growth rate is

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different for different body parts (Nestor *et al.*, 1985; Havenstein *et al.*, 2003), which

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creates skeletal-biomechanical imbalances (Lilburn, 1994; Corr *et al.*, 2003a, 2003b)

Deleted: . As a result, the contribution of the breast muscle to total body weight has increased significantly

and increases susceptibility to metabolic disorders (Scheele, 1996; Gonzales *et al.*,

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1999; Havenstein *et al.*, 2003).

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Time spent on different behaviours has changed in fast growing broilers

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compared with other lines (Bokkers *et al.*, 2000; Bokkers and Koene, 2003), while the

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normal behavioural repertoire of a chicken has maintained. Incidence of several

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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

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posture with increasing age (Weeks *et al.*, 1994; Reiter and Kutritz, 2001; Bokkers and

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Koene, 2003).

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Fast growing broilers are the most common lines kept for chicken meat

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production. There are, however, slow growing lines that are also kept for chicken meat

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production. Roughly, there are two types of slow growing broilers: "medium" and

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"normal". Medium-slow growers grow to a slaughter weight of 2100 g in about 8 weeks

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whereas normal slow growers need 12 weeks to reach the same slaughter weight.

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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,

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as one of the factors for welfare problems in conventional broiler production (EU, 2000;

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

71 A decision to introduce an organic broiler production system that includes
 72 keeping slow growing broilers at a low stocking density is expected to affect the welfare
 73 status positively. Such a decision in favour of welfare, however, also has economic,
 74 ecological, and other social consequences, as shown, e.g., in egg production systems
 75 (Mollenhorst *et al.*, 2006). Organic regulations, for example, determine that animals

76 should have outdoor access for a certain period of their life or of the year. In addition to
 77 improved animal welfare, such regulations may have negative environmental
 78 consequences, such as, higher ammonia volatilisation or nitrogen leaching

79 (Hermansen *et al.*, 2004). Making a well-reasoned, holistic consideration
 80 whether one production system contributes more to sustainable development than
 81 another, therefore, requires comparison of the economic, ecological, and social
 82 performance of both production systems. In our case, the contribution to sustainable
 83 development of a conventional broiler production system and an organic broiler
 84 production system should be assessed. In this study, we compared the combined
 85 economic, ecological, and social performance of a defined conventional broiler
 86 production system with a defined organic broiler production system.

87 METHODOLOGY

88 The four step methodology used in this study was based on ideas of Bell and Morse
 89 (1999), and was developed further by Mollenhorst and De Boer (1999). This
 90 methodology has been used to evaluate the economic, ecological, and social (EES)
 91 performance of different egg production systems (Mollenhorst *et al.*, 2006), and seems
 92 suitable to evaluate the EES performance of broiler production systems. The
 93 methodology consists of four steps: 1) description of the problem situation and
 94 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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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

Deleted: . This methodology has been conducted for different egg production systems

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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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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.

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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Economic issues¶
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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 anticoagulants 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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3 171 For the conventional system, calculation of net farm income was based on intensive
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5 172 animal production in the Netherlands (KWIN, 2003-2004; 2006), whereas for the
6
7 173 organic system calculation of net farm income was based on data of Vermeij (2004)
8
9 174 (Table 2). Vermeij (2004) made several assumptions for the organic system because
10
11 175 data were lacking. These assumptions are summarised. Water intake is related to feed
12
13 176 in a ration of 1.8:1. Water intake of a broiler was 7 l in 43 days, so water intake was
14
15 177 assumed to be 11.5 l in 70 days. Costs for health care were expected to be higher for
16
17 178 an organic system than for a conventional system, because extra vaccinations are
18
19 179 necessary due to outdoor access. Costs per bird for electricity were expected to be
20
21 180 lower than in a conventional system due to natural ventilation and natural daylight. a
22
23 181 Although a similar amount of energy is used in both systems to heat one m³ of air,
24
25 182 heating costs per bird were expected to be higher in an organic system than in a
26
27 183 conventional system. This difference was expected because in an organic system,
28
29 184 fewer birds are kept per m², which makes it more expensive to heat the building when
30
31 185 expressing the costs per bird. Costs per bird for bedding were higher in an organic than
32
33 186 in a conventional system, because more litter is used per square meter and birds are
34
35 187 kept in a lower stocking density. Costs for catching and loading the birds for slaughter
36
37 188 were higher for an organic system due to smaller flocks. Costs for legal animal health
38
39 189 levies collection service for dead animals were similar for both systems. Manure
40
41 190 transport for the conventional system was based upon a farm with no land. Because
42
43 191 there is a manure surplus in the Netherlands, the removal of manure from the farm
44
45 192 involves costs. This situation is different for an organic system. There was enough
46
47 193 demand for organic poultry manure that no costs for manure removal and transport
48
49 194 needed to be taken into account.

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195 INSERT TABLE 2

196 *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.

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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).

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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).

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

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

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

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

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251 ECOLOGICAL PERFORMANCE

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

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261 Acidification and eutrophication

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

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266 Ammonia (NH₃) emission from animal manure is a major contributor to
267 acidification (Groot Koerkamp, 1994). The NH₃ emission per kg live weight, therefore,
268 is a relevant indicator for acidification (Thomassen and de Boer, 2005). Conventional
269 broilers on litter emitted on average 11.2 mg per h, which is 0.08 kg NH₃ per bird place
270 per year (0.08 kg = 11.2 mg/h/bird x 24 h x (365/53) rounds x, 43 days of
271 life)/1,000,000 (Groot Koerkamp et al., 1998). This value is used as the emission
272 factor for broilers in the Netherlands (VROM, 2002). Assuming a live weight of 2.1 kg
273 per bird, 5.5 g NH₃ volatilises per kg of live weight annually. For an organic system, the
274 NH₃ emission per bird place per year is unknown. A conventional broiler, however,

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

282 The NH₃ emission of a conventional broiler was 0.08 kg NH₃ per bird place per
 283 year, or 0.066 kg N. Assuming a similar NH₃ emission factor of 12.1% (100 x
 284 0.066/0.543), the NH₃ emission of an organic broiler is 0.10 kg N per bird place per
 285 year. Based on a live weight of 3.050 kg at 81 days, 8.3 g NH₃ volatilizes per kg of live
 286 weight annually. Hence, annual NH₃ emission per kg of live weight is 51% higher for an
 287 organic system than for a conventional system.

288 The previous computation was based on the assumption that the N content of
 289 manure, and its related NH₃ emission factor, were equivalent for conventional and
 290 organic systems. The N content of manure depends mainly on the composition of the
 291 feed, and composition of the feed does not need to be different between the
 292 conventional and the organic system. The NH₃ emission factor, however, depends on
 293 the housing system, stocking density, air temperature and velocity, and pH of manure
 294 (Groot Koerkamp, 1994). No information is available, however, to quantify the influence
 295 of these factors on NH₃ emission.

296 Organic broilers must have an outdoor run for at least one third of their life (EU,
 297 1999), which might also influence the NH₃ emission factor. Emission of NH₃ in the
 298 outdoor run depends on the time broilers spend outside, which itself depends on
 299 conditions, such as weather, season, temperature, facilities, and experience of the
 300 broilers. The influence of an outdoor run on NH₃ emission is unknown, and requires
 301 further research. Besides its contribution to acidification, an outdoor run carries a risk to
 302 ecology regarding eutrophication through leaching of excess of nitrate and phosphate.

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- Deleted: The total living space and stocking density, for example, which differ between fast and slow growing broilers, might influence the NH₃ emission factor (Groot Koerkamp, 1994). At this moment, however, no
- Deleted: In addition, the fact that organic birds spend time in the outdoor run influences the NH₃ emission factor.
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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~~).

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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.

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Deleted: suggested that a organic produced broiler contributes more

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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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1
2
3 357 ~~estimated to be 92-119% higher (Williams *et al.*, 2006; Blonk *et al.*, 2007). This,~~
4 358 difference between ~~the~~ conventional and organic ~~system~~ is ~~because~~ organic broilers
5 359 ~~were~~ fed organic feed. The harvest per hectare of ~~organically grown crops~~ is ~~generally~~
6 360 lower than ~~that~~ of conventionally grown crops. Hence, more land is used ~~to produce~~ for
7 361 1 kg of feed in ~~an~~ organic ~~system~~ than in ~~a~~ conventional ~~system~~. Another factor ~~that~~
8 362 ~~might~~ influence ~~land use per kg of broiler meat~~ is the feed conversion, which is higher
9 363 in organic than in conventional broilers. The more feed ~~that~~ is needed to produce 1 kg
10 364 of meat, the more land is needed for the production of feed.

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366 SOCIAL PERFORMANCE

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.

Deleted: Social issues¶

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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

Deleted: Walking behaviour

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383 broilers at 6 weeks of age (Weeks, 2002). ~~At 5 weeks of age,~~ slow growers walked
 384 4.4% of their time, ~~whereas~~ fast growers walked 1.5% of the time, both housed with a
 385 ~~stocking density of 20 birds per m² (Reiter and Kutritz, 2001).~~ This finding is in
 386 accordance with results of Bokkers and Koene (2003), who kept broilers in a lower
 387 stocking density (4 birds per m²) ~~and found~~ that slow growers walked 6.7% of the
 388 observed time at 6 weeks of age, ~~whereas fast growers walked 2.0%. Percentage,~~
 389 walking decreased to 5.8% ~~in slow growers~~ and ~~to 1.2% in fast growers at 12 weeks of~~
 390 age. ~~Time~~ spent on walking is low in both fast and slow growers ~~compared with~~ chicks
 391 ~~of a layer line (13.4% at 6 weeks of age) (Bokkers, not published).~~
 392 ~~Gait score is~~ another way to study walking behaviour. ~~Gait score~~ has a six point
 393 scale: ~~from~~ 0 = no detectable walking abnormalities ~~to~~ 5 = incapable of sustained
 394 walking on its feet (Kestin *et al.*, 1992). ~~A high gait score, therefore, means worse~~
 395 ~~walking behaviour and consequently an indicator for impaired welfare. Average gait~~
 396 score was 0.25 for slow ~~growing~~ and 2.18 for fast growing female broilers at 78 days
 397 of age (Nielsen *et al.*, 2003). One percent of the slow growing ~~line~~ and 87% of the fast
 398 growing ~~line~~ had a gait score higher than 1 at that age (Nielsen *et al.*, 2003). ~~Fast~~
 399 growing ~~lines~~ had a gait score of 2.9 at 54 days of age and 3.8 at 81 days, ~~whereas~~
 400 slow growing ~~lines~~ had a gait score of 1.5 ~~at 54 days of age~~ and 2.0 at ~~81 days~~ (Kestin
 401 *et al.*, 2001). Based on walking behaviour and gait scores, ~~therefore, we~~ concluded that
 402 walking performance ~~was~~ better in slow growing broilers than in fast growing broilers.
 403 Fast growing broilers seemed to be physically restricted but the motivation to walk ~~was~~
 404 still present (Bokkers *et al.*, 2007), which can be interpreted as a situation of reduced
 405 welfare.
 406 ~~Footpad lesions affect welfare because they might cause pain. Unfavourable~~
 407 housing conditions, such as moisture and chemical irritants in the litter, ~~were~~
 408 ~~associated with footpad lesions~~ (Ekstrand *et al.*, 1998). ~~Stocking density, activity of the~~
 409 ~~birds, and location in the house affected litter quality (Gordon, 1992; Su *et al.*, 2000;~~
 410 ~~Tasistro *et al.*, 2004).~~ Footpad lesions were found in 75.5% of fast growers and 1.5% in

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- Deleted: and fast growers 2.0%
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1
2 411 slow growers at 84 days of age (Nielsen et al., 2003). In addition, 78.3% of fast
3
4 412 growers had footpad lesions at 40.5 days of age compared with 5.4% of medium-slow
5
6 413 growers at 50 days (van Horne et al., 2003). In the UK, 14.8% of conventional reared
7
8 414 fast growing broilers had footpad lesions at 39 days of age, whereas 9.6% of medium-
9
10 415 slow growing broilers had lesions at 49 days (Pagazaurtundua and Warriss, 2006).
11
12 416 Rodenburg et al. (2004) found more footpad lesions in fast growing (88.5% at 41 days
13
14 417 of age) and medium-slow growing (16% at 55 days of age) broilers with a roofed
15
16 418 outdoor run than in fast growing (83.5% at 41 days of age) and medium-slow growing
17
18 419 (11.5% at 55 days of age) broilers that were kept indoors. In both situations, the fast
19
20 420 growing broilers had a higher prevalence than the medium-slow growing broilers.

21
22 421 In an organic broiler production system, a prevalence of footpad lesions of
23
24 422 98.1% was found at 70 days of age (Pagazaurtundua and Warriss, 2006). A higher age
25
26 423 and the outdoor run were associated with this high prevalence of footpad lesions. So, it
27
28 424 appeared that results of different studies are contradictorily because footpad lesions
29
30 425 appeared more frequently in fast growing broilers, but an outdoor run – as compelled in
31
32 426 an organic broiler production system – also has negative consequences.

33
34 427 Heart abnormalities in broilers are associated with growth and, therefore, are a
35
36 428 useful indicator for welfare. Heart abnormalities were found more frequently in fast
37
38 429 growers (22.0%) than in slow growers (4.3%) at 12 weeks of age (Bokkers and Koene,
39
40 430 2003). Mortality due to cardiovascular disorders was higher in fast growers (2.1%) kept
41
42 431 until 42 days of age than in medium-slow growers (0.4%) kept until 56 days of age (van
43
44 432 Horne et al., 2003).

45
46 433 In animal production, mortality is the ultimate consequence of a failing
47
48 434 biological adaptation mechanism. Mortality, therefore, is an indirect or cumulative
49
50 435 animal welfare indicator. Mortality rate at commercial farms averages 4% for
51
52 436 conventional systems after 43 days (KWIN, 2006) and 3% for organic systems after 70
53
54 437 days (Tacken et al., 2003; Vermeij, 2004). In two experiments, mortality rate for fast
55
56 438 growers averaged 4.8% at 42 days of age and for medium-slow growers averaged

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439 1.5% at 56 days of age (van Horne, *et al.*, 2003). Cause of death, such as heart failure,
440 is not well documented, in contrast to the number of deaths.

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441 *Food safety*

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

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446 Using antibiotics in animal production results in a high risk of organisms developing
447 resistance to antibiotics, especially when these organisms are infectious for animals
448 and humans. Resistance may occur when medicines such as tetracyclines and
449 quinolones are used in animals and humans (Kramer, *et al.*, 2003). In a Dutch study,
450 residues of antibiotics were found in 8.3% broiler product samples of a conventional
451 system, whereas there were found in 0% broiler products samples of an organic
452 system (Kramer, *et al.*, 2003). None of the samples exceeded the legal maximum
453 residue level as laid down by the European Union, (Kramer, *et al.*, 2003), Samples of
454 broiler products, of both conventional and organic systems, contained bacteria strains
455 with resistance to several antibiotics (van der Zee, *et al.*, 2005). Samples of
456 conventional system broiler products, however, showed a higher resistance and a
457 resistance to more antibiotics than samples of an organic system (van der Zee, *et al.*,
458 2005). It seems, therefore, that meat from an organic system contains fewer residues
459 of antibiotics and has less antibiotic resistant micro-organisms than from a conventional
460 system.

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

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 (Erdsieck, 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

Deleted: . In another Dutch study, no statistical difference was found between *Campylobacter* presence on organic (49%) and on conventional (43%) broiler meat

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Deleted: 2003)

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Deleted: . A Danish research for *Campylobacter* presence in organic and conventional broiler production using cloacal swabs at slaughter showed that *Campylobacter* was isolated from 100% of organic flocks and from 36.7% of conventional flocks

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Deleted: indicating a high risk for the meat to be contaminated when birds are slaughtered, especially organic poultry meat. ¶ *Salmonella* spp. are a second group of zoonotic pathogens for which broiler meat is a major cause of infections

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Deleted: (Humphrey, 2006)

Deleted: . 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. (... [38]

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Deleted: (van der Zee *et al.*, 2005)

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493 (4.25 birds per m², but birds were not kept according to organic regulations) at 83 days

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494 of age and fast growing male broilers (17 birds per m², conventionally kept) at 48 days

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495 of age. They found that the appearance of cooked breast meat from slow growers was

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496 more uniform in colour and had more visible moisture than from fast growers. They

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497 found also that the texture of breast meat from slow growers was less tough, fibrous,

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498 and resistant to the knife than that from fast growers. Results for the same indicators

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499 however, were the opposite when judging the thigh meat. A consumer panel of 100

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500 found that breast meat from medium-slow growers at 56 days of age was less juicy and

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501 tender, and tougher than breast meat of fast growers at 42 days of age (van Horne et

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502 al., 2003). No difference was found for thigh meat. Another consumer panel of 90 found

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503 no difference for tenderness between breast meat of slow growing broilers with outdoor

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504 access and fast growing broilers kept indoor, both slaughtered at the same weight

Deleted: Van Horne et al. (2003) used a

505 (Fanatico et al., 2006). Juiciness of breast meat from fast growers kept indoors was

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506 judged better than from slow growers with access to outdoors.

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507 Furthermore, breast meat from fast growers had a higher odour intensity than

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508 breast meat from slow growers (Farmer et al., 1997). Breast meat of medium-slow

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509 growers, however, had a better odour and appearance than fast growers (van Horne et

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510 al., 2003). In thigh meat the odour intensity, qualified as "chicken odour" and "abnormal

Deleted: in that study. Fanatico et al. (2006) also used a

511 odour", was higher in fast growers than in slow growers (Farmer et al., 1997). Fast

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512 growers kept indoors scored a higher for flavour of thigh meat than slow growers with

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513 access to outdoors (Fanatico et al., 2006), but Farmer et al. (1997) did not find such a

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514 difference for flavour.

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515 In studies on product quality a large number of factors affect the outcome, such

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516 as age, genotype, sex and weight of the birds, feed, housing system, way of preparing

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517 the samples, and cultural background of the panellists. These factors were not similar

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518 between different studies, which makes a comparison between, and interpretation over

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519 studies hard. Product quality, nevertheless, can be a useful indicator when used

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520 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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Deleted: . Physical complaints may occur, for example, due to dust and gaseous pollutants in the broiler house

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

550 GENERAL DISCUSSION AND CONCLUSION

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

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

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

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

Deleted: . No comparative studies, however, were found for indicators concerning working conditions in the field of broiler production. ¶

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Deleted: Both may fluctuate over years. So, data

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Deleted: 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 elat[... [48]

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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

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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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ACKNOWLEDGEMENT

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

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834 Table 1: Technical data of a conventional and an organic broiler production system for
835 2003.

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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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836 *the outdoor run must be accessible at least 1/3 of their life

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

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Table 2: Economic data of a

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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		
Economic data (EUR per bird) [*]	Conventional	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

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

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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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8 has much more consequences than

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

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15 the contribution to sustainable development of all relevant issues. An

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18 for that. In this way a production system

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25 , economic profitable and ecologically sound.

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

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36 . Making a well reasoned holistic consideration whether one production system
37 contributes more to sustainable development than another, therefore, requires a
38 comparison of the economic, ecological and societal performance of both production
39 systems. In other words, the contribution of a system with slow growing broilers and a
40 system with fast growing broilers to sustainable development should be assessed. In this
41 study, we compared the combined economic, ecological and societal performance of a
42 defined organic production system with slow growing broilers with a defined conventional
43 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 and 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 Calster et al., 2004), we selected the following EES issues: economic performance

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

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46 47 48 49	Page 16: [20] Deleted capacities of broilers is by using the gait score. The gait	bokke001	12/23/2008 12:36:00 PM
50 51 52 53	Page 16: [21] Deleted The higher the score the more welfare is	bokke001	12/23/2008 12:36:00 PM
54 55 56 57 58 59 60	Page 16: [22] Deleted Kestin et al. (2001) found that when fed ad libitum fast	bokke001	12/23/2008 12:36:00 PM

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8	Foot pad lesions affect welfare because they are a health problem and may		
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14	and genotype affect the appearance of food pad lesions. Appearance of foot		
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18	is therefore a useful indicator. Dermal lesions on foot pads		
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54	foot pad dermatitis		
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11 genotypes

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15 foot pad dermatitis

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19 of age

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23 foot

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35 growing broilers

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39 inside

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47 Commercially grown

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51 broilers had

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55 appears

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4	food		
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12	provided to		
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16	broilers		
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20	in relation to foot pad lesions		
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24	problems		
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56	can be considered		
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9 is on average 4.0% for fast growing broilers

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13 for slow growing broilers 3%

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17 was 3.9% and 5.6

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25 was 1.4% and

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29 . Samples of conventional broilers showed however resistance against more antibiotics.
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31 In case resistance against a antibiotic was found in samples of both production systems,
32 samples of the conventional production method had a higher resistance than the organic
33 samples
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39 . Although based upon only two studies, it seems that organic poultry meat contains
40 fewer residues of antibiotics and has less antibiotic resistant micro-organisms.
41
42 *Campylobacter* spp. is a zoonotic pathogen of humans and an important cause of
43 bacterial diarrhoeal disease worldwide
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50 . Broiler meat is considered one of the most important sources of *Campylobacter*
51 spp. infection for humans
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3 . Measurements can be conducted at farms to detect sources of risk but also at
4
5 broiler product outlets to assess the direct risk for consumers. The percentage of
6
7 samples of fresh chicken products bought in supermarkets, from poulterer and from
8
9 butchers spread over the Netherlands and over a whole year which were contaminated
10
11 with *Campylobacter* spp. was for conventional broilers 25.9% in 2003 and 29.3% in 2004
12
13 and for organic broilers 36.3% in 2003 and 43.9% in 2004
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15
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18 . Conventional poultry meat tends to be contaminated with Salmonella more
19
20 often. The percentage of samples of fresh chicken products taken over a whole year that
21
22 were contaminated with *Salmonella* spp. was for conventional broilers 11.2% in 2003
23
24 and 7.4% in 2004, and for organic broilers 3.4% in 2003 and 2.1% in 2004
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29 . Although in the study of Kramer et al.
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33 also no statistical difference was found, salmonella contamination on organic
34
35 broiler meat (4%) tended to be lower than on conventional broiler meat (8%).
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39 Some aspects of eating quality can be measured objectively, but most aspects are
40
41 subject to individual or cultural preferences and expectations.
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45 is, therefore, hard to define but it
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49) which in studies are judged, e.g., a five or nine point Likert scale.
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53 Van Horne et al. (2003), however, found that breast
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57 Fanatico et al. (2006) found that fast
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5 , that have an affect on the outcome. This
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9 these confounding factors are taken into account
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13 less efficient than fast growing broilers, the contribution to global warming will be
14
15 higher in slow growing broiler production systems; unless the extra energy needed is
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17 compensated with a high use of local grown feed which deceases energy use. Several
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19 issues were elaborated for societal performance.
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