**Animal Board Invited review: Comparing conventional and organic livestock production systems on different aspects of sustainability**

C.P.A. van Wagenberg, Y. de Haas, H. Hogeveen, M.M. van Krimpen, M.P.M. Meuwissen, C.E. van Middelaar, T.B. Rodenburg

**Supplementary Table S4:** Reviewed studies comparing welfare indicators between conventional and organic livestock production

| Reference | Welfare indicator | Study country | Sample type | # units/samples: conventional (organic) | Unit | Value conven-tional | Value  organic | Signifi-cance | Explanation observed differences |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Dairy cows* |  |  |  |  |  |  |  |  |  |
| Abuelo *et al.* (2014) | 23 metabolites and immunological parameters | Spain | Blood metabolites | 1 (2) herds and 22 (40) cows | Concentration | Study gave a large number of p<0.05 differences. Overall, higher prevalence of subclinical ketosis on organic farms and higher levels of Serum amyloid A (an inflammatory agent) on conventional farms | | | |
| Abuelo *et al.* (2015) | 4 markers of oxidant production | Spain | Serum | 1 (2) herds and 22 (40) cows | Concentration | Study did not give blood values per system, only model estimates. | | | |
| Ahlman *et al.* (2011) | Longevity | Sweden | I&R records | 5 335 (402), herds | Days of productive life | 1,087 | 1,154 | - | Higher risk of culling on organic farms due to mastitis |
| Alvasen *et al.* (2012) | Mortality | Sweden | I&R records | 6 898 herds | % mortality | 61 | 55.9 | NS |  |
| Bennedsgaard *et al.* (2003) | Production diseases (Mastitis, retained placenta, ketosis) | Denmark | Milk, treatments | 99 (82) herds | Somatic cell count1  Mastitis treatments per cow per year  % calvings with retained placenta treatment  % calvings with ketosis treatment | 290-360  0.58-0.69  9.1-10.7  1.3-2.4 | 270-410  0.29-0.63  4-11.5  0.1-1.9 |  |  |
| Bidokhti *et al.* (2009) | Bovine coronavirus, bovine respiratory syncytial virus | Sweden | Blood ELISA | 20 (20); 699 samples from 624 cows | Prevalence:  BCV (%)  BRSV (%) | 96  91 | 78  72 | p<0.05  p<0.05 | Less animal trading between organic farms |
| Brenninkmeyer *et al.* (2013) | Hock lesions | Germany | Body condition | 33 (38) herds, 30 - 50 cows/herd | Prevalence | 68 | 22 | p<0.01 | Organic better cubicle design and lying comfort |
| Blanco-Penedo *et al.* (2014) | Metabolics (Co, Cu, Fe, I, Mn, Mo, Se, Zn) | Sweden | Blood | 10 (10) farms, 8 cows per farm, two samples in time | Concentration |  |  | NS |  |
| Blanco-Penedo *et al.* (2012a) | Metabolics (BHBA, NEFA, insulin, ketosis) | Sweden | Blood | 13 (13) farms, 81 samples | Concentration | Significant (P<0.05) lower BHBA and NEFA, not related to ketosis | | | No reason given, study was aimed at change of feeding legislation on organic farms |
| Cazer *et al.* (2013) | *Mycobacterium avium* (for Johne’s disease) | USA | Elisa test on Blood | 292 farms total  ~1/3 organic | Optical density | - | - | NS | Only final model was provided |
| Cicconi-Hogan *et al.* (2013a) | Mastitis (Somatic cell count) | USA | Bulk milk tank | 100 (192) | Concentration | 166 000 | 195 000 | NS | No difference after multivariate modelling |
| Cicconi-Hogan *et al.* (2013b) | Mastitis(*S. aureus*) | USA | Bulk milk tank | 100 (192) | Positive/negative | 42% of tanks | 67% of tanks | NS | No difference after multivariate modelling |
| Fall and Emanuelson (2009) | Mastitis, reproduction | Sweden | Milk production recording | 20 (20) | Somatic cell count concentration  Percentage success at first insemination, | -  - | -  - | NS  NS | No difference |
| Fall *et al.* (2008a) | Diseases (mastitis, ketosis, other) | Sweden | Veterinary treatments | 154 (156) cows within 1 split herd 12 years | Treatment | 192 | 198 | NS |  |
| Fall *et al.* (2008b) | Mastitis | Sweden | Milk production recording | 156 (154) cows within 1 split herd, 12 years | Somatic cell count  Percentage success at first insemination, | -  - | -  - | NS  NS | No difference |
| Fall *et al.* (2008b) | Reproduction | Sweden | Calving interval | 154 (156) cows within 1 split herd, 12 years | Calving-first insemination interval | 75 | 73 | NS |  |
| Fall *et al.* (2008c) | Metabolic status (NEFA, BHBA, Insulin, glucose, BCS) | Sweden | blood samples | 20 (20) | Concentration, level | - | - | NS | No difference |
| Fossler *et al.* (2004) | Salmonella | USA (4 states; MI, MN, NY, WI) | Cow faeces | 84 (26) farms, 5 visits, 22,417 samples | Prevalence:  herd  cow | 92.8  4.7 | 92.3  4.9 | NS  NS |  |
| Fossler *et al.* (2005a) | Salmonella | USA (4 states, MI, MN, NY, WI) | Cow faeces | 97 (32), 5 visits | Prevalence herd | Only regression modelling results were given. No raw or least square estimates were provided. Farm type was NS | | |  |
| Fossler *et al.* (2005b) | Salmonella | USA (4 states, MI, MN, NY, WI) | Calf faeces | 97 (32), 5 visits | Prevalence herd | Only regression modelling results were given. No raw or least square estimates were provided. Farm type was NS | | |  |
| Garmo *et al.* (2010) | Mastitis (Somatic cell count) | Norway | milk production recording | 25 (24) | Concentration  Days | -  377 | Lower  376 | p<0.05  NS | No explanation provided |
| Hardeng and Edge (2001) | Mastitis, ketosis, milk fever | Norway | Veterinary treatments database | 93 (31) | Incidence:  mastitis  Ketosis  Milk fever | 29%  7.8 %  12.3 % | 14%  2.8 %  7.3 % | p<0.01  p<0.01  p<0.01 | Recording bias, while no difference in Somatic cell count. Different types of treatments |
| Hoglund *et al.* (2010) | Helminths | Sweden | Bulk milk | 105 (105) herds | ODR *O. ostertagi*  Incidence *D. vivparus*  Incidence *F. hepatica* | 0.66  9%  6.7% | 0.82  18%  7.6% | p<0.001  NS  NS |  |
| Kuhnert *et al.* (2005) | *E*. *coli* STEC O157:H7 | Switzerland | Cow faeces | 60 (60) farms, 500 cows | Herd level STEC  O157:H7 | 100%  17% | 100 %  25% | NS  NS |  |
| Langford *et al.* (2009) | Diseases | United Kingdom | Questionnaire (farmer reported) | 40 (40) farms, 2 visits per farm | Yearly incidence of:  Culling  Endometritis  Cystic ovaries  Retained placenta  Lameness  Mastitis  Ketosis  Milk fever  Displaced abomasum | 26.3  10.8  6  10.4  31.9  41.6  2.3  14.9  1.8 | 19.6  6.1  5  7  36.5  30.1  2.1  7.8  1.1 | p<0.01  p<0.05  NS  NS  NS  NS  NS  p<0.05  NS | Different feeding regime and milk production level on organic farms. Note: these are farmer reported data and biased with treatment strategy |
| Langford *et al.* (2011) | Aggression feeding gate | United Kingdom | Animal behaviour | 20 (20) herds | Frequency | 30 | 36 | p<0.05 | Conventional better roughage quality: less aggression |
| Langford *et al.* (2011) | Lying post-feeding | United Kingdom | Animal behaviour | 20 (20) herds | Percentage of time spent lying | 43 | 38 | p<0.01 | Organic better leg health? Correlation lying and lameness |
| Loef *et al.* (2007) | Reproduction | Sweden | Breeding data from milk production recording database | 2,258 (170) | Calving interval  Calving – 1st AI  Calving – last AI  AI/animal  Culling | 403  91  122  1 | 399  88  127  OR=0.8 | p=0.04  p<0.05  p<0.01  NS  p<0.001 | Least square means are provided.  No explanation provided |
| Mueller and Sauerwein (2010) | Mastitis | Germany | Bulk milk tank | 33 (35) farms | Somatic cell count  Cow prevalence elevated cow Somatic cell count | 205 790  36 % | 218 750  44% | NS  NS | Farms were equal despite that dry cow therapy was not provided on organic farms |
| Nauta *et al.* (2006) | Mastitis | The Netherlands | Milk production recording | 966 (404) | Somatic cell scores  calving interval Score | -  - | +50 000  - | p<0.05  NS | Dry cow therapy, deep litter stalls |
| Park *et al.* (2012) | Mastitis | USA | Milk bacteriology | 2 farms, before and after transition | Prevalence  At parturition  At drying off | 47  45 | 70  42 | 0.006  NS | Paper gives differences in text and table. Cannot be interpreted |
| Reksen *et al.* (1999) | Reproduction | Norway | Breeding data | 87 (29) farms, 3 years of data | Days open  Calving interval | 117  374 | 119  383 | NS  p<0.01 | The energy requirements might be managed less well on organic farms |
| Roesch *et al.* (2007) | Mastitis | Switzerland | California mastitis test on quarter samples | 60 (60) | Prevalence | 12-15% | 15-18% | p<0.02 | Dry cow management |
| Roesch *et al.* (2005) | Metabolic disorders | Switzerland | Blood | 60 (60), 1 000 cows | Concentration | No differences in blood parameters glucose, NEFA, BHBA | | |  |
| Rutherford *et al.* (2009) | Lameness | United Kingdom | Locomotion scores | 40 (40) matched farms (straw or cubicles), 2 or 3 visits | Prevalence during :  Autumn, straw  Autumn cubicles  Winter straw  Winter cubicles  Spring straw  Spring cubicles | 14.5  19.1  15.3  21  17.8  23.1 | 8.3  16  9  16  12.4  18 |  | In final model, significant difference for winter period (LSM: 14.2 organic and 19.9 for conventional farms). No explanation given. |
| Sato *et al.* (2005) | Mastitis, parasitic disease | USA | Bulk milk tank | 30 (30) farms | Somatic cell count  *O. ostertagi* | 285 000  ? | 263 000  ? | NS  p<0.05 | Grazing |
| Silverlås and Blanco-Penedo (2013) | *Cryptosporidium* | Sweden | Faeces | 13 (13) farms, 221 calves and 259 cows | Prevalence:  Calves  Cows | 52.3  3.8 | 44.7  3.1 | NS  NS |  |
| Stiglbauer *et al.* (2013) | Mastitis | USA | Bulk milk tank | 100 (192) samples | Somatic cell count Concentration | 210 000 | 221 000 | NS | No difference after multivariate modelling |
| Sundberg *et al.* (2009) | Mastitis | Sweden | milk production records over 7 years | 6 567 (471) herds | Monthly average somatic cell count, averaged per lactation:  Parity 1  Parity 2  Parity 3 | 55 093  71 641  93 963 | 57 760  76 322  99 959 | NS  NS  NS | Difference in raw data disappeared after correction for milk production level |
| Sundberg *et al.* (2009) | Reproduction | Sweden | Breeding data records of 7 years | 6 567 (471) herds | Calving interval:  Parity 1  Parity 2  Parity 3 | 409  401  397 | 415  408  402 | p<0.05  p<0.05  p<0.05 | Some other reproduction parameters were also significant. No explanation given |
| Thatcher *et al.* (2014) | Mastitis | New Zealand | Bulk milk tank | 1 experimental farm, split up in two herds with 51 (46) cows | Average somatic cell count over 5 years | 152 000 | 163 000 | p<0.05 | In first years, differences were significant, later not. Management on organic farms was adjusted |
| Thomsen *et al.* (2006) | Mortality | Denmark | I&R data | 6 839 herds of which 5 % organic | Risk of mortality (herd level; LSM) | 15.9 | 0 | p<0.001 | Study was aimed at mortality, not specifically at organic farming. No explanation given. |
| Thomsen *et al.* (2007) | Loser cows | Denmark | Cow observations | 40 random herds, 3 visits | Prevalence | No quantitative descriptive results of loser cows in relation to farm system were described. Organic farming had OR of 4.8 compared to conventional farms | | | No explanation provided |
| Vaarst and Bennedsgaard (2001) | Mastitis | Denmark | Bulk milk tank | 57 (27) samples | Somatic cell count | No averages nor a significance level were provided. Somatic cell count was higher on organic farms | | | Not given |
| Vaarst *et al.* (1998) | Lameness | Denmark | Sole disorders observations | 7 (6) farms, cow observations from claw trimmer | Percentage without disorders | 59% | 41% | NS |  |
| Valle *et al.* (2007) | Culling and diseases | Norway | Questionnaire | 159 (149) | Somatic cell count (\* 1 000)  Calving interval  Culling rate  Mastitis treatment  Milk fever treat  Ketosis treatment  Retained placenta treatment | 118  390  43  31  5.4  6.3  2.8 | 126  388  37  17  4.8  3.4  1.8 | NS  NS  p<0.05  p<0.05  NS  p<0.05  p<0.05 | Higher activity of organic farmers in health handling  Because of the link to treatment, disease results are biased. |
| Weller and Cooper (1996) | Mastitis, lameness, vulval discharge, retained placenta, milk fever, ketosis | United Kingdom | Farmer recorded | 11 farmers, before and after conversion | Prevalence:  Mastitis  Lameness  Vulval discharge  Retained placenta  Milk fever  Ketosis | 40.5  27.9  8.5  3.8  4.9  0.4 | 45.8  24.5  5  3.3  4.9  0.5 | -  -  -  -  -  - | No significances are described. Difference in lameness due to high forage diet. |
|  |  |  |  |  |  |  |  |  |  |
| *Beef cattle* |  |  |  |  |  |  |  |  |  |
| Blanco-Penedo *et al.* (2012b) | Mastitis, reproductive disorders, abortion, podal disorders, milk fever, ketosis | Spain | Farmer reported veterinary treatments | 26 (24) farmers, farm visit, interview | Prevalence:  Mastitis  Reproductive disorders  Abortion  Podal disorders  Milk fever  Ketosis | 0.1%  0.4%  3.4%  0.1%  0  0 | 0,2%  3.8%  6.6%  3.2%  0.4%  0.2 | NS  p<0.05  NS  NS  NS  NS | Farmer reported data, so there is a bias in management and reporting. |
|  |  |  |  |  |  |  |  |  |  |
| *Pigs* |  |  |  |  |  |  |  |  |  |
| Eijck and Borgsteede (2005) | Coccidia infections | Netherlands | fecal | 9 (11) herds, 10 (10) samples | Prevalence | 67 | 91 | NS |  |
| Eijck and Borgsteede (2005) | Ascarid infections | Netherlands | fecal | 9 (11) herds, 10 (10) samples | Prevalence | 11 | 73 | p<0.05 | Conventional housing reduces the risk of worm infections |
| Knage-Rasmussen *et al.* (2014) | Lameness | Denmark | behaviour | 44 (9) herds, 30 samples | Prevalence | 24 | 5 | p<0.05 | Organic sows less lameness due to outdoor access and space |
| Millet *et al.* (2005) | Haptoglobin | Belgium | blood | Experiment: 8 (8) groups of 4 pigs | Log concentration | 0 | -0.6 | p<0.05 | Organic better ability to cope with stress |
| Millet *et al.* (2005) | Lactate | Belgium | blood | Experiment: 8 (8) groups of 4 pigs | Concentration | 7.5 | 5 | p<0.05 | Organic better ability to cope with stress |
|  |  |  |  |  |  |  |  |  |  |
| *Broilers* |  |  |  |  |  |  |  |  |  |
| Van Overbeke *et al.* (2006) | Newcastle Disease | Belgium | blood | 11 (9) flocks, 20 (20) samples | Mean antibody titers | 5 | 3 | NS |  |
| Van Overbeke *et al.* (2006) | Infectious Bursitis | Belgium | blood | 11 (9) flocks, 20 (20) samples | Mean antibody titers | 2 800 | 6 500 | p<0.001 | Timing of vaccination with regard to slaughter age organic |
| Van Overbeke *et al.* (2006) | Infectious Bronchitis | Belgium | blood | 11 (9) flocks, 20 (20) samples | Mean antibody titers | 5 000 | 1 000 | p<0.01 | Poorer respiratory health conventional (no clinical signs) |
| Tuyttens *et al.* (2008) | Acute Phase Proteins | Belgium | blood | 7 (7) flocks, 10 (10) samples | Concentration | 5.45 | 6.21 | p<0.01 | Organic better ability to cope with stress |
| Tuyttens *et al.* (2008) | Latency to lie | Belgium | behaviour test | 7 (7) flocks, 10 (10) samples | Latency time (s) | 256 | 547 | p<0.001 | Organic better leg health |
| Tuyttens *et al.* (2008) | Hock lesions | Belgium | body condition | 7 (7) flocks, 10 (10) samples | Condition (scale: 0=very good to 3=very bad) | 1.64 | 0.3 | p<0.001 | Organic better leg health, more active |
| Williams *et al.* (2013) | Hock lesions | United Kingdom | body condition | Experiment: 4 groups of 60 birds | Incidence after challenge | 45 | 22 | p<0.05 | Organic better ability to cope with stress |
| Williams *et al.* (2013) | Footpad lesions | United Kingdom | body condition | Experiment: 4 groups of 60 birds | Incidence after challenge | 32 | 2 | p<0.05 | Organic better ability to cope with stress |
|  |  |  |  |  |  |  |  |  |  |
| *Laying hens* |  |  |  |  |  |  |  |  |  |
| Jansson *et al.* (2010) | Worm infections | Sweden | fecal | 134 (35) flocks, 26 (26) samples | Prevalence | 2 | 75 | p<0.05 | Cage housing reduces risk of worm infections |

1 Provided are the minimum and maximum values for conventional and organic farms over the years. E.g., somatic cell count on conventional farms varied from 290 000 to 360 000 cells per cow per year and cell count on organic farms varied from 270 000 to 410 000 cells per cow per year.

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