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| | |

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Contaminants and micro-organisms in Dutch organic food products;

Comparison with conventional products

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Abstract

Organic products were analysed for the presence of contaminants, micro-organisms and antibiotic resistance, and compared with those from conventional products. No differences were observed in the *Fusarium* toxins deoxynivalenol and zearalenone in organic and conventional wheat, both during a dry period and a very wet period which promoted the production of these toxins. Nitrate levels in head lettuce produced organically in the open field were much lower than those in conventional products. In iceberg lettuce and head lettuce from the green house no differences were detected. Organically produced carrots contained higher nitrate levels than conventional products. Both organic and conventional products contained no residues of non-polar pesticides above the legal limits, although some were detected in conventional lettuce. Organic products contained no elevated levels of heavy metals. *Salmonella* was detected in 30% of pig faeces samples obtained from 30 organic farms, similar to the incidence at conventional farms. At farms that switched to organic production more than 6 years ago, no *Salmonella* was detected, with the exception of one

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3 stable with young pigs recently purchased from another farm. No *Salmonella* was detected in
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5 faeces at the nine farms with organic broilers, and at one out of 10 farms with laying hens.
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8 This is comparable to conventional farms where the incidence for *Salmonella* lies around
9
10 10%. *Campylobacter* was detected in faeces at all organic broiler farms, being much higher
11
12 than at conventional farms. One of the most remarkable results was the fact that faeces from
13
14 organic pigs and broilers showed a much lower incidence of antibiotic resistant bacteria,
15
16 except for *Campylobacter* in broilers. It is concluded that the organic products investigated
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18 scored as equally well as conventional products with regard to food safety and at the same
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20 time show some promising features with respect to antibiotic resistance.
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29 **Key words**

30
31 Organic, lettuce, carrots, pigs, broilers, antibiotic resistance, *Salmonella*, *Campylobacter*
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Introduction

Organic production differs from conventional production in a number of ways. The use of synthetic pesticides is e.g. prohibited, the use of antibiotics is restricted and under strict control, only animal manure is used for fertilization and animals are allowed to forage outside. Theoretically this may result in a different composition of the products, both in terms of natural ingredients, but also with regard to contaminants and micro-organisms. It has e.g. been suggested that wheat may contain higher levels of mycotoxins, since no fungicides are used during production. On the other hand, the mechanical treatment of the soil against weeds, which is not so common in conventional practice, and the much poorer fertilization may create less advantageous conditions for survival of moulds during the winter. Foraging outside might expose the animals to higher levels of environmental contaminants, which end up in the edible products. This has e.g. been demonstrated in the case of organic eggs, which may contain elevated levels of dioxins and dioxin-like PCBs (Traag et al. 2005, Schoeters and Hoogenboom 2006, Van Overmeire et al. 2006, Kijlstra et al. 2007). The use of animal manure may also result in increased levels of heavy metals in organically produced vegetables and the presence of dangerous micro-organisms like *Salmonella* and *E. coli* O157. The restricted use of antibiotics might be expected to result in a decreased antibiotic resistance, especially against the newer generation of antibiotics.

A number of studies have focussed on potential differences between organic and conventional products, but these are still limited (Woese et al. 1997, Soil Association 2001, Magkos et al. 2006). The aim of the present study was first to examine the food safety aspects of organic products and secondly to look for potential differences with conventional products, focussing on a limited number of contaminants and micro-organisms. A major issue in this type of studies is the sampling of the products, since various factors may influence the results. It was decided to focus on Dutch products and to sample these as much as possible at the

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3 farms, thus allowing a check on the source. Furthermore it allowed an analysis of factors that
4
5 might contribute to the occurrence or levels of certain contaminants or micro-organisms.
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8 Certain conventional products were sampled at stores. In other cases data were compared with
9
10 data from existing monitoring programmes. The study included the most important organic
11
12 vegetable products in The Netherlands, being lettuce, wheat, carrots and potatoes. In addition,
13
14 eggs, broilers, pigs and cows were studied. Investigated were factors like mycotoxins, nitrate,
15
16 heavy metals, pesticides and *E. coli* O157 in vegetables, and *Salmonella*, *E. coli* O157,
17
18 antibiotic resistant bacteria, heavy metals and veterinary drugs in animals or their products.
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20 As such the study contributes to the essential and fortunately growing amount of information
21
22 about the food safety of organically produced food products.
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29 **Materials and Methods**

30 ***Sampling of products***

31 *Vegetables*

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34 Samples of 1 kg organic or conventional wheat were collected in August 2003 and
35
36 August/September 2004 at processing plants. Due to limited availability, this comprised in
37
38 2003 nine samples conventional winter wheat and 9 samples organic summer wheat, and in
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40 2004 fourteen samples conventional winter wheat, 17 samples conventional summer wheat
41
42 and 22 samples organic summer wheat. Samples came from several provinces in the
43
44 Netherlands, with the exception of the organic summer wheat in 2004 that came primarily
45
46 from the centre of the Netherlands, Flevoland.
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53 Organic lettuce was collected in 2003 and 2004 at 3 distribution centres and at small
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55 farms. Samples came from various locations in The Netherlands. Conventional lettuce was
56
57 sampled at super markets. Each sample contained 3-8 pieces of lettuce. The lettuce produced
58
59 in the field was sampled in 2003 in September/October, and in 2004 in June/July. Lettuce
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3 from the greenhouse was sampled in January till March in 2004. In each case similar numbers
4
5 of samples were taken from both types of production.
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8 Organic carrots were sampled in 2003 at farms shortly after the harvest (October-
9
10 November). In addition, organic and conventional carrots were sampled at farms (15 organic,
11
12 4 conventional), distribution centres (4 conventional) and shops (7 conventional) in March-
13
14 April 2004. Although spread all over the Netherlands, most farms were located in Flevoland.
15
16 Each sample contained 40 carrots.
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19 Organic potatoes were to a large extent sampled at the same farms as the carrots in
20
21 October-November 2004 shortly after the harvest. Each sample contained 40 potatoes.
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24 *Animal products*

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26 In the case of pigs, 31 organic pig farms were visited, 10 in December 2003-January 2004 and
27
28 21 in April-May 2005. For analysis on *Salmonella* and *E. coli* O157, at each farm faeces
29
30 sampled from 12 pigs, short before slaughter, were pooled into a combined sample. On farms
31
32 with more stables, 2 or 3 pooled samples were taken. To study the incidence of antibiotic-
33
34 resistant bacteria, faecal samples were taken from 5 pigs per farm. All samples were
35
36 immediately sent to the laboratories. Pig kidneys and diaphragm from 20 animals of 20
37
38 different organic farms were sampled at the slaughterhouse.
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43 Samples of bovine faeces were collected at 10 organic farms according to routine
44
45 procedures of the Food and Consumer Products Safety Authority. The ten farms were visited
46
47 in October-November 2003. One farm with a positive result on *E. coli* O157 was revisited in
48
49 June 2004. Each pooled sample consisted of faeces from 12 cows. The number of samples per
50
51 farm was 2 for less than 40 cows, 3 for 40-59 cows, 4 for 60-199 cows and 5 for more than
52
53 200 cows. Samples were put in polystyrene boxes and shipped immediately to the laboratory.
54
55
56 Ten bovine kidneys from 10 organic farms were sampled at the slaughterhouse.
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3 For examining *Salmonella* in faeces of laying hens and broilers, respectively 10 (April-
4 May 2004) and 9 (April-June 2005) organic farms were visited and 5 pooled samples, each
5
6 from 12 fresh droppings, were collected and sent immediately to the laboratory, according to
7
8 the protocol of the Product Boards for Livestock, Meat and Eggs (PVE). For antibiotic-
9
10 resistant bacteria in broilers, 5 samples of 1 fresh dropping per farm were collected and send
11
12 to the laboratory, according to standard protocols. At 10 organic farms with eggs, 30 fresh
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14 eggs per farm were collected and mixed at the laboratory into one pooled sample per farm.
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22 *Analysis of samples*

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24 For chemical analysis, lettuces, carrots and potatoes were frozen in liquid nitrogen and
25
26 homogenized. Wheat was milled with a sieve of 1 mm. For microbiological examination
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28 samples were not pre-treated.
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34 *Mycotoxins in wheat*

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36 The 71 wheat samples were analyzed for mycotoxins using an LC-MS/MS multi-method,
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38 including aflatoxin B₁, fumonisins B₁ and B₂, ochratoxin A, zearalenone, deoxynivalenol, T-2
39
40 and HT-2 toxins. Zearalenone was also examined with an HPLC method and fluorescence
41
42 detection. In short, from each sample two portions of 10 g were taken. One portion was
43
44 extracted with water and the other portion with a mixture of acetonitrile/water (84:16 v./v).
45
46 Both portions were extracted by shaking intensively for at least 3 hours. After filtering from
47
48 each extract 250 µL was mixed and injected on a LC-MS-MS system in multiple reaction
49
50 monitoring (MRM) mode. To diminish matrix influences, the analytical method was
51
52 performed by a standard addition protocol. The analysis of mycotoxins was performed on a
53
54 Waters Ultima LC-MS/MS system in the MRM-mode. A water (5 mM formic
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56 acid)/acetonitrile (5 mM formic acid) gradient was run at a flow of 0.20 ml/min on a
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1
2
3 Phenomenex Synergy HydroRP column (150 x 2 mm, 5 µm). All mycotoxins were analysed
4
5 under ESI+ conditions with the exception of zearalenone which was analysed under ESI-
6
7 conditions. Reference substances (>95% purity) were obtained from Biopure Reference
8
9 Substanzen GmbH (Tulln, Austria). Reference materials (Test materials) were obtained from
10
11 FAPAS (Central Science Laboratory, York, Great-Britain). Detection limits were 0.1 mg/kg
12
13 for deoxynivalenol and T-2 toxin, 0.1 mg/kg for HT-2 and fumonisins B₁ and B₂, 5 µg/kg for
14
15 aflatoxin B₁, and 50 µg/kg for ochratoxin A and zearalenone.
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22 *Heavy metals and arsenic*

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24 Samples were treated with 70% HNO₃ in a microwave oven (MARS 5). An aliquot was
25
26 subsequently analyzed in an electrothermal atomic absorption spectrophotometer (ETAAS,
27
28 SIMAA 6100) for cadmium, lead and arsenic by atomic adsorption at 228.8, 283.3 and 193.7
29
30 nm. Concentration measurements were determined from a working curve (linear) after
31
32 calibrating the instrument with standards of known concentration.
33
34

35
36 Another aliquot was analyzed for mercury in a Flow Injection Mercury System, FIMS 100
37
38 (Perkin Elmer, Groningen, The Netherlands). In short, the mercury in the digested samples
39
40 was reduced to the elemental state by tin (II) chloride solution and liberated from solution in a
41
42 closed vessel system, cold vapor technique (CV AAS). The mercury vapor passed through a
43
44 cell positioned in the light path of an atomic absorption spectrometer (FIMS). Its absorbance
45
46 is measured at a wavelength of 253.7 nm. The absorbance signal is a function of the mercury
47
48 concentration in the samples.
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55 *Nitrate*

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57 Samples of lettuce, carrots and potatoes were analyzed according to the SKALAR method. In
58
59 short, any debris (e.g. soil) from the sample was removed (without water) and a representative
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3 part of the sample was heated with water for 10-15 min on a boiling water bath. After cooling
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5 down, the volume was fixed to a known amount and the samples filtered. The method
6
7 procedure for the determination of nitrate is based on the hydrazinium reduction method
8
9 (Skalar Methods, catnr. 455-311) In short, the nitrate in the sample was reduced to nitrite with
10
11 hydrazinium sulphate and the nitrite was determined by diazotizing with sulphanilamide and
12
13 coupling with naphthylethylenediamine dihydrochloride to form a highly coloured azo dye.
14
15 This dye was measured at 540 nm in a continuous flow detector (Skalar, Breda, The
16
17 Netherlands).
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24 *Pesticides*

25
26 Pesticides were analyzed by a multi-method based on Anastassiades et al. (2003). Samples
27
28 were extracted by a modified Quechers method (Díez et al. 2006). After addition of
29
30 magnesium sulphate and salt, the mixture was centrifuged and an aliquot of the acetonitrile
31
32 was purified with primary-secondary amine. After cleaning by dispersive solid-phase
33
34 extraction the extracts were analysed on an Agilent Technologies 6890N GC (Waldbronn,
35
36 Germany) equipped with an ATAS Optic 3 PTV injector (Veldhoven, The Netherlands) and a
37
38 LECO Pegasus III TOF-MS (St. Joseph, MI, USA). A Restek RTX-CL Pesticides column
39
40 (30m x 0.25 mm, 0.25 μ m, Bellefonte, PA, USA) was employed with helium as carrier gas
41
42 and a linear programmed temperature program from 40°C to 280°C with 10°C/min. All
43
44 analytes were measured in EI+ mode. Reference substances were obtained from Dr.
45
46 Ehrenstorfer (Augsburg, Germany). The method quantifies a number of selected pesticides
47
48 and detects a large number of others qualitatively. If detected, these pesticides are quantified
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50 by injection of standards. LOQs vary between 0.01 and 0.5 mg/kg. The method is able to
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52 detect over 300 pesticides, including the major organophosphates, organochlorines and
53
54 pyrethroids.
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Veterinary drugs

Eggs, kidneys and meat were investigated for the presence of antibiotics (macrolides, aminoglycosides, sulphonamides, tetracyclines, quinolones, colistin) using microbial methods (Nouws et al. 1999, Pikkemaat et al. 2007a). Test systems consisted of a series of agar plates, each one specific for a group of residues and optimized for a particular matrix (Pikkemaat et al. 2007b). Methods were validated conform 657/2002/EC. Detection limits (CC_β) were below the EC maximum residue limits, except for valnemulin, cloxacillin and dicloxacillin in kidney and valnemulin, cefapirin, cefalexin, kanamycin, cloxacillin and dicloxacillin in meat (1 to 4 times the MRL).

Eggs were analysed for residues of toltrazuril and its metabolite ponazuril by LC-UV according to the method described by Mulder et al. (2005). In brief, homogenized whole egg was extracted with ethyl acetate. The solvent was evaporated and the residue dissolved in 0.02 M trisodium phosphate buffer. Purification was carried out by solid phase extraction on an Oasis[®] HLB cartridge. LC-UV analysis was performed on a Symmetry[®] C18 150 x 3.0 mm column with a methanol/water/acetic acid gradient and UV detection at 245 nm. The detection limit was 25 µg/kg for toltrazuril and 10 µg/kg for ponazuril.

Livers from broilers were analysed for residues of nitrofurans metabolites by LC-MS/MS based on the method of Hoogenboom et al., 1991 as modified by Cooper et al, 2005. In brief, homogenized liver samples were treated overnight with 0.1 M hydrochloric acid in the presence of 2-nitrobenzaldehyde. The samples were extracted twice with ethyl acetate. After evaporation the residue was dissolved in mobile phase. LC-MS/MS analysis was performed on a Symmetry[®] C18 150 x 3.0 mm column with a acetonitrile/water/acetic acid gradient and detection with positive ESI in multiple reaction monitoring mode. The detection limit for

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3 furazolidone and furaltadone metabolites was 0.5 µg/kg and for nitrofurazone and
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5 nitrofurantoin 1.0 µg/kg. Quantification was performed by isotope dilution.
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10 *Salmonella and E coli O157*

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12 Lettuce was examined for *Salmonella* using two methods. An aliquot of 25 gram of sample
13 (outer leaves) was incubated in 225 mL buffered peptone water (BPW) for 18 h at 37°C. This
14 pre-enrichment broth was subcultured in 2 selective enrichment media: Rappaport Vassiliadis
15 soya broth (RVS) and Müller-Kaufmann tetrathionate novobiocin broth (MKTTn). After 24 h
16 incubation at respectively 41.5 and 37°C aliquots of the selective media were streaked at both
17 XLD and BGA selective media. After 24 h incubation at 37°C the plates were evaluated for
18 the presence of specific *Salmonella* colonies. Suspected colonies were confirmed using
19 biochemical and serological methods. The VIDAS screenings method, based on an Enzyme
20 Linked Fluorescent Assay, was started from the selective enrichment broths after 6-8 h.
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22 VIDAS-negative samples do not require confirmation and can be considered “*Salmonella* not
23 detected”. VIDAS-positive samples were further treated as described above.
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38 Lettuce was examined for *E. coli* O157 as follows. An aliquot of 25 gram of sample (outer
39 leaves) was incubated in 225 mL modified tryptone soy bouillon at 41.5°C. After both 6 h and
40 18-24 h an immunomagnetic separation was carried out with Dynabeads® anti-*E.coli* O157.
41 Aliquots were plated on 2 selective plates (CT-SMAC and Chromagar O157™). After 18-24
42 h incubation at 37°C the plates were evaluated for the presence of specific colonies.
43
44 Suspected colonies were confirmed based on indole-production and agglutination with
45 specific antiserum. Positive isolates were also confirmed by the RIVM (Bilthoven, The
46 Netherlands).
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57 Faeces samples were examined for *Salmonella* according to both the VIDAS method or
58 the ISO 6579:2002 method, as described for lettuce. From February 2004 faeces samples,
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3 after enrichment in BPW, were also inoculated in modified semi-solid Rappaport Vassiliadis
4 medium (MSRV) with 0.01 g novobiocin/L. After incubation for 24 and 48 h at 41.5°C, plates
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6 were evaluated for specific growth areas, if necessary inoculated at selective growth media
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8 XLD and BGA, and further treated as described above. *E. coli* O157 in faeces was examined
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10 as described above for lettuce.
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15 16 17 *Antibiotic resistant bacteria*

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19 The isolation of *E. coli*, *Enterococcus faecium*, and *Campylobacter* spp. was started directly
20 upon arrival of the samples at CIDC-Lelystad by making a 1:10 w/v suspension of the faeces
21
22 in buffered peptone water with 20% glycerol, from which on the same day selective media
23
24 were inoculated. Subsequently the suspensions were stored at -20°C. *E. coli* and *E. faecium*
25
26 were isolated on respectively MacConkey agar and Slanetz and Bartley agar by inoculating 50
27
28 µL of a serial dilution series of the 1:10 diluted sample with a spiral plater (*E. faecium*) or by
29
30 direct inoculation of the plates with sterile swabs (*E. coli*). The MacConkey plates were
31
32 incubated overnight aerobically at 37°C and the Slanetz Bartley plates during two days
33
34 aerobically at 42°C. From each sample, an *E. coli* colony with the typical morphology was
35
36 subcultured on Heart Infusion agar with 5% sheep blood and a colony typical of *E. faecium* on
37
38 Columbia agar with 5% sheep blood. Both were incubated overnight at 37°C. Subsequently
39
40 the strains were suspended in buffered peptone water with 20% glycerol and stored at -80°C.
41
42 All *E. coli* isolates were identified biochemically by the Indole reaction. The species
43
44 identification of *E. faecium* was performed with a Polymerase Chain Reaction (PCR)
45
46 described by Dutka Malen et al. (1995). For the isolation of *Campylobacter* spp. CCDA-agar
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48 was used with 32 µg/mL cefoperazone and 10 µg/mL amphotericine B to suppress the growth
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50 of Gramnegative bacteria and moulds. Plates were inoculated directly upon arrival of the
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52 samples with a swab. The CCDA-plates were incubated for 48 h in microaerophilic conditions
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3 at 42°C. Typical colonies were streaked on HIS-plates and again incubated for 48 h
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5 microaerophilically at 37°C. The isolates were all identified as *Campylobacter coli* by PCR.
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8 The susceptibility of the isolates was determined quantitatively using a broth micro
9
10 dilution method according to CLSI guidelines (M31-A2 and M100-S16), with cation-adjusted
11
12 Mueller Hinton broth. Microtiter plates with dehydrated dilution series of a panel of
13
14 antibiotics (see Figures 1 and 2) were provided by Trek Diagnostic Systems (Basingstoke,
15
16 UK). For *Campylobacter* spp. the plates, after inoculation with 50 µL per well of a 200-fold
17
18 diluted 0.5 McFarland suspension in NaCl 0.85% solution, were incubated microaerophilic in
19
20 a shaking incubator at 37°C for 24 h. ATCC strains *E. coli* 25922, *E. faecalis* 29212 and *C.*
21
22 *jejuni* ATCC 33560 were tested daily to control the quality of the results.
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27 The minimum inhibitory concentrations (MICs) were defined as the lowest antibiotic
28
29 concentration at which visually bacterial growth was observed. Strains with MICs higher than
30
31 the MIC breakpoints defined by CLSI were classified as resistant. For those antibiotics (e.g.
32
33 neomycin and florfenicol for *E. coli*, the former growth promoters for the enterococci) and
34
35 bacterial species (*Campylobacter* spp.), for which CLSI has not defined clinical MICs,
36
37 breakpoints used in the Dutch Resistance Monitoring Programme were used (Maran 2004).
38
39 Subsequently resistance proportions were calculated for each individual antibiotic tested.
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41 Moreover, proportions of fully susceptible isolates and resistant to 1, 2, 3, 4 and more than 4
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43 different antibiotic classes were calculated.
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Results and Discussion

The present study focussed on a limited number of contaminants and micro-organisms in organic products and organic production systems. Selection was based on a report of the Expertise Centre for Agriculture in the Netherlands, and information on other projects already running in this area. Contaminants already studied in ongoing studies, like dioxins in eggs (Kijlstra et al. 2007), were not included in this study. Results were subsequently compared with those from conventional agriculture, partly coming from this project and partly from other monitoring programmes in the Netherlands. In addition a comparison was made with results from other studies.

A very important issue is the sampling strategy and in particular the site of sampling; the farm or the shop/supermarket (Magkos et al. 2006). Samples taken at a shop, give information on the products actually bought by the consumer. However, in this study the choice was made to collect data as much as possible at the farm, thus allowing the control on the origin of the product and a survey on the actual farming conditions. This would also allow an investigation on potential causes for undesirable contaminants or micro-organisms. It should be stressed that organic farming in the Netherlands is a growing market and that most of the organic farms switched to organic practices only recently. In cases where sampling at the farms was not possible, due to logistic or hygienic reasons, samples were taken at distribution centres and slaughterhouses. At the time of this study there were about 500 farms involved in the organic production of vegetables, potatoes and grains. In the present study 24, 35 and 21 farms were sampled for lettuce, carrots and potatoes respectively. Results will be described and discussed for each type of product investigated.

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3 *Wheat (pesticides, mycotoxins, heavy metals)*
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6 Wheat was collected in 2003 and 2004. Twelve of the 20 organic samples came from farms
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8 that switched to organic less than 5 years ago. The organic wheat covered races like Melon,
9
10 Lavett and Pasteur, the conventional wheat was not inventoried. Yield of organic wheat varied
11
12 between 4300 and 7900 kg/hectare. Eighteen pooled samples of organic wheat were
13
14 investigated for non-polar pesticides but none of the more than 300 different compounds
15
16 could be detected.
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20 The levels of the 7 examined mycotoxins in wheat were below detection limits in the
21
22 conventional and organic wheat samples, with the exception of the *Fusarium* toxins
23
24 deoxynivalenol (DON) and zearalenone (ZON) (Table 1). In most of the samples collected in
25
26 2003, levels of DON were below the action limit of 0.1 mg/kg, with the exception of 6
27
28 conventional products showing levels between 0.1 and 1 mg/kg. Of the samples collected in
29
30 2004 before the end of August, nine out of 14 samples (64%) of conventional winter wheat
31
32 and 8 out of 11 samples (73%) of conventional summer wheat, contained DON levels above
33
34 the action limit (range 0.1-1.5 mg/kg), as compared to five out of seven (71%) samples
35
36 organic summer wheat (range 0.1-1.8 mg/kg). However, after a period with heavy rain fall by
37
38 the end of August 2004, DON was detected in all samples at levels up to 11 mg/kg. In these
39
40 samples also zearalenone was increased with levels up to 5.7 mg/kg. Overall there was no
41
42 significant difference between organic and conventional wheat. This is contradictory to
43
44 studies by Malmauret et al. (2002) who did find higher levels of the *Fusarium* toxins DON,
45
46 nivalenol and zearalenone in organic wheat and barley. However, Döll et al. (2002), Bernhoft
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48 et al. (2003), Schneweis et al. (2005), Rossi et al. (2006) and Pussemier et al. (2006) also
49
50 observed lower average levels in organic cereals. Czerwiecki et al. (2002), analyzing various
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52 cereals in Poland in two subsequent years for ochratoxin A, observed higher frequencies of
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54 contamination of organic cereals in one year, but the opposite in the next year with some very
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3 high levels in some conventional wheat. In general, there is a tendency for organic cereals to
4 contain lower mycotoxins levels but differences appear to be rather small (Magkos et al.
5
6 2006) and factors like climate may play a much more crucial role than the type of production.
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10 Lead, mercury and arsenic levels in most samples were below the detection limits of
11
12 respectively 0.1, 0.01 and 0.1 mg/kg. In 4 organic wheat samples mercury levels just above
13 the LOD were detected, i.e. levels of 0.013, 0.011, 0.016 and 0.016 mg/kg. Cadmium could
14
15 be detected in most samples but the highest level of 0.077 mg/kg was well below the EU-limit
16
17 of 0.2 mg/kg. There was no difference in cadmium levels between organic and conventional
18
19 wheat (data not shown). This is contrary to Rossi et al. (2006), who found slightly lower
20
21 cadmium but higher lead levels in organic wheat, although not at levels exceeding the EU-
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23 limits.
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29 *Lettuce (micro-organisms, pesticides, nitrate, heavy metals)*
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31 Organic lettuce was sampled at 3 distribution centres, responsible for 70% of the organic
32
33 lettuce. Half of the farms produced organically for two decades or more, the other half for less
34
35 than ten years. Conventional lettuce was obtained from local stores. None of the samples
36
37 tested positive for *Salmonella* or *E. coli* O157, two types of micro-organisms that might be
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39 introduced through the use of animal dung. This shows that this is not a common problem but
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41 cannot exclude the presence of these pathogenic micro-organisms in a small fraction of the
42
43 products. To minimize the potential risk of contamination, several countries like the US and
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45 Canada do not allow the use of non-composted manure.
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50 Ten pooled samples of organic and conventional lettuce were examined for non-polar
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52 pesticides but none of the organic products tested positive. Two pooled samples of
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54 conventional lettuce contained residues of the permitted pesticide vinclozolin and one of these
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56 in addition malathion and piperonylbutoxide. Levels were below the residue limits.
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3 In both organic and conventional iceberg lettuce produced outside, nitrate levels were
4 below the limits, with a range of 370 to 1759 mg/kg for organic and 652 to 1367 mg/kg for
5 conventional products (Table 2). In the case of organic head lettuce produced outside (19
6 samples) and the greenhouse (10 samples), one sample of each exceeded the limit. In the case
7 of conventional head lettuce, this frequency was much higher. Levels above the limit were
8 detected in 18 out of 19 samples grown outside and 4 out of 14 samples from the greenhouse.
9 In comparison with conventional head lettuce, nitrate levels were much lower for organic
10 products. This confirms results from previous studies (Consumentenbond 2002, Woese et al.
11 1997, Soil Association 2001). In the case of iceberg lettuce, no differences were observed.
12 Levels of arsenic and the heavy metals lead, cadmium and mercury were below the limits.
13 Cadmium levels showed a large variation, as shown in Table 2. However, no differences were
14 observed between organic and conventional products.
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34 *Carrots (pesticides, nitrate, heavy metals)*

35 Organic carrots were sampled at farms with varying experience, ranging from 2-18 years.
36 Most of them switched to organic less than 5 years ago. More than 11 different varieties were
37 used but Nerac was most popular. Yields varied between 35 and 75 tons/hectare. Four pooled
38 samples of organic carrots were investigated for non-polar pesticides but none of the more
39 than 300 different compounds could be detected.
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48 Nitrate levels in organic carrots showed a large variation, with a range in 2004 of 11 to
49 864 mg/kg and a median of 244 mg/kg (Table 3). This was 3 times higher than in
50 conventional carrots harvested in the same year, showing a median of 58 mg/kg and a range
51 from 16 to 180 mg/kg. Previous studies showed lower levels in organic carrots
52 (Consumentenbond, 2002) but the present data confirm those from other studies showing an
53 increase in nitrate levels in organic carrots (Bokhorst, personal communication). Malmauret et
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3 al. (2002) also observed higher levels in organic carrots, i.e. 394 versus 113 mg/kg product in
4
5 conventional carrots. Studies at the farms showed that a relatively high use of dung and plant
6
7 waste materials, as compared to previous years, is probably the cause of the rise in nitrate
8
9 levels. This is partly related to farms that switched only recently to organic practices.
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12 Heavy metals and arsenic were only analyzed in the organic carrots samples in 2003.
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14 None of the levels exceeded the limits, although some cadmium levels were close to the limit
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16 of 0.1 mg/kg.
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22 *Potatoes (pesticides, nitrate, heavy metals)*

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24 Organic potatoes were sampled at the farms, conventional potatoes were not investigated.
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26 Most of the farms were also sampled for carrots, again most of them with less than 5 years of
27
28 experience. Agria and Sante were the most popular races with yields between 23 and 47
29
30 tons/hectare. Four pooled samples of organic potatoes were investigated for non-polar
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32 pesticides but none of the more than 300 different compounds could be detected.
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36 The nitrate level in organic potatoes was low with an average of 87 mg/kg but the
37
38 variation was quite large (range 8-390 mg/kg). There were no Dutch data on conventional
39
40 potatoes for comparing the data. However, levels were lower than those reported by Hajšlová
41
42 et al. (2005) for organic potatoes. In that study levels in conventional potatoes were higher
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44 than in organic ones.
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48 None of the samples levels exceeded the limits for heavy metals, although some cadmium
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50 levels were close to the limit of 0.1 mg/kg.
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55 *Pigs (veterinary drugs, heavy metals, micro-organisms, antibiotic resistance)*

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3 In total 31 organic farms with pigs were visited, representing 53% of the organic pig farms in
4 the Netherlands. Fourteen farms were more experienced (6-14 years), the other 17 switched to
5 organic only recently (1-4 years). The number of pigs varied between 20 and 1100 (Table 4).
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10 No residues of antibiotics were detected with a bacterial test in samples of kidneys and
11 meat of 20 organic pigs, sampled at the slaughterhouse. Only one kidney sample showed a
12 slight inhibition of bacterial growth on the macrolides plate but below the action level. Levels
13 of arsenic in meat were below the detection limit of 0.1 mg/kg. Similar was true for levels of
14
15 led and mercury in the kidneys of these animals, being below respectively 0.05 and 0.005
16 mg/kg with one exception, being a mercury level of 0.008 mg/kg. Cadmium levels varied
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18 between less than 0.005 and 0.38 mg/kg (median 0.11 mg/kg), all of them being below the
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20 EU-limit of 1 mg/kg.
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30 Initially 10 farms were visited in the winter of 2003 and all the pooled faeces samples of
31 the 12 animals per farm scored negative for *Salmonella*. Another set of 20 farms was sampled
32 in the spring of 2005 and this time 8 farms were positive for *Salmonella*. Interestingly, this
33 included 7 farms that only recently switched to organic (3 years or less). The other farm
34 turned to organic in 1996 and on this farm 3 barns were sampled. One of these samples,
35 derived from a stable with young pigs that were purchased elsewhere, was positive. Overall
36 the incidence of *Salmonella* was 27% and comparable to data known from conventional farms
37 in the Netherlands. However, the fact that *Salmonella* could not be isolated from dung
38 collected at the more experienced organic pig farms, is of potential interest. Possible causes
39 could be the use of more rough fibre rich and more diverse feeds at organic farms compared
40 to conventional pig farms, which may influence the colonisation of *Salmonella* in the GI-tract
41 (Knudsen et al. 2001).
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58 *Campylobacter* was one of the bacteria generally used for the assessment of antibiotic
59 resistance and could be isolated from 56% of the faeces samples, being similar to
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3 conventional farms. When focussing on the farms, *Campylobacter* could be isolated from one
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5 or more of the 5 sampled pigs at 81% of the farms. *E. coli* O157 was not detected in any of
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7 the samples, but this was only analysed in samples from the first 10 farms. This was decided
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9 because the data were in line with conventional farms where the prevalence of *E. coli* O157 is
10
11 0-2%.
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15 The use of antibiotics at organic farms is restricted although 19 of the 31 farms mentioned
16
17 the occasional use of antibiotics. The resistance level to a number of antibiotics was
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19 investigated in *E. coli*, *E. faecium* and *Campylobacter* spp., isolated from faeces of the 5
20
21 animals per farm (1 isolate per sample). *E. coli* could be isolated from all 155 animals and
22
23 resistance was only observed for older drugs like amoxicillin, neomycin, tetracycline,
24
25 sulfamethoxazole, trimethoprim and chloramphenicol. No resistance was observed in *E. coli*
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27 from organic farms against newer drugs like cefotaxim, gentamicin, the quinolones
28
29 ciprofloxacin and nalidixinic acid, and florfenicol. Figure 1A shows that in general the
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31 resistance in organic pigs is lower than observed in conventional pigs, based on data from the
32
33 Dutch regular monitoring program (MARAN, 2004). In this program one animal per slaughter
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35 batch is sampled, according to guidelines of the European Food Safety Authority. Regarding
36
37 the limited number of farms, it was decided to use five animals per farm in the present study,
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39 which could have some influence on the results. *E. Faecium* was isolated from 80% of the
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41 samples or on 97% of the farms. Significant resistance was only observed against doxycyclin,
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43 quinupristin/dalfopristin (Synercid[®]) and bacitracin, and to flavomycin but this *Entorococcus*
44
45 species is intrinsically resistant to this drug. Figure 1B shows that also for this species in
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47 general the resistance is lower than in conventional pigs, in particular true for erythromycin
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49 and salinomycin. Bacitracin has been used as a growth promoter until 1999 and resistance is
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51 rather widespread in conventional pigs, and apparently also in organic pigs. Synercid is
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53 related to virginiamycin, also used as a growth promoter until 1999.
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3 As mentioned above, *Campylobacter (jejuni and coli)* could be isolated from 80% of the
4 samples, or at 77% of the farms. In comparison to *E. coli* and *E. faecium*, *Campylobacter*
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6 showed resistance to many of the tested drugs (9 out of 12). Remarkable was the resistance
7
8 against the quinolones ciprofloxacin and nalidixinic acid, since this type of drugs is only used
9
10 to treat individual pigs. In general, resistance in organic pigs was lower than in conventional
11
12 pigs (Figure 1C). When looking at the fraction of bacteria resistant to 1, 2, 3, 4 or more than 4
13
14 antibiotics, 32% of the *E. coli* isolates from organic pigs were multiple drug resistant
15
16 (resistant to 2 or more independent classes of antibiotics), as compared to 55% in
17
18 conventional pigs (Table 5). For *E. faecium* figures were similar for organic and conventional,
19
20 being respectively 75% and 74%, but for *Campylobacter* spp. lower for organic, i.e. 45%
21
22 versus 80%. Although the lack of difference for *E. faecium* seems remarkable, differences
23
24 became more clear when focussing on multiple resistance against 3 or more antibiotic classes,
25
26 showing 33% resistance for organic versus 46% for conventional. Furthermore, low level
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28 resistance (<10%) was observed in *Enterococci* isolated from organic farms for erythromycin
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30 and salinomycin compared to the resistance levels found in conventional animals.
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41 *Lactating cows (veterinary drugs, micro-organisms)*

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43 Ten kidney samples of cows, reared in organic farms, were collected at the slaughterhouse
44
45 and tested for bacterial growth inhibition. Three samples showed a slight inhibition at the
46
47 aminoglycosides plate but below the action limit.
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51 Ten farms with lactating cows were visited in September-November 2003 and samples of
52
53 dung were collected. Farm size varied between 35-74 cows and one bigger farm with 250
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55 animals. *E. coli* O157 was detected in all three samples of one farm and in one of four
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57 samples of another farm, the latter collected at a pasture with non-lactating cows and young
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3 animals. The first farm was revisited in September 2004 and found negative than, as was the
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5 case for the second farm revisited in June 2004.
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10 *Laying hens (veterinary drugs, micro-organisms, heavy metals)*

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12 Ten farms out of a total of 100 were visited and both eggs and dung collected. Number of
13
14 hens per farm varied between 170 and 10900, and farms switched to organic between 1994
15
16 and 2003. Dung was tested for the presence of *Salmonella* using different methods, including
17
18 the standard MSRV method. Most samples scored negative, except for one farm where one of
19
20 the two barns tested positive. Except for one, hens were vaccinated against *Salmonella*, but
21
22 antibiotics were reported not to be applied. All eggs tested negative for toltrazuril, and for the
23
24 presence of aminoglycosides, sulfonamides, beta-lactam, tetracyclins, quinolones and colistin.
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26 Levels of cadmium, led, arsenic and mercury were below the detection limits of respectively
27
28 0.005, 0.05, 0.1 and 0.005 mg/kg. This is in contrast to the rather high levels of heavy metals
29
30 observed by Van Overmeire et al. (2006) in eggs from private owners in Belgium, indicating
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32 that heavy metals may be transferred to eggs, as previously shown for dioxins.
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41 *Broilers (veterinary drugs, micro-organisms, heavy metals, antibiotic resistance)*

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43 The number of organic farms with broilers is rather limited in the Netherlands and these were
44
45 all visited. Most farms turned organic since 1998 and the number of animals varied between
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47 380 and 8000. Animals belonged to slow-growing varieties, as reflected by the age at
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49 slaughter of 70-81 days (for conventional broilers this is around 40 days). Antibiotics were
50
51 reported not to be used. Other veterinary drugs and anthelmintics were used on 2 and 1 farms,
52
53 respectively. Livers were checked for nitrofurans and all tested negative. Led, arsenic
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55 and mercury in livers was below the detection limits of respectively 0.05, 0.1 and 0.01 mg/kg.
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3 Cadmium levels varied between <0.005 and 0.029 mg/kg, well below the EU-limit of 0.5
4 mg/kg.
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8 On none of the 9 organic farms, animals were carriers of *Salmonella* as determined with
9 the MSRV-method. Of course, the number of farms is very small but the data are in line with
10 those observed by the VWA in 2003 and 2004 in meat, showing an incidence of 2 and 3%
11 respectively, as compared to 11 and 7% in meat from conventional broilers (VWA 2004b,
12 2005). *Campylobacter* was detected in faeces samples at all farms, and overall could be
13 isolated from 32 of the 45 samples. In conventional broilers the incidence is much lower, in
14 2000, 2001 and 2002 respectively 24, 16 and 27% (VWA 2004a). The VWA detected
15 *Campylobacter* in 36 and 44% of the meat products of organic broilers, as compared to 26 and
16 29% of the conventional products (VWA 2004b, 2005). Heuer et al. (2001) examined organic
17 and conventional farms in Denmark and detected *Campylobacter* in respectively 49 and 100%
18 of the faeces samples collected during slaughter. Remarkable was the high incidence of 91%
19 for *Campylobacter jejuni* and only 9% *C. coli*, whereas Rodenburg et al. (2004), who also
20 observed a high incidence of *Campylobacter* in organic broilers, reported incidences of 30%
21 for *C. jejuni* and 70% for *C. coli*. This is relevant since in particular *C. jejuni* is responsible
22 for infections in humans. Our data are however in line with those of Heuer et al. (2001), also
23 reporting primarily *C. jejuni*, independent of the type of production.
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45 In *Campylobacter* highest resistance against antibiotics was found against amoxicillin,
46 doxycyclin, metronidazole and the quinolones nalidixinic acid and ciprofloxacin (Figure 2C).
47 There were no clear differences in resistance proportions with data from 57 samples from
48 conventional broilers. This was also the case for multi drug resistance (resistant against 2 or
49 more independent classes of antibiotics) showing figures of 72 and 63% in organic versus
50 conventional broilers (Table 6).
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3 *E. coli* could be isolated from all 45 faecal samples, *E. faecium* from 89% of the samples..
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5 Considerable resistance was observed in *E. coli* against amoxicillin, tetracycline,
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7 sulfamethoxazole, trimethoprim and to a lesser extent nalidixinic acid, but not against the
8
9 newer antibiotics. Figure 2A shows a comparison with data from conventional broilers,
10
11 demonstrating that in conventional broilers resistance occurred much more frequently than in
12
13 organic animals. *E. faecium* showed considerable resistance against doxycyclin, bacitracin,
14
15 synergid, and to a lesser extent to erythromycin, salinomycin and streptomycin but again
16
17 much lower than in conventional broilers. This organism is known to be resistant against
18
19 flavomycin as shown in Figure 2B. Overall, 27% of the *E. coli*'s were multiple resistant (2 or
20
21 more independent classes of antibiotics) as compared to 81% of the conventional broilers. For
22
23 *E. faecium* figures are respectively 69 and 94% (Table 6). The observed reduced resistance
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25 against antibiotics confirms previous studies by the Dutch Food and Consumer Products
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27 Safety Authority in the Netherlands (VWA, 2005).
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34 The fact that in organic broilers in the commensal gut flora (*E. coli* and *E. faecium*) less
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36 antimicrobial resistance occurs than in conventional broilers can mainly be explained by the
37
38 absence of selection pressure in organic animals. The fact that in *Campylobacter* spp. this
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40 difference was not observed is likely to be caused by the fact that in broilers *Campylobacter*
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42 colonisation occurs after environmental contamination with this organism. In a densely
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44 populated country like the Netherlands it can be speculated that the *Campylobacter* spp.
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46 isolated from the organic broilers originate from conventionally reared poultry and were
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48 already resistant at the moment of colonisation.
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55 Conclusions

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57 Although some of the results suggest a difference between organic and conventional, it should
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59 be stressed that the present study was only a survey focussing on one set of samples and one
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3 or two production years. However, in a number of cases the results are similar to those from
4
5 other studies, like the lower nitrate levels in head lettuce, the lack of increased mycotoxin
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7 levels in organically produced grains, less *Salmonella* but more *Campylobacter* in broilers,
8
9 and less antibiotic-resistant bacteria in pigs and broilers. In the case of nitrate in carrots there
10
11 are indications for increasing levels in organic cultivation and further studies are required to
12
13 confirm this. Also the lower incidence of antibiotic resistant bacteria in pigs and the lower
14
15 incidence of *Salmonella* in more experienced pig farms deserve more attention.
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3 Figure 1. Incidence of antibiotic resistant *E. coli*'s (A), *E. faecium* (B) and *Campylobacter* (C)
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5 in faeces of organic (blue bars) and conventional (red bars) pigs. Five and one faeces samples
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7 were collected at each organic and conventional farm respectively. *E. coli*'s were isolated
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9 from respectively 155 and 296 samples, *E. faecium* from 105 and 110 samples,
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11 *Campylobacter* from 84 and 198 samples.
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17 Figure 2. Incidence of antibiotic resistant *E. coli*'s (A), *E. faecium* (B) and *Campylobacter* (C)
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19 in faeces of organic (blue bars) and conventional (red bars) broilers. Five and one faeces
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21 samples were collected at each organic and conventional farm respectively. *E. coli*'s were
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23 isolated from respectively 45 and 300 samples, *E. faecium* from 45 and 180 samples,
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25 *Campylobacter* from 32 and 57 samples.
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Table 1. Levels of DON and ZON (median and range) in organic and conventional wheat sampled in 2003 and 2004.

| Sample date | Production type | | DON (mg/kg) | ZON (mg/kg) | Number of samples |
|--|-----------------|--------|--------------------|-----------------------|----------------------|
| 2003 | Organic | Summer | <0.1 (<0.1-0.2) | <0.05 | 9 |
| | Conventional | Winter | 0.3 (<0.1-1.0) | <0.05 | 9 |
| 2004, until 24 th August | Organic | Summer | 0.2 (<0.1-1.8) | <0.05 (<0.05-0.12) | 7 |
| | Conventional | Summer | 0.2 (<0.1-1.5) | <0.05 (<0.05-0.13) | 11 |
| | Conventional | Winter | <0.1 (<0.1-0.4) | <0.05 | 14 |
| 2004, after 24 th August | Organic | Summer | 1.7 (<0.1-11.0) | 2.6 (<0.05-5.7) | 15 |
| | Conventional | Summer | 2.0 (0.5-6.3) | 0.7 (<0.05-5.2) | 6 |

No significant differences between conventional and organic (Student t-test, two-sided)

Table 2. Nitrate and cadmium levels in organic (O) and conventional (C) iceberg and head lettuce produced outside and in the greenhouse.

| Type | production | | Nitrate** (mg NO ₃ /kg) | | n | Cadmium (mg/kg) | |
|--------------|------------|---|---------------------------------------|-----------|----|--------------------|---|
| | | | median | range | | range | n |
| Iceberg | field | O | 939 | 370-1759 | 13 | <0.02-0.022 | 5 |
| Iceberg | field | C | 966 | 652-1367 | 13 | <0.02-0.038 | 4 |
| Head lettuce | field | O | 1275* | 139-3212 | 19 | <0.02-0.042 | 6 |
| Head lettuce | field | C | 3280* | 1818-4357 | 19 | <0.02-0.052 | 8 |
| Head lettuce | greenhouse | O | 3223 | 946-4129 | 10 | <0.02-0.043 | 9 |
| Head lettuce | greenhouse | C | 3515 | 2439-5197 | 14 | <0.02-0.066 | 8 |

* Differences between nitrate in conventional and organic head lettuce from the field were statistically significant (Student t-test, $p < 0.001$)

** EU-limits for head lettuce from the field are 2500 mg/kg, harvested between 1st April and 30th September, and 4000 mg/kg when harvested between 1st October and 31st March; for head lettuce from the greenhouse 3500 mg/kg, when harvested between 1st April and 30th September, and 4500 mg/kg when harvested between 1st October and 31st March; for iceberg lettuce from the field 2000 mg/kg (EC 2001, 2002).

Tabel 3. Nitrate levels in organic (O) and conventional (C) carrots.

| Production | Year | Nitrate (mg NO ₃ /kg) | | n |
|--------------|------|----------------------------------|--------|----|
| | | median | range | |
| Organic | 2003 | 192 | 34-449 | 20 |
| Organic | 2004 | 244 | 11-864 | 15 |
| Conventional | 2004 | 58 | 16-180 | 15 |

Differences between nitrate in conventional and organic carrots from 2004 were statistically significant (Student t-test, $p < 0.001$).

Table 4. Description of the farms with organic pigs, including the results from the studies on *Salmonella* and *Campylobacter*.

| Farm number | Organic since | Animals | <i>Salmonella</i> | <i>Campylobacter</i> * | Rough fiber-rich feed |
|-------------|---------------|---------|-------------------|------------------------|-----------------------|
| 1 | 1997 | 340 | negative | 5/5 | + |
| 2 | 1990 | 75 | negative | 5/5 | +++ |
| 3 | 1998 | 500 | negative | 4/5 | + |
| 4 | 1998 | 122 | negative | 3/5 | ++ |
| 5 | 1998 | 200 | negative | 2/5 | + |
| 6 | 1995 | 140 | negative | 4/5 | + |
| 7 | 1999 | 120 | negative | 5/5 | + |
| 8 | 1999 | 525 | negative | 5/5 | + |
| 9 | 1997 | 850 | negative | 5/5 | + |
| 10 | 1990 | 450 | negative | 0/5 | + |
| 11 | 2003 | 500 | positive | 3/5 | + |
| 12 | 2004 | 700 | negative | 4/5 | ± |
| 13 | 1996 | 460 | positive | 3/5 | - |
| 14 | 2003 | 400 | positive | 2/5 | + |
| 15 | 2002 | 325 | negative | 5/5 | + |
| 16 | 2002 | 257 | positive | 3/5 | + |
| 17 | 2002 | 950 | negative | 5/5 | - |
| 18 | 2004 | 400 | positive | 3/5 | - |
| 19 | 2003 | 106 | negative | 5/5 | ± |
| 20 | 2002 | 620 | negative | 1/5 | + |
| 21 | 2001 | 400 | negative | 2/5 | - |
| 22 | 2002 | 120 | positive** | 2/5 | + |
| 23 | 1998 | 400 | negative | 5/5 | - |
| 24 | 2003 | 1100 | positive** | 0/5 | - |
| 25 | 2003 | 450 | positive | 0/5 | + |
| 26 | 2002 | 80 | negative | 4/5 | + |
| 27 | 2002 | 440 | negative | 1/5 | + |
| 28 | 1998 | 700 | negative | 0/5 | - |
| 29 | 1998 | 300 | negative | 0/5 | + |
| 30 | 2002 | 450 | negative | 1/5 | + |
| 31 | 1999 | 20 | ni*** | 0/5 | - |

* number of faeces samples from which *Campylobacter* could be isolated for antibiotic resistance

** negative with the MSR/V method

*** ni: not investigated due to loss of sample

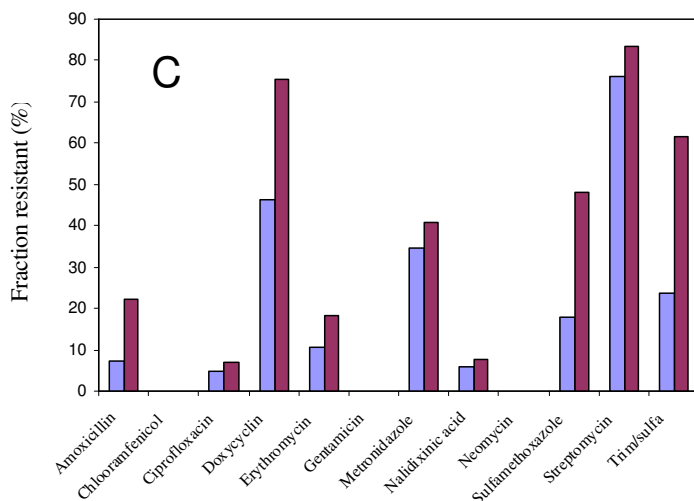
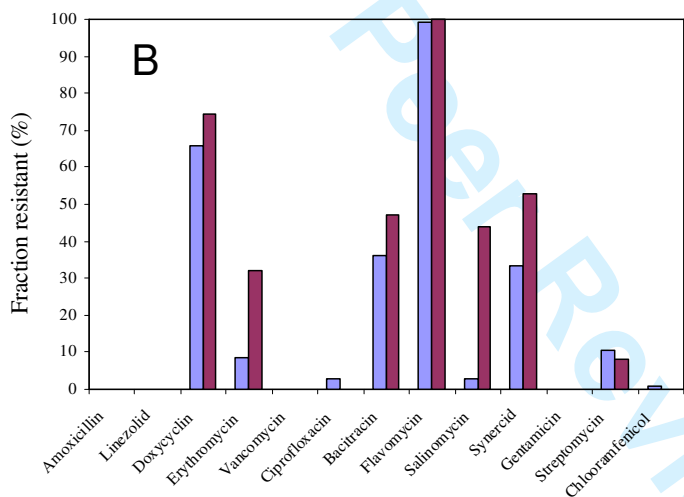
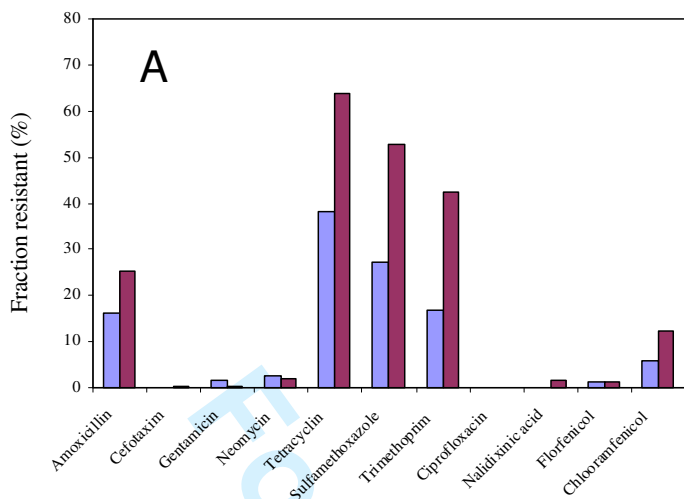
Table 5. Resistance of bacteria from pig faeces against different classes of antibiotics. Data expressed as the percentage of bacteria resistant against 0, 1, 2, 3, 4 or more than 4 classes of antibiotics. Conventional data from the MARAN study (MARAN, 2004).

| Resistant to classes | <i>E. coli</i> | | <i>E. faecium</i> | | <i>Campylobacter</i> | |
|----------------------|----------------|--------------|-------------------|--------------|----------------------|--------------|
| | Organic | Conventional | Organic | Conventional | Organic | Conventional |
| 0 | 43 | 27 | 3 | 5 | 22 | 5 |
| 1 | 25 | 19 | 22 | 21 | 33 | 15 |
| 2 | 15 | 14 | 43 | 28 | 22 | 26 |
| 3 | 7 | 16 | 22 | 17 | 14 | 25 |
| 4 | 6 | 17 | 9 | 17 | 4 | 16 |
| >4 | 4 | 8 | 2 | 12 | 5 | 13 |

Table 6. Resistance of bacteria from broiler faeces against different classes of antibiotics.

Data expressed as the percentage of bacteria resistant against 0, 1, 2, 3, 4 or more than 4 classes of antibiotics. Conventional data from the MARAN study (MARAN, 2004).

| Resistant to classes | <i>E. coli</i> | | <i>E. faecium</i> | | <i>Campylobacter</i> | |
|----------------------------|----------------|--------------|-------------------|--------------|----------------------|--------------|
| | Organic | Conventional | Organic | Conventional | Organic | Conventional |
| 0 | 53 | 10 | 3 | 1 | 28 | 19 |
| 1 | 20 | 9 | 30 | 6 | 0 | 18 |
| 2 | 16 | 8 | 38 | 10 | 31 | 23 |
| 3 | 2 | 13 | 20 | 16 | 22 | 26 |
| 4 | 9 | 22 | 8 | 22 | 13 | 7 |
| >4 | 0 | 38 | 3 | 46 | 6 | 7 |



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Figure 1

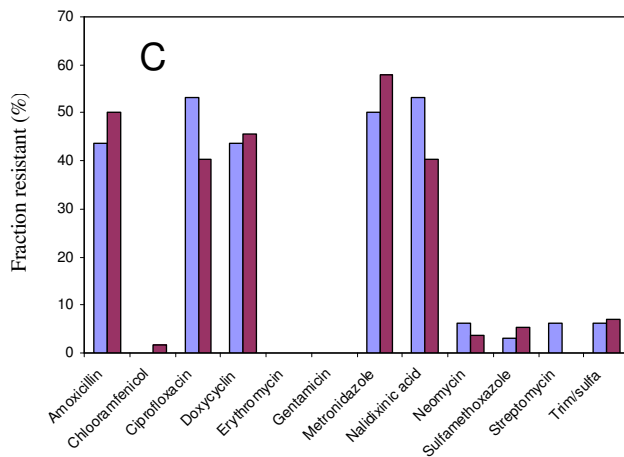
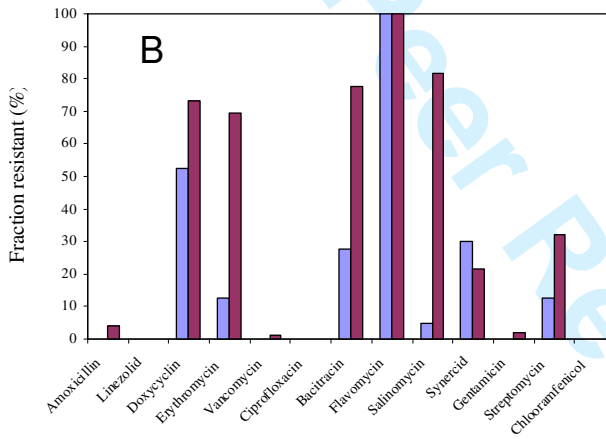
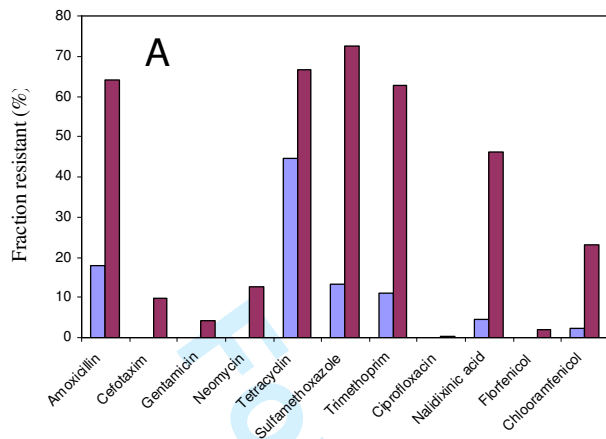


Figure 2.