Vitenskapskomiteen for mattrygghet
Norwegian Scientific Committee for Food Safety

Comparison of organic and conventional food and food production

Part IV: Human health – hygiene and pathogens

Opinion of the Panel on biological hazards and the Steering Committee of the Norwegian Scientific Committee for Food Safety

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Persons working for VKM, either as appointed members of the Committee or as ad hoc experts, do this by virtue of their scientific expertise, not as representatives for their employers. The Civil Services Act instructions on legal competence apply for all work prepared by VKM.

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The Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM) has appointed an ad hoc group consisting of both VKM members and external experts to answer the request from the Norwegian Food Safety Authority. The members of the ad hoc group are acknowledged for their valuable work on this opinion.

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Assessed by

The report from the ad hoc group has been evaluated and approved by Panel on biological hazards and Scientific Steering Committee of VKM.

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Summary

The Norwegian Food Safety Authority (NFSA) has requested an assessment of current knowledge on comparison between conventional and organic production in order to provide support in their daily management of food safety. NFSA needed to clarify to what extent existing research can determine whether there are differences between organic production systems and products and conventional production methods and products. Furthermore, if there are significant differences, how would these differences impact public health?

The assessment was divided between several panels, where the Panel for Biological Hazards summarised and evaluated current knowledge on comparisons between foods from conventional and organic production with regard to contamination with human pathogens and antimicrobial resistance. The assessment is based on comprehensive literature searches in scientific publications and reports. The panel concludes:

- Contamination of the final food product with pathogens is the consequence of a complex interaction between several pre-harvest, harvest, and post-harvest factors. The probability of contamination, and the magnitude of the contamination once it occurs, depends on many factors, of which some may differ between organic and conventional production systems. The number of factors involved, the probability of contamination associated with each factor, and the interaction between them, varies widely between, and within production system. They also differ between individual farmers and processing units.
- No investigations from Norway were found which directly compare contamination with pathogens or prevalence of resistance to antimicrobial agents in foods from different production systems. Thus, our assessment is based on investigations carried out in other countries, although the results cannot necessarily be extrapolated to Norwegian conditions.
- Several comprehensive reviews have been published on contamination with pathogens as a function of conventional versus organic food production. The reviewers agree that the quantity and methodological soundness of primary research comparing the prevalence of pathogens in foods from organic and conventional production, is limited. Overall, existing research does not consistently support, nor refute, an association between prevalence of pathogens and production type. There is currently no firm evidence to support the assertion that organic products are more or less microbiologically safe than conventional food.
- The literature review is based on investigations into antimicrobial resistance, which were carried out in countries where use of antimicrobials in animal husbandry is substantially higher than in Norway. The results indicate that the prevalence of antimicrobial resistance is lower in organic foods than in conventional foods, which is plausible in countries where antimicrobial usage in conventional production is high. However, the majority of available research suffers from methodological problems, which makes difficult to combine similar trials in order to obtain a larger number of samples to improve the evaluation of whether statistically reliable differences exist between two production systems. Therefore, a good meta-analysis is not easy to perform. Based on these studies, it is therefore not warranted to make firm conclusion regarding an association between prevalence of antimicrobial resistance and production systems.
- The public health consequences of a possible high rate of pathogenic bacteria in organic products or high prevalence of resistant bacteria in conventional products have not been assessed in the studies reviewed in this report.

- In Norway, it would be expected that the difference in between organic and conventional foods regarding contaminations with pathogens is fairly modest, because the enzootic levels of human pathogens s in domestic and wild-living animal populations are comparatively low. Moreover, the climatic conditions prevailing in Norway are less favorable for outdoor rearing and for the growth and survival of most pathogens in the environment. In addition, the likelihood of contamination from untreated irrigation water is relatively small, given the low enzootic and endemic levels of pathogens.
- Likewise, it would be expected that in Norway the difference between organic and conventional foods with regard to prevalence of antimicrobial resistant bacteria, would be small or insignificant, because the use of antimicrobial agents and the presence of antimicrobial resistant bacteria in conventional production system is comparatively low.
- Imported foods represent a higher risk of human infection in Norway compared with domestically produced foods, regardless of whether the products are organic or conventional, because the enzootic and endemic levels of many pathogens and the prevalence of antimicrobial resistant bacteria are higher in most other countries, within and outside the EU.
- Other factors being equal, proper production practices are especially important, including sufficient composting of manure (which is required in organic as well as conventional production). Failure to comply with safe food production practices may confer a higher risk of contamination with pathogens than in conventional systems due to more frequent use of animal manure, outdoor husbandry and other variables contributing to contamination.

Sammendrag

Vitenskapskomiteen for mattrygghet (VKM), Faggruppen for hygiene og smittestoffer, har på oppdrag fra Mattilsynet oppsummert og evaluert dagens kunnskap om forurensning med patogener og forekomst av antibiotika resistente patogener i økologisk og konvensjonell mat. Vurderingen er basert på omfattende litteratursøk i vitenskapelige publikasjoner og rapporter. Faggruppen konkluderer:

- Kontaminering av mat er et resultat av samspill av faktorer før, under og etter innhøsting. Sannsynligheten for, og omfanget av kontamineringen, er avhengig av mange faktorer. Noen av disse faktorene kan være ulike i økologisk og konvensjonell produksjon. Det forekommer også variasjon innenfor produksjonssystemer og mellom den enkelte bonden.
- Det ble ikke funnet noen norske studier hvor det er gjort en direkte sammenligning av kontaminering av økologisk og konvensjonell mat med patogener, eller forekomst av antibiotika resistens. Denne rapporten er derfor basert på studier fra andre land, og det er derfor usikkert i hvor stor grad resultatene kan overføres til norske forhold.
- Det er publisert flere omfattende oversiktsartikler hvor forekomst av patogener i økologisk og konvensjonelt produsert mat sammenlignes, og det er enighet om at det er begrenset tilgang på gode enkeltstudier. Ut i fra eksisterende forsøk er det ingen sammenheng mellom tilstedeværelse av patogener og produksjonstype. På nåværende tidspunkt er det ingen klar bevis for å hevde at økologiske produkter er mer eller mindre mikrobiologisk trygge enn konvensjonell mat.
- Studiene av antimikrobiell resistens er utført i land der bruk av antimikrobielle stoffer i husdyrhold er vesentlig høyere enn i Norge. Resultatene indikerer at forekomsten av resistensutvikling er lavere i økologisk mat enn i konvensjonell mat, noe som rimelig i land hvor forbruk av antimikrobielle midler i konvensjonell produksjon er høy.

Allikevel er det ikke mulig, på grunn av metodologiske svakheter ved de fleste studiene, å gjøre gode meta-analyser, og heller ikke mulig å konkludere om det er sammenheng mellom forekomsten av antimikrobiell resistens og økologiske og konvensjonelle produksjonssystemer.

- I studier som danner bakgrunn for de to ovenstående punkter i denne rapporten er det ikke vurdert om mulig høy forekomst av patogene bakterier i økologisk mat eller høy forekomst av antimikrobiell resistens i konvensjonell mat har effekter på befolkningens helse.
- Siden forekomst av humane patogener hos dyr i Norge, både tamme og ville, er lav antas det at det er liten forskjell i forekomst av disse i mat. Klimaet i Norge er heller ikke gunstig for vekst og overlevelse av patogener i miljøet.
- Siden det generelt er lavt forbruk av antimikrobielle midler og lav forekomst av antibiotika resistente bakterier i konvensjonelt landbruk i Norge, forventes det at det vil være små og ikke signifikante forskjeller i forekomst av antibiotika resistente bakterier i mat fra økologisk og konvensjonelt landbruk.
- Importerte matvarer utgjør en høyere risiko for smitte til menneske i Norge sammenlignet med norskproduserte matvarer, uavhengig av om produktene er fra økologisk eller konvensjonell produksjon. Dette er fordi enzootiske og endemiske nivået av patogener og utbredelsen av antimikrobielle resistente bakterier er høyere i de fleste andre land, både i og utenfor EU.
- Riktig produksjonspraksis er viktig, inkludert tilstrekkelig kompostering av husdyrgjødsel (kreves ved både organisk og konvensjonell produksjon). Avvik fra kravene til trygg matproduksjon praksis kan gi en høyere risiko for forurensning med patogener ved økologisk enn ved konvensjonell drift på grunn bruk av hyppigere bruk av husdyrgjødsel, utendørs dyrehold og andre faktorer som kan bidra til forurensning.

Contents

Background

The goal of the Norwegian government is that 15% of the agricultural production is organic in 2020 (St. Meld. 9, 2011-2012). However, knowledge on the impact of an increase in organic production in Norway is limited. If and how organic production practices may affect human health, animal health and welfare, plant health, the environment and sustainability is not clear.

In order to be able to give scientifically based information and advice on this issue to consumers and other target groups, the Norwegian Food Safety Authority (NFSA) requested a scientific evaluation of current research and other data on organic food and food production from The Norwegian Scientific Committee for Food (VKM). The scientific evaluation and the knowledge will also be used in connection with the NFSA's regulatory and international work on organic food production. The NFSA first prepared a draft request that was put out for public consultation. Remarks from the bodies that commented on the proposal clearly stated that there are limitations in the basic data for such an evaluation. NFSA therefore limited the scope and focus of the request somewhat. Sustainability aspects and environmental impact of organic and conventional agricultural practices are not addressed. In addition, organic aquaculture, which has only been practiced for a few years, is excluded from the request.

All foodstuffs on the market shall be safe and wholesome. Whereas all food produced and marketed shall comply with relevant legislation, food marketed as organic must in addition comply with regulations specific for organic production.

Organic food production is defined in Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products as "The use of the production method compliant with the rules established in this Regulation, at all stages of production, preparation and distribution". The regulation on organic food production is part of the EEA Agreement and covers inputs, crop production, livestock production, rules for processing, labeling, and inspection, and provides provisions for imports from third countries.

According to Council Regulation (EC) No 834/2007, organic production shall be based on the following principles (article 4):

(a) the appropriate design and management of biological processes based on ecological systems using natural resources which are internal to the system by methods that:

- i) use living organisms and mechanical production methods;
- ii) practice land-related crop cultivation and livestock production or practice aquaculture which complies with the principle of sustainable exploitation of fisheries;
- iii) exclude the use of GMOs and products produced from or by GMOs with the exception of veterinary medicinal products;
- iv) are based on risk assessment, and the use of precautionary and preventive measures, when appropriate;

(b) the restriction of the use of external inputs. Where external inputs are required or the appropriate management practices and methods referred to in paragraph (a) do not exist, these shall be limited to:

- i) inputs from organic production;
- ii) natural or naturally-derived substances;
- iii) low solubility mineral fertilisers;

(c) the strict limitation of the use of chemically synthesised inputs to exceptional cases these being:

i) where the appropriate management practices do not exist; and
ii) the external inputs referred to in paragraph (b) are not available on the market; or
iii) where the use of external inputs referred to in paragraph (b) contributes to unacceptable environmental impacts;

(d) the adaptation, where necessary, and within the framework of this Regulation, of the rules of organic production taking account of sanitary status, regional differences in climate and local conditions, stages of development and specific husbandry practices.

Terms of reference

The Norwegian Food Safety Authority (NFSA) requests the Norwegian Scientific Committee for Food Safety (VKM) to evaluate current scientific knowledge on organic production and organically produced food based on existing national and international research results and other documentation. The NFSA wants the evaluation to focus primarily on Norwegian production.

NFSA has found it appropriate to divide this comprehensive evaluation of organic production and organic food into five parts:

1. Plant health – plant production
2. Animal health – animal welfare and feed
3. Human health – nutrition and contaminants
4. Human health – hygiene and pathogens
5. Human health – pesticide residues

NFSA would like VKM to compare the effects of organic versus conventional production based on the evaluations that are done in the five areas above. If lack of data prevents such a comparison, this fact should also be reported.

Part IV. Human health – hygiene and pathogens
NFSA requests VKM to identify and/or assess:

- differences in levels of human pathogenic microorganisms (*E. coli, Campylobacter* and *Salmonella etc)* and where relevant, toxins, in food from organic versus conventional production systems.
- consumption of human pathogenic microorganisms (*E. coli, Campylobacter* and *Salmonella* etc) and where relevant, toxins, in food from organic versus conventional production systems, and possible influence on human health.

Introduction

The Norwegian Scientific Committee for Food Safety (Vitenskapskomiteen for mattrygghet, VKM) has at the request of the Norwegian Food Safety Authority (Mattilsynet, NFSA) compared organic and conventional food and food production in relation to possible impact on plant health, animal health and welfare and human health. The assessment is based on published peer reviewed scientific literature and assessment reports by international and national scientific bodies.

The following aspects of organic food production were not addressed in the assessment as they were not part of the request; sustainability aspects and environmental impacts of organic and conventional agricultural practices, and furthermore: aquaculture, because organic aquaculture has only been practiced for a few years.

At the request of the Norwegian Food Safety Authority the assessment was divided into five parts addressing:

I) Plant health and plant production (assessed by Panel on Plant Health)
II) Animal health and animal welfare (assesses by Panel on Animal Health and Welfare)
III) Humane health - nutrition and contaminants (Panel on Nutrition, Dietetic Products, Novel Food and Allergy)
IV) Human health – hygiene and pathogens (assessed by Panel on Biological Hazards)
V) Pesticide residues (assessed by Panel on Plant Protection Products)

The present report focuses solely on human health – hygiene and pathogens. VKM appointed a working group consisting of VKM members and external experts to prepare a draft opinion. The opinion was approved by VKMs Panel on biological hazards. The Scientific Steering Committee of VKM approved the final opinion, i.e. this document.

Factors influencing contamination of food with human pathogens – a general introduction

Foods may become contaminated with pathogenic microbes at any stage along the production and distribution chain, from farm to fork. The probability of contamination, and the magnitude of the contamination once it occurs, depends on many factors, of which some may differ between organic and conventional production systems.

The presence of human pathogens in foods of animal origin (meat, egg, honey, milk and dairy products) depends on:

- The occurrence of pathogens in food-producing animals (the prevalence, the number of microbes shed by individual animals, and the frequency of such shedding), that in turn varies with:
  - Presence of pathogens in feed
  - Indoor rearing in confined environments, with disinfected drinking water and implementation of hygiene barriers, as opposed to outdoor husbandry / free-range conditions with access to soil and water in the open, and contact with wildlife
  - Contact with other domestic animals of the same or a different species, including dogs and cats (e.g. farms operated on a single age, all-in/all-out basis as opposed to keeping several ages and species on the same farm)
  - Breeding system (e.g. a closed system where animals are born and reared on the same farm, in contrast to an open breeding pyramid where age groups are transferred between producers)
  - Herd size, stocking density, pasture rotation systems, housing, and bedding material affecting the survival and spread of pathogens
  - Susceptibility to colonization (e.g. general animal health and selection of resistant breeds)
  - Feed additives, probiotics and feed composition (hay versus, grain, silage or concentrates) that influence colonization and shedding by altering the enteric environment
  - The use of antimicrobial agents for therapeutic and prophylactic purposes, or as growth promoters
  - Vaccines against zoonotic agents
  - Age at slaughter
  - Transport conditions which may induce stress and shedding of pathogens
- In addition, the occurrence of pathogens in animal products is influenced by a number of post-harvest factors such as slaughtering procedures, processing, chilling, the use of decontamination using synthetic disinfectants, irradiation, heat treatment including pasteurization, and chemical food additives that repress bacterial growth, as well as other factors along the production, processing and distribution chain.

The presence of pathogens on fresh produce (vegetables, fruits, and berries) and cereals varies with (FAO/WHO 2008, EFSA 2013)

- The frequency with which animal manure and livestock excrements is used versus synthetic fertilizers
- Presence of pathogens in manure
- Composting or other manure treatments, and the efficiency of such procedures for decimation or inactivation of pathogens
- Treatment of irrigation water and efficacy of the treatment procedure if any. The presence of pathogens in the raw water
- Technique used for irrigation (e.g. spray or drip watering)
- Cultivation in climate-controlled greenhouses, in contrast to cultivation in the field where plants are exposed to ambient weather, and to wildlife
- Climatic, edaphic and biological factors affecting survival and multiplication of pathogens in soil
- Susceptibility to colonization of the phyllosphere, and presence of factors influencing such colonization (e.g. humidity, sunlight, choice of resistant species and varieties)
- Crop rotation, previous and present usage of the production area and adjacent land
- Access by domestic and wild animals to the production sites or the water sources
- Contamination from insects – use of pesticides
- Hygienic failure during harvesting, handling, processing and packaging
- The use of sanitizing agents to disinfect harvested products or equipment (e.g. chlorinated water for disinfection of sprout seeds or leaf greens)

The factors listed above, the number of factors involved, the probability of contamination associated with each factor, and the interaction between them, varies widely between, and within production systems, depending on the certification standards used for organic production, and the general food safety regulations implemented in different countries. They also differ between individual farmers and processing units. The factors are not independent. There is usually a complex interaction in which one or more factors may increase, decrease or subvert the effect of other variables, and *vice versa*. It is, therefore, not warranted to state categorically whether or not a given factor is *independently* associated with increased or decreased risk of contamination, without controlling for the influence of confounding variables in the context concerned.

Regulations governing organic production in Norway

In Norway, organic production of agricultural products is governed by National Regulation FOR 2005-10-04 nr 1103 (MAF 2005), which implements Council Regulation (EEC) 2092/91(EEC 1991) in Norwegian jurisdiction, with specific amendments. Pursuant to this regulation a number of provisions are laid down with regard to, among other things, prohibition on the use of synthetic fertilizers and pesticides, treatment and application of livestock manure and animal excrements, feed additives, restricted use of synthetic compounds for cleaning and disinfection of livestock building and installations, requirements for access to free-range areas, minimum age at slaughter, etc. The Norwegian regulations are now in the process of being revised, including implementation of Council Regulation (EC) No 834/2007 (EC 2007) and Commission Regulation No 889/2008 (EC 2008a). Commission Regulation (EC) No 1235/2008 lays down detailed rules for imports of organic products from third countries (EC 2008b).

It is important to emphasize that all production, processing, distribution and sale of food in Norway, whether organic or conventional, is subject to the requirements pursuant to the Law on Food Production and Food Safety (MHCS 2003). According to the law and its accompanying regulations a number of provisions are implemented pertaining to biosecurity, food safety, food quality, consumer protection, animal health and welfare, environmental protection etc. at all stages of the food chain.

Literature search

Primary literature search

The primary literature search was undertaken using the Advanced Search Builder provided by PubMed (www.ncbi.nlm.nih.gov/pubmed). The following search terms were used:

- organic
- organic food OR organic foods
- safety
- outbreak OR outbreaks
- antibiotic resistance OR antimicrobial resistance
- case-control OR case-case
- VTEC OR STEC OR EHEC OR ETEC OR EIEC
- salmonell*
- campylobacter*
- yersini*
- shigell*
- vibrio*
- lister*
- bacillus
- clostridium
- staphylococcus
- Escherichia coli OR E. coli
- virus OR norovirus OR norwalk OR hav OR hepatitis
- parasit*
- protozoa*
- helminth*
- Nematod*
- cryptosporidi*
- toxoplasm*
- taeni*
- cysticerc*
- trichinell*
- ascari*
- balantidi*
- fasciol*

All terms where sought in the search field Title/Abstract.

Search strings were constructed by combining the search terms using the bolean variable AND. The search strings employed are shown below. There was no restriction on language or publication year. Some searches were limited to reviews.

Relevance screening

The titles of all hits were scanned, and for those that were of potential relevance, the abstracts were also inspected. The relevance screening was performed by the members of the *ad hoc* group, independently. Citations were excluded if they did not relate to the terms of reference. The reference lists in selected citations were scrutinized to identify additional articles or reports, overlooked by the PubMed searches.

Search strings

General searches

(organic food[Title/Abstract]) OR organic foods[Title/Abstract] - 206 citations

(organic food[Title/Abstract]) OR organic foods[Title/Abstract] Filters: Review – 28 citations

(organic food[Title/Abstract] OR organic foods[Title/Abstract]) AND safety[Title/Abstract] - 18 citations

(outbreak[Title/Abstract] OR outbreaks[Title/Abstract]) AND organic[Title/Abstract] – 221 citations

(outbreak[Title/Abstract] OR outbreaks[Title/Abstract]) AND organic[Title/Abstract] Filters: Review – 35 citations

(organic food[Ttile/Abstract] OR organic foods[Ttile/Abstract]) AND (case-control[Ttile/Abstract] OR case-case[Ttile/Abstract]) – 39 citations

(organic food[Ttile/Abstract] OR organic foods[Ttile/Abstract]) AND (case-control[Ttile/Abstract] OR case-case[Ttile/Abstract]) Filters: Review – 4 citations

Search string specific for bacteria

Search: (organic[Title/Abstract]) AND salmonell*[Title/Abstract] – 858 citations

Search: (organic[Title/Abstract]) AND listeri*[Title/Abstract] – 208 citations

Search: (campylobacter*[Title/Abstract]) AND organic[Title/Abstract] – 111 citations

Search: (yersini*[Title/Abstract]) AND organic[Title/Abstract] – 55 citations

Search: (organic[Title/Abstract]) AND shigell*[Title/Abstract] – 50 citations

Search: (organic[Title/Abstract]) AND vibrio*[Title/Abstract] – 396 citations

Search: (organic[Title/Abstract]) AND (VTEC[Title/Abstract] OR STEC[Title/Abstract] OR EHEC[Title/Abstract] OR ETEC[Title/Abstract] OR EIEC[Title/Abstract]) – 25 citations

Search: (organic[Title/Abstract]) AND (Escherichia coli[Title/Abstract] OR E. coli[Title/Abstract]) – 1918 citations

Search: (organic[Title/Abstract]) AND (staphylococcus[Title/Abstract]) – 494 citations

Search: (organic[Title/Abstract]) AND (bacillus[Title/Abstract]) – 938 citations

Search: (organic[Title/Abstract]) AND (clostridium[Title/Abstract]) – 295 citations

Search string specific for antimicrobial resistance

(organic food[Title/Abstract] OR organic foods[Title/Abstract]) AND resistance[Title/Abstract] – 6 citations

(organic food[Title/Abstract] OR organic food[Title/Abstract]) AND (antibiotic resistance[Title/Abstract] OR antimicrobial resistance[Title/Abstract]) – 2 citations

organic[Title/Abstract] AND (antibiotic resistance[Title/Abstract] OR antimicrobial resistance[Title/Abstract]) – 155 citations

Search string specific for viruses

(organic food[Title/Abstract]) OR organic foods[Title/Abstract]) AND virus[Title/Abstract] - 0 citations

(organic food[Title/Abstract]) OR organic foods[Title/Abstract]) AND noro virus[Title/Abstract] – 0 citations (organic food[Title/Abstract]) OR organic foods[Title/Abstract]) AND norwalk[Title/Abstract] – 0 citations

(organic food[Title/Abstract]) OR organic foods[Title/Abstract]) AND hav[Title/Abstract] – 0 citations

(organic food[Title/Abstract]) OR organic foods[Title/Abstract]) AND hepatitis[Title/Abstract] – 0 citations

Search string specific for parasites

The initial search combined the search terms (Title and Abstract) "organic food*" OR "organic farm*" with a variety of parasite terms (parasit*, protozoa*, helminth*, Nematod*, cryptosporidi*, toxoplasm*, taeni*, cysticerc*, trichinell*, ascari*, balantidi*, fasciol*). However it became apparent that various potentially relevant publications were being missed by the narrowness of the "organic food*" and "organic farm*" search terms (such as titles/abstracts containing "organic pork" or "organic Swedish farm"), and therefore the same parasite terms were used in combination with "organic". The titles of all hits were scanned, and for those that were of potential relevance, the abstracts were also scanned. Of these, for those of potential relevance, the full text was obtained and assessed whether it was of relevance to this Opinion. Articles that were not in English or a Nordic language (Swedish, Danish, Finnish, Norwegian) were excluded.

The final search strings and results are as below:

(organic [Title/Abstract]) AND parasit* [Title/Abstract] - 1034 citations)

(organic [Title/Abstract]) AND protozoa* [Title/Abstract] - 1472 citations)

(organic [Title/Abstract]) AND helminth* [Title/Abstract] - 144 citations)

(organic [Title/Abstract]) AND nematod* [Title/Abstract] - 380 citations)

(organic [Title/Abstract]) AND cryptosporidi* [Title/Abstract] - 80 citations)

(organic [Title/Abstract]) AND toxoplasm* [Title/Abstract] - 50 citations)

(organic [Title/Abstract]) AND taeni* [Title/Abstract] - 23 citations)

(organic [Title/Abstract]) AND cysticerc* [Title/Abstract] - 19 citations)

(organic [Title/Abstract]) AND trichinell* [Title/Abstract] - 20 citations)

(organic [Title/Abstract]) AND ascari* [Title/Abstract] - 84 citations)

(organic [Title/Abstract]) AND balantidi* [Title/Abstract] - 2 citations)

(organic [Title/Abstract]) AND fasciol* [Title/Abstract] - 27 citations)

Search string specific for prions

The literature search of prions was performed with an advanced search builder in the database software Reference Manager, allowing internet search of the PubMed database.

The primary search combined the term "Prion"[Title and abstract] AND Organic Food [All fields]; this retrieved zero publications. The same result appeared when substituting "Prion" with "TSE" or "TSE-agent" or with "Unconventional virus" – zero publications. Substituting "Organic Food" with "Organic Foods" did not retrieve any publications.

Review of the literature

Bacterial pathogens

We have not identified investigations from Norway that compare the status of foods from conventional and organic production systems regarding contamination with human pathogens. Likewise, there is no published analytic epidemiological study where the putative risk of infection associated with consumption of organic foods has been assessed among Norwegian consumers. Since adequate comparative data from Norway is lacking, a comparison of organic and conventional food as regards contamination with pathogens must therefore rely on investigations carried out in other countries, where the production practices and other conditions cannot necessarily be extrapolated to Norway. Comprehensive reviews have been published by Smith-Spangler et al. (2012), Magkos et al. (2006), Wilhelm et al. (2009), and Bourn & Prescott (2002), and the following discussion is based on their papers.

Smith-Spangler et al. (2012):

Are organic foods safer or healthier than conventional alternatives?

Smith–Spangler et al. (2012) conducted a formal meta-analysis. They warned that the studies are heterogeneous, applied different methods, and are limited in number. Publication bias may be present. The standards for organic production varied. Also, the specific regulations governing organic production vary across countries as well as between certifiers (Nelson et al. 2004, Magkos et al. 2006). Based on their analysis Smith-Spangler and co-workers concluded that they found no difference in the risk of generic *E. coli* contamination between organic and conventional produce. Contamination of retail chicken and pork with enteric pathogens was common, but unrelated to farming method. Differences in the prevalence of bacterial contamination between organic and conventional animal products were not statistically significant. However, with removal of one outlier study, results suggested that organic produce has a higher risk for contamination with *E. coli*.

Interestingly, an analytic epidemiological study (case-case-study) conducted in UK, found that consumption of organic meat in the winter was associated with increased risk of campylobacteriosis (Gillespie et al. 2003). Smith-Spangler et al. (2012) also cited a U.S. study which reported that "produce from organic farms using manure for fertilization was at significantly higher risk for contamination with *E. coli* than was produce from organic farms not using animal waste (odds ratio, 13.2 [CI, 2.6 to 61.2])" (Mukherjee et al. 2007).

Magkos et al. (2006):

Organic food: Buying more safety or just peace of mind? A critical review of the literature.

In their critical review from 2006, Magkos and co-workers suggested that generalized conclusions regarding the health benefits and/or hazards of food products of organic versus conventional origin, remain tentative in the absence of adequate comparable data. Scientific evidence in support of the perception that organic foods are safer is scarce. They also referred to The UK Food Standards Agency (FSA): The FSA view is that there is currently no firm evidence to support the assertion that organic produce is more or less microbiologically safe than conventional food (FSA 2000). In addition, they cited a review by the UK Ministry of Agriculture, Fisheries and Food (MAFF) which concluded that there is insufficient information at present to state categorically whether the risk of pathogen transfer to produce on organic farms differs significantly from that associated with conventional farming practices (Nicholson et al. 2000). Finally, Magkos and co-workers emphasized that the bulk of available evidence from comparative studies shows no significant differences in the bacterial status of organically and conventionally grown cereal (wheat, rye) and vegetable (carrots, spring mix, Swiss chard, salad vegetables) crops (Marx et al. 1994, Rosenquist&Hansen 2000, Hamilton-Miller&Shah 2001, Phillips&Harrison 2001, Moreira et al. 2003, Ponce et al. 2003).

Nevertheless, some investigations have detected several *E. coli* strains (not O157:H7) and *Salmonella* spp. more frequently in organically than in conventionally grown vegetables (Bailey et al. 1999, Mukherjee et al. 2003).

Bourn & Prescott (2002):

A comparison of the nutritional value, sensory qualities, and food safety of organically and conventionally produced foods.

Bourn & Prescott (2002) compared the nutritional value, sensory qualities, and food safety of organically and conventionally produced foods. They concluded that it was evident from their assessment that there are few well-controlled studies that are capable of making a valid comparison. There is no evidence that organic foods may be more susceptible to microbiological contamination than conventional foods. Irrespective of food production system, all foods need to be produced in such a manner to ensure that they are safe to eat. The question of whether the consumption of organically grown food confers any greater microbiological risk to consumers than conventional food, has not yet been addressed in a scientific manner.

Wilhelm et al. (2009):

Prevalence of zoonotic or potentially zoonotic bacteria, antimicrobial resistance, and somatic cell counts in organic dairy production: current knowledge and research gaps.

Using a systematic review methodology Wilhelm et al. (2009) identified, evaluated, and summarized the findings of all primary research published in English or French, investigating prevalence of zoonotic or potentially zoonotic bacteria in organic dairy production, or comparing organic and conventional dairy production. Among 47 studies included in the review, 32 comparison studies were suitable for quality assessment. The review findings indicated that the quantity and methodological soundness of primary research investigating prevalence of zoonotic or potential zoonotic bacteria in organic dairy production is limited. They emphasized that caution is warranted when comparing results from different studies. The most studied bacteria in their review were *E. coli*, *Salmonella* spp., and *Staphylococcus aureus*. In general, no consistent association was observed between the prevalence of zoonotic or potentially zoonotic bacteria and the type of production employed (organic or conventional). However, the range of studies per bacterial outcome was one to seven, indicating that more studies per outcome are needed to identify potential trends. They suggested that contradictory findings among studies could result from a number of different factors, including effects of geographic location, differing sampling and testing protocols, or data analysis approaches.

They concluded that the existing primary research on prevalence of zoonotic and potentially zoonotic bacteria in organic dairy production is limited to a small number of studies conducted mostly in Europe and the United States. Overall, existing research does not consistently support an association between prevalence of zoonotic bacteria and production type. Well-designed, executed, and reported primary research investigating this question in various stages of organic and conventional dairy production is necessary.

Table 1 Four review articles comparing bacterial contamination in organic and conventional food

Review article	No. of citations	Main conclusions
Smith-Spangler et al. (2012)	5908 potentially relevant articles identified. 237 met inclusion criteria. 17 selected for the meta-analysis on microbial contamination	The authors warned that the studies are heterogeneous, applied different methods, and are limited in number. Publication bias may be present. Differences in the prevalence of bacterial pathogens between organic and conventional animal products were not statistically significant.
Magkos et al. (2006)	43 citations in their chapter on pathogenic microbes	The authors suggested that generalized conclusions regarding the health benefits and/or hazards of food products of organic versus conventional origin; remain tentative in the absence of adequate comparable data. Scientific evidence in support of the perception that organic foods are safer is scarce. There is insufficient information at present to state categorically whether the risk of pathogen transfer to produce on organic farms differs significantly from that associated with conventional farming practices
Bourn & Prescott (2002)	16 citations in their chapter on microbial safety of organic foods	The authors concluded that it was evident from their assessment that there are few well-controlled studies that are capable of making a valid comparison. The question of whether the consumption of organically grown food confers any greater microbiological risk to consumers than conventional food has not yet been addressed in a scientific manner.
Wilhelm et al. (2009)	32 studies comparing prevalence of bacteria and/or antimicrobial resistance in organic and conventional dairy production (Table 1)	The review findings indicated that the quantity and methodological soundness of primary research investigating prevalence of zoonotic or potential zoonotic bacteria in organic dairy production is limited. They emphasized that caution is warranted when comparing results from different studies. Overall, existing research does not consistently support an association between prevalence of zoonotic bacteria and production type. Well-designed, executed, and reported primary research investigating this question in various stages of organic and conventional dairy production is necessary.

Conclusion

The reviewers agree that the quantity and methodological soundness of primary research comparing the prevalence of human pathogenic bacteria in foods from organic and conventional production, is limited. Overall, existing research does not consistently support, nor refute, an association between prevalence of pathogenic bacteria and production type. There is currently no firm evidence to support the assertion that organic products are more or less microbiologically safe than conventional food.

Antimicrobial resistance

Results

The literature search strings on antimicrobial resistance resulted in 155 citations.

Titles and abstracts of all identified citations were screened and were excluded if they did not relate to the terms of reference. Review and original articles, which studied antimicrobial resistant bacteria in organic and conventional produced food, were included. All foods investigated were raw and either was supplied in stores or ready to supply to the stores. No foods were "ready to eat" products.

Studies, which included produce at farm level and not ready to supply to the stores, were excluded. By using these criteria, 13 original articles met inclusions criteria in the antimicrobial resistant part of this assessment.

A list of the selected articles, with the country of origin, is presented in Table 3 and summary of the findings is presented below:

Cui et al. (2005)

Prevalence and antimicrobial resistance of Campylobacter spp. and Salmonella serovars in organic chickens from Maryland retail stores.

Most organic (76%) and conventional (74%) chickens were contaminated with campylobacters. Salmonellae were recovered from 61% of organic and 44% of conventional chickens.

Campylobacter and *Samonella* isolates from both production systems were examined against 17 antimicrobial agents. All campylobacters were susceptible to chloramphenicol. Resistance to tetracycline was most common (78%), followed by resistance to erythromycin (46%) and ciprofloxacin (8%). More isolates from the conventional chickens (20%) were resistant to ciprofloxacin than those from the organic chickens (5%). Rates of resistance to erythromycin and tetracycline were higher in organic chicken isolates (49% and 81%, respectively) than conventional chicken isolates (36% and 69%, respectively).

All *Salmonella enterica* serovar Typhimurium isolates from conventional chickens were resistant to five or more antimicrobials, whereas most *S. enterica* serovar Typhimurium isolates (79%) from organic chickens were susceptible to 17 antimicrobials tested.

Luangtonkum et al. (2006)

Effect of conventional and organic production practices on the prevalence and antimicrobial resistance of Campylobacter spp. in poultry.

The prevalence of *Campylobacter* species was: Conventional 66% vs. organic 83%

Less than 2% of *Campylobacter* strains isolated from organically raised poultry were resistant to fluoroquinolones, while 46% and 67% of *Campylobacter* isolates from conventionally raised broilers and conventionally raised turkeys, respectively, were resistant to these antimicrobials. In addition, a high frequency of resistance to erythromycin (80%), clindamycin (64%), kanamycin (76%), and ampicillin (31%) was observed among *Campylobacter* isolates from conventionally raised turkeys. None of the *Campylobacter* isolates obtained in this study was resistant to gentamicin, while a large number of the isolates from both conventional and organic poultry operations were resistant to tetracycline.

Multidrug resistance was observed mainly among *Campylobacter* strains isolated from conventional turkey (81%).

Miranda et al. (2007)

Antimicrobial resistance in Enterococcus spp. strains isolated from organic chicken, conventional chicken, and turkey meat: a comparative survey.

Organic chicken meat may have higher numbers of *Enterococcus* (3.01 log CFU/g) vs. 2.06 log CFU/g in conventional chicken meat.

The resistance data obtained showed that isolates from organic chicken meat were less resistant than enterococci isolates from conventional chicken meat to ampicillin, chloramphenicol, doxycycline, ciprofloxacin, erythromycin, and vancomycin. In addition, isolates from organic chicken were less resistant than conventional turkey meat isolates to ciprofloxacin and erythromycin.

Multidrug-resistant isolates were found in every group tested, but rates of multidrug-resistant strains were significantly higher in conventional chicken and turkey than those obtained from organic chicken meat.

Miranda et al. (2008)

Comparison of antimicrobial resistance in Escherichia coli, Staphylococcus aureus, and Listeria monocytogenes strains isolated from organic and conventional poultry meat.

The authors found significantly higher ($P < 0.0001$) prevalence of *E. coli* but not of *S. aureus* and *L. monocytogenes* in organic poultry meat as compared with conventional poultry meat.

E. coli isolated from organic poultry meat exhibited lower levels of antimicrobial resistance against 7 of the 10 antimicrobials tested as compared with isolates recovered from conventional meat. In the case of *S. aureus* and *L. monocytogenes* isolated from conventional poultry, antimicrobial resistance was significantly higher only for doxycycline as compared with strains isolated from organic poultry. In the case of *E. coli*, the presence of **multi-resistant** strains was significantly higher ($P < 0.0001$) in conventional poultry meat as compared with organic poultry meat.

Lestari et al. (2009)

Prevalence and antimicrobial resistance of Salmonella serovars in conventional and organic chickens from Louisiana retail stores.

Salmonella was isolated in 22% of conventional and 20.8% of organic chicken samples. All isolate were susceptible to amakacin, ceftriaxone, and ciprofloxacin; however, decreased susceptibility to quinolones (7.1%) or extended-spectrum cephalosporins (45.2%) was observed. Resistance to multiple antimicrobials (two or more) was found among 52.4% of the *Salmonella* isolates. *Salmonella* Kentucky isolates from organic chicken samples were susceptible to 11 of the antimicrobials tested, whereas those from conventional chickens were only susceptible to 4 antimicrobials. Three *Salmonella* Kentucky isolates from conventional chickens possessed multidrug resistance phenotype MDR-AmpC.

Cohen Stuart et al. (2012)

Comparison of ESBL contamination in organic and conventional retail chicken meat.

The prevalence of ESBL producing micro-organisms was 100% on conventional and 84% on organic samples ($p<0.001$). Median loads of ESBL producing micro-organisms were 80 (range < 20-1360) in conventional, and <20 (range 0-260) CFU/25 g in organic samples ($p=0.001$).

The distribution of ESBL genes in conventional samples and organic samples was 42% versus 56%, respectively.

Melendez et al. (2010)

Salmonella enterica isolates from pasture-raised poultry exhibit antimicrobial resistance and class I integrons.

The authors concluded that the prevalence and serotypes of *Salmonella* isolates identified from these pastured poultry are similar to those reported by conventional poultry studies.

Salmonella isolates from the pastured poultry farms and purchased poultry carcasses in this initial survey exhibited similar antimicrobial resistance and possessed class I integrons.

Álvarez-Fernández et al. (2012)

Influence of housing systems on microbial load and antimicrobial resistance patterns of Escherichia coli isolates from eggs produced for human consumption.

Eggs from domestic production (organic) had the highest contamination loads ($P < 0.05$) for aerobic bacteria, *Enterococcus* spp., moulds, yeasts and the highest prevalence of *E. coli*.

19% *E. coli* isolates were susceptible to all antimicrobials tested, and 81 % were resistant to one (22.50%) or more (58.33%) antimicrobials.

According to the authors, the results suggest that a relationship exists between the prevalence of antimicrobial resistance in *E. coli* strains and the more frequent use of antimicrobials in conventional production (cage, barn, and free range) than in domestic and organic chicken housing systems. Eggs from organic and domestic production systems had the lowest resistance per strain.

Thibodeau et al. (2011)

Presence and characterization of Campylobacter jejuni in organically raised chickens in Quebec.

A total of 54 C. jejuni isolates were recovered from the sampled lots from the total of lots. The lots came from 6 organic chicken producers. Antimicrobial resistance was found only for tetracycline (44%), erythromycin (6%), azithromycin (6%) and clindamycin (2%).

Except for clindamycin, for which the resistance level seems to be the same in this study as reported in the Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS), resistance appeared to be slightly lower in the organic chicken isolates sampled in 2009 compared to the CIPARS data.

Kola et al. (2012)

High prevalence of extended-spectrum-β-lactamase-producing Enterobacteriaceae in organic and conventional retail chicken meat, Germany.

No differences could be observed in the prevalence of ESBL producers Enterobacteriaceae between organic and conventional samples. 73.0% of the ESBL producing bacteria showed co-resistance to tetracycline, 35.7% to co-trimoxazole and 7.6% to ciprofloxacin.

Miranda et al. (2009)

Influence of farming methods on microbiological contamination and prevalence of resistance to antimicrobial drugs in isolates from beef.

No *Salmonella* spp. were isolated from any of the beef samples, regardless of production system. No significant differences between organic and conventional beef were obtained for prevalence of *E. coli*, *S. aureus* or *L. monocytogenes*

For *L. monocytogenes* no differences were obtained between isolates obtained from organic or conventional beef for any of the nine tested antimicrobials. Organically farmed beef samples showed significantly lower rates of antimicrobial resistance in *E. coli* (ampicillin, ciprofloxacin, doxycycline, gentamicin and sulfixoxazole) and *S. aureus* isolates (ciprofloxacin, doxycycline, and gentamicin) compared with conventionally farmed beef samples.

Barlow et al. (2008)

A comparison of antibiotic resistance integrons in cattle from separate beef meat production systems at slaughter.

Integrons carrying antibiotic resistance genes were common in cattle from differing production systems at slaughter and the likelihood of presence appears unrelated to the production system.

Ruimy et al. (2010)

Organic and conventional fruits and vegetables contain equivalent counts of Gram-negative bacteria expressing resistance to antibacterial agents.

The overall median resistance score was 80% with no significant difference between organic and conventional products. *E. coli* and *Klebsiella* spp, which are the most commonly pathogenic Gram-negaive bacteria, were detected rarely. *Stenotrophomonas* and *Acintobacter*, which are only pathogenic for immunocompromised patients, were frequently found in products from both production systems

Of the products tested, 13% carried bacteria producing extended-spectrum beta-lactamases (ESBL), all identified as *Rahnella* sp.. *Rahnella* sp strains are widely distributed in nature. Thus, both organic and conventional fruits and vegetables may constitute significant sources of resistant bacteria and of resistance genes.

Resistance against clinically relevant antimicrobial agents

In nine of 13 studies included in this assessment, the prevalence of antimicrobial resistance was higher in bacterial isolates from conventional than organic production system (Table 3). Not all studies have observed this association for all tested antimicrobial agents. In the study performed by Cui and co-workers (Cui et al. 2005), the rates of resistance to erythromycin and tetracycline were higher in *Campylobacter* isolated from organic chicken (49% and 81%, respectively) than from conventional chicken (36% and 69%, respectively). In five studies, there was no significant difference in prevalence of resistance in the conventional and organic production systems examined (Barlow et al. 2008, Melendez et al. 2010, Ruimy et al. 2010, Thibodeau et al. 2011, Kola et al. 2012). In four of these studies (Barlow et al. 2008, Melendez et al. 2010, Thibodeau et al. 2011, Kola et al. 2012), molecular methods like PCR were used to identify the resistance genes rather than determination of MIC-values by culturing of bacteria. Only a single study presented in Table 3 compared the bacterial contamination of vegetables and fruit from conventional and organic production systems (Ruimy et al. 2010). In that study, all bacterial species except *Listeria* showed resistance against all antimicrobial agents investigated.

Multi-drug resistant bacteria were defined as bacterial isolates, which exhibited resistance against at least two, but usually several different antimicrobial agents. Rates and prevalence of multi-drug resistance were significantly higher in bacteria isolated from conventional production system than organic production system.

Parasites

Background and nomenclature

The human burden of parasitic infection is enormous. On a global basis, billions of people are infected by parasites and the DALY (disability-adjusted life year) toll due to parasitic infections is correspondingly huge (WHO 2008).

Infectious diseases caused by foodborne parasites are often referred to as neglected diseases, and from the food safety perspective parasites have not received the same level of attention as other foodborne biological and chemical hazards. Nevertheless, they cause a high burden of disease in humans and may have prolonged, severe, and sometimes, fatal outcomes (WHO/FAO 2012).

Foodborne parasites can be transmitted by ingesting fresh or processed foods that have been contaminated with the transmission stages (spores, cysts, oocysts, ova, larval and encysted stages) via the environment, animals (often from their faeces), or people (often due to inadequate hygiene). Foodborne parasites can also be transmitted through the consumption of raw and undercooked or poorly processed meat and offal from domesticated animals, wild game, and fish containing infective tissue stages (WHO/FAO 2012).

There is considerable geographical variation in the distribution of foodborne parasitic diseases; for example, *Trypanosoma cruzi* infections are seldom transmitted outside South America, whilst *Fasciola gigantica*, for example, is mainly distributed in Africa and Asia.

For the purposes of this evaluation, only those parasites that are of particular relevance to Norway and Norwegian conditions were considered, and only these specific parasites (along with the groups to which they belong) were used as search terms. Specific parasites included are:

Protozoa

- *Cryptosporidium parvum* (relatively common in calves in Norway, and human outbreaks of infection associated with calves, lambs, and goat kids have been documented).
- *Balantidium coli* (data on the prevalence of infection with *Balantidium coli* in pigs in Norway are lacking, but data from Denmark suggests it may be relatively common. No data are available on the occurrence of human cases).
- *Giardia duodenalis* (sewage analysis demonstrates that this is a common infection in people in Norway, and an extensive waterborne outbreak was documented in Bergen. The zoonotic potential of *Giardia* infections in Norway is unresolved, but seems to be of lesser importance.
- *Toxoplasma gondii* (exposure considered to be relatively common in sheep, goats and cervids in Norway – for example a recent seroprevalence study from goats indicated 75 % seroprevalnce at the herd level and 17 % at the individual level (Stormoen et al. 2012), and between and 1% and 40% amongst cervids depending on species, with the highest seroprevalence amongst roe deer (Vikoren et al. 2004); although recent data are not available from cats, data from around 35 years ago indicate an almost 25 % seroprevalence and there is no reason to assume that this has reduced).

Nematodes

- *Ascaris* spp. (while *Ascaris suum* is considered to be a relatively common parasite of pigs in Norway, the prevalence of *Ascaris lumbricoides* is unknown. Whether *A. suum* and *A. lumbricoides* should be considered as separate species or not, is not fully resolved, and therefore *Ascaris* spp. should be considered a relevant parasite in Norway).

- *Trichinella* spp. (although trichinosis has not been identified in pork in Norway for several years, its presence in wildlife means that it is a relevant parasite for animal production in Norway).

Cestodes

- *Taenia saginata* (although considered relatively rare among Norwegian cattle, infection was reported in 2012, with cattle infected via faeces from an infected person being included in manure spreading over pastureland).

Trematodes

- *Fasciola hepatica* (recent data indicate that *F. hepatica* infection is common in sheep in some regions in Norway; human infections are probably relatively few, however there are individual case reports in the literature, both imported and acquired domestically)

In addition, infections that may result in contamination of fresh produce with the transmission stages of parasites that are of public health importance, such as *Toxocara canis* and *Toxocara cati,* were also considered, although not sought for individually in the literature search.

Literature search

It should be noted that in considering parasites in food from farms, either conventional or using organic farming, that could be a hazard to human health three main categories should be considered. These are: 1) parasites transmitted as contaminants (of either fresh produce or meat or dairy produce) – these include nematode and cestode eggs, trematode metacercariae, or protozoan cysts or oocysts. These tend to be environmentally robust and can only be detected when the food product is analysed for the transmission stage of that parasite, or its DNA; 2) parasites transmitted as an intrinsic part of the product and that is normally detected by inspection or analysis of the product when it is collected or at slaughter (e.g. *Taenia* cysts in pork or beef, *Trichinella* in pigs); 3) parasites transmitted as an intrinsic part of the product and that is normally detected by tests prior to collection or slaughter (e.g. *Toxoplasma* in lamb, pork etc.)

Results

Although several articles were identified in which a particular parasite or group of parasites were reported from an organically grown product or on an organic farm, the number of articles that specifically compared the occurrence of parasites in organically raised products compared with conventionally raised products was relatively few.

The articles that specifically compared organic and conventional produce are described briefly in the sections below according to parasite, and then summarized in Table 1.

Toxoplasma gondii

There are several routes of infection with *T. gondii,* but one of the most frequent is consumption of undercooked meat containing *Toxoplasma* bradyzoites. As all domestic animals appear to be susceptible to *Toxoplasma* infection, then most meat products could be potential sources of infection. In Europe, mutton and lamb seem to be particularly likely sources of infection, not least due to the habit in some countries of eating this meat undercooked, but in other countries, pork and poultry seems to be an emerging consideration.

In Norway, consumption of raw/undercooked pork was considered an important risk factor for exposure (OR = 2.4, p = 0.03), although the odds ratio was higher for raw/undercooked mutton (OR = 11.4, p = 0.005). Eating unwashed raw vegetables or fruits was associated with increased risk (OR = 2.4, p = 0.03) (Kapperud et al, 1998). *Toxoplasma* bradyzoites have not particular sites of predilection and the bradyzoite cysts are microscopic. There are currently no meat inspection routines for *Toxoplasma*, and thorough cooking inactivates the bradyzoites.

A study from the Netherlands (Kijlstra et al. 2004) compared occurrence of *Toxoplasma* in pigs from three different types of farm using serological testing: organic (660 pigs from 16 farms), free-range (635 pigs from 17 farms) and regular (conventional; 621 pigs from 30 farms). *Toxoplasma* was not detected in any of the pigs from conventional farms, but 30 pigs (4.7 %) from 10 free-range farms (59 %) were seropositive, and 8 pigs (1.2 %) from 3 organic farms (18 %) were seropositive. The authors speculate that the presence of cats and inappropriate rodent control on the organic farms may have been relevant risk factors for *Toxoplasma* infection on organic and free-range pig farms. A further study from the Netherlands (van der Giessen et al. 2007) demonstrated a higher seroprevalence of *Toxoplasma* in pigs from free-range and organic farms (5.62 % and 2.74 % prevalence, respectively) compared with intensive (conventional) farms (0.38 % prevalence). Many routine practices in modern pig farms (biosecurity measures including confinement rearing, systematic rodent control, more hygienic feed handling procedures, exclusion of cats) are combined to reduce the risk of exposure of pigs to *T. gondii* (EFSA 2011a).

A study from USA investigated the prevalence and genotypes of *T. gondii* on two organic farms (Dubey et al. 2012). Although no direct comparison with the prevalence and genotypes of *T. gondii* on conventional farms during this particular study, the results obtained compared with general *Toxoplasma* seroprevalence data from pigs in USA (Hill et al. 2010), suggested to the authors that organic pork may pose an increased risk of transmitting *T. gondii* to humans. As this publication does not provide a direct comparison, it is not included in the table of summarised comparisons.

Trichinella spiralis

Trichinella spp. can only be transmitted by ingestion of the infective larvae with the tissue of an animal that was previously infected. The domestic lifecycle is particularly associated with *T. spiralis* and pork. Standard methods are available for analysing meat for *Trichinella* larvae. Serological methods can also be used to determine infection, but these methods are currently under standardisation. In the publication by van der Giessen et al (2007) that investigated *Toxoplasma* seroprevalence among pigs, seroprevalence of *Trichinella* was also investigated. Using a cut-off value of 99.5 %, none of the samples from pigs from free-range or intensive (conventional) farms were seropositive, but one sample of 402 from an organic farm was positive. As the very low number of seropositive animals detected might fall within the accepted range of false positive test results, the authors conclude that all the animals tested in the study were free of *Trichinella* infection (van der Giessen et al. 2007). *Trichinella*-free herds have to fulfill several requirements. An efficient surveillance system is necessary. A number of requirements are related to biosecurity/general hygiene and rodent control. In addition, fattening pigs (from *Trichinella*-free herds) are not allowed to have access to outdoor facilities as of their fourth week and only if strict conditions are met during the first four weeks (EFSA 2011a).

Taenia saginata

Bovine cysticercosis occurs when cattle are infected with the metacestode stage of the tapeworm *Taenia saginata*. The definitive host of this parasite is humans, and they are infected by consuming undercooked beef containing infective metacestodes. In Europe, cattle are visually inspected at slaughter for metacestodes. A study from Denmark investigated the occurrence and factors associated with bovine cysticercosis recorded in cattle at meat inspection from 2004 until 2011 (Calvo-Artavia et al. 2013). Of the over 4 million cattle slaughtered during this period, 348 were recorded with cysticercosis. Of these, 38 (11%) were from organic farms and 309 (89 %) from conventional farms. However, as only 6 % of the total number of cattle slaughtered was from organic farms, the authors concluded that organic farming was associated with a higher risk of positive animals being selected at slaughter, and that 50 % of positive animals from organic herds were infected due to being raised under organic farming practices.

Various helminths on fresh produce (vegetables and fruit)

Some reports suggest that organic vegetables and other fresh produce might be at a higher risk of contamination with helminth eggs (or protozoan cysts/oocysts) than produce grown under conventional conditions (e.g.(Kajiya et al. 2006). However, the only publication that could be identified that systematically compares contamination of fresh produce with parasite transmission stages on organic and conventional farms, found more contaminated products on conventional farms than organic farms, although the difference was not significant (Klapec&Borecka 2012). The study was conducted in Poland in 2008-2009, and involved the examination of a range of different fresh produce from 8 conventional farms and 11 organic farms for contamination with helminth eggs. *Ascaris* spp. eggs, *Trichuris* spp. eggs, and *Toxocara* spp. eggs were reported on the produce from both types of farms, but with 18.9 % of 77 products positive from organic farms and 34.7 % of 46 products positive from conventional farms. The authors suggest that the stricter system of standards on organic farms could be responsible for the lower levels of contamination.

Table 2 Number of articles comparing contamination of organic and conventional products.

	Conclusions	**Ref.**
***Toxoplasma* in pork**	Two publications from the Netherlands indicate that the seroprevalence of toxoplasmosis is higher among pigs raised on organic farms than on conventional farms	Kijlstra et al, 2004; Van der Giessen et al, 2007
***Trichinella* in pork**	Although seropositive animals detected only amongst pigs raised on organic farms, the authors conclude none of the animals in the study were positive for *Trichinella* infection, as the low number of seropositive results fall within the accepted range of false positive test results	Van der Giessen et al, 2007
***Taenia saginata* in cattle**	A study from Denmark indicates that organic farming was associated with a higher risk of bovine cysticercosis being detected in cattle at slaughter.	Calvo-Artavia et al, 2013
Helminth eggs on fresh produce	A study from Poland indicated that fresh produce from organic farms was no more likely to be contaminated with helminth eggs than fresh produce from conventional farms	Klapec and Borecka, 2012

Prions - Agents causing prion diseases or transmissible spongiform encephalopathies (TSEs)

Background and nomenclature

Prions are arbitrarily classified among sub-viral agents, separate from viroids and satellites (http://en.wikipedia.org/wiki/Virus_classification). Several proteins with prion-like behaviour have been identified in fungi, such as yeast. These are unrelated to prions causing disease in mammals and will therefore not be discussed here.

The prion diseases used to be called transmissible spongiform encephalopathies (TSEs) and prions were commonly denoted TSE-agents. The prion concept/hypothesis was developed by Nobel laureate Stanley B. Prusiner in the early 1980-ties (Bolton et al. 1982, Prusiner et al. 1984, Prusiner 1998) and is today commonly accepted. Prions are proteinaceous particles, devoid of nucleic acids, consisting largely, if not solely of misfolded and aggregated isoforms of the prion protein (PrP). Upon transmission or infection, exogenous PrP-aggregates somehow orchestrates a template misfolding of host-encoded PrP (through direct interaction), thereby growing larger aggregates of which certain fragments (oligomers) cause neuronal death and ultimately death of the host organism.

Thus, the molecular pathology of prion disease shares most of the characteristics of protein misfolding and aggregation diseases, so-called proteinopathies, among which Alzheimer's disease is well known. However, and importantly, the prion diseases are the only known proteinopaties that under certain circumstances are infectious.

Two aspects of particular importance in epidemiological analysis and surveillance of prion diseases are; a) prions are physiochemically robust and resist harsh environmental conditions and most treatments traditionally used for inactivation of infectious agents and; b) prions and prion infectivity are difficult to detect and monitor.

The only known food-borne prion disease in humans is variant Creutzfeldt-Jakob disease (vCJD), which is caused by oral infection with the same prion that caused the Mad-Cow-Disease or Bovine spongiform encephalopathy (BSE) epidemic in cattle. Other well-known prion diseases affecting farm animals or wild-ranging ruminants, such as scrapie (classical and atypical forms) in sheep and goats and chronic wasting disease (CWD) in deer are considered harmless for humans. Despite this, due to the high degree of similarity with BSE prions, stringent measures are in place to avoid scrapie prions or CWD prions to enter the human food chain as well as the food chain of farm and pet animals.

Results

The literature search of prions showed that no specific investigation of prions (or prion infectivity) in relation to organic food production or products versus conventional food production/products has been carried out.

Virus

Background

Infections with virus rank among the most important causes of diseases in humans (Cliver 2001, Koopmans 2002, Cook 2013). Among viral infections, gastroenteritis has been estimated to be second in frequency after the common cold (Jay et al. 2005),with Norovirus and hepatitis A virus as the most important agents (Duizer&Koopmans 2009).

The Norovirus are small (30-38 nm) single stranded RNA viruses giving food borne infections with symptoms as vomiting, stomach pain, diarrhoea, headache and mild fever. Norovirus infections affect persons at all ages and typically last some days. A large range of foods have been associated with Norovirus outbreaks. During the period from 2006 to 2012, a total of 432 foodborne outbreaks were notified in Norway (www.fhi.no, vesuv). Of these outbreaks, Norovirus were responsible for 32 % (139).

The hepatitis A virus is classified into the family Picornaviridae that comprise small (22-30 nm) single stranded RNA viruses. Persons of all ages may be infected by hepatitis A, but the severity generally increases by the age of first contact with the virus (Koopmans 2002). The symptoms observed are more unspecific than for Norovirus infections, and may include fever, headache, nausea, stomach pain and vomiting, followed by hepatitis later in the cause of the disease. A large range of different foods have been associated with hepatitis A outbreak, including oyster, clams, caviar, mineral water, orange juice, sandwiches, as well as lettuce, melons, strawberry, pomegranate and other fruits and berries. Today, hepatitis A is rare in Norway with between 22 and 57 cases annually in the period from 2005 to 2012, predominantly infected abroad (www.fhi.no).

Results

The literature search strings on virus gave no matches. As pointed out by Lairon (2010) several enteric viruses belonging to the families Picornaviridae, Caliciviridae, Astroviridae, Reoviridae and Adenoviride are important as food borne pathogens in humans. However, there seems to be a complete lack of comparative studies on the relative importance of conventional and organically produced foods as vehicles for these vira. Since the most important food borne virus are non-zoonotic, the application of fertilisers derived from animals will probably no pose an increased risk of viral contamination of food products from organic farming. However, transmission of virus may also occur by irrigation water contaminated by human faecal material or by handling of products. No information on the relative importance of conventional and organically produced foods as virus transmitter by irrigation water or handling is available.

Data gaps

There are no published investigations from Norway which directly compare the prevalence of human pathogenic bacteria in foods from organic and conventional production systems. Well designed and executed research is clearly needed to investigate this question at various stages along the production and distribution chain. The investigations should be designed and conducted in a manner which enables multivariable analysis in order to identify factors that are independently related to bacterial contamination. Such research should include analytic-epidemiological studies, where confounding variables are carefully controlled, to assess whether consumption of organic foods is independently associated with increased risk of infection. Likewise, experimental studies and field studies may be conducted to enable control of extraneous factors, and reduce biased conclusions.

Although there are some data comparing organic and conventional farming regarding the occurrence of parasites in produce (particularly *Toxoplasma* exposure of pigs, *Trichinella* in pork, *Taenia saginata* in cattle, and helminth eggs on fresh produce), on the whole the data are scarce and no such studies could be identified from Norway.

Enteric viruses are important as food borne pathogens in humans. There is a lack of comparative studies between conventional and organically produced foods in the available scientific literature.

Data regarding the prevalence of antimicrobial resistant bacteria, both from conventional and organic, from countries other than European or USA is lacking.

Data comparing antimicrobial resistance in organic and conventional products from Norway is not available.

Discussion

The following discussion consists of three sections:

- General considerations,
- Norwegian conditions, and
- The literature review

General considerations

Contamination with human pathogens

The discussion in the present section does not relate to any particular geographical area, and comprises arguments which may enhance interpretation of the international literature reviewed in this report. A discussion of contamination of foods with pathogens under Norwegian conditions is given in the next section.

Other factors being equal, and on average, it may be argued that organic production bears a higher risk in terms of foodborne infections, because some regulations for organic production encourage practices that increase the probability of contamination with pathogens (O'Doherty Jensen et al. 2001, Smith-Spangler et al. 2012). Such practices include outdoor rearing and the use of animal manure or excrements as the sole or predominant principle for fertilization. Both these practices are likely to impact on the probability of zoonotic pathogens occurring in food products, although the data to support this theory are generally scant. In addition, some organic farming standards discourage or even prohibit procedures that are employed to remove or reduce such contamination, repress colonization, prevent bacterial multiplication in foods, and to treat infected animals (e.g. synthetic feed additives intended to reduce colonization with pathogens, decontamination with synthetic disinfectants, synthetic food additives, vaccines, use of antimicrobial agents for therapeutic and prophylactic purposes. According to regulations implemented in EU and Norway, the use of vaccines, treatment with antimicrobial agents (but not prophylactic) and of some synthetic disinfectants are allowed in this area, but may be prohibited in other countries.

On the other hand, it may be disputed whether this potentially increased risk is counteracted in part by other qualities associated with organic farming, such as the use of closed breeding systems where all animal age groups are kept on the same farm, a practice which is likely to reduce transfer of pathogens between production units (but not necessarily between age groups or between different species on the same farm). It is also possible that organically produced animals may be more resistant to colonization and disease due to putative better health and welfare, as a consequence of less intensive production, and that organic produce may be less susceptible to colonization of the phyllosphere, although data to support this are scarce.

However, the use of closed breeding systems and animal health considerations are not unique to organic husbandry. In conventional production, the primary goal at farm level is risk reduction for the main hazards, which can be achieved through preventive measures such as herd health programs and closed breeding pyramids, Good Hygiene Practices and Good Farming Practices and finally categorisation of animals based on the carrier state of these agents. A study of the closed health and breeding pyramid of the Norwegian Specific Pathogen Free (SPF) herds in the period from 1996 to 2006 indicates that it is possible to establish clusters free from *Y. enterocolitica* and to keep the herds free from this human pathogen for many years (Nesbakken et al. 2007).

The size of a production unit, although not directly related to its status as organic (usually smaller) or conventional (usually larger), may also affect the prevalence of pathogens (Sanchez et al. 2007, Wilhelm et al. 2009). In small production units the maintenance of a robust biosecurity control program may be less optimal as compared with large, industrial plants where more resources are available. According to Wilhelm et al. (2009) the difference in size of organic and conventional farms might explain some differences in bacterial prevalence.

Likewise, climatic and edaphic factors may influence the survival, multiplication and spread of pathogens in the environment. It is therefore important to control for such variables when comparing foods from different production system.

FAO & WHO (2008) have addressed the pathways for contamination, survival and persistence of microbiological hazards associated with leafy vegetables and herbs, and the potential management options from primary production through to the consumer. EFSA (2013) has recently presented a scientific opinion where potential risk factors for microbial contamination during pre-harvest processes and harvest for selected foods of non-animal origin, are reviewed. It is referred to those two reports for detailed description, discussion and references.

Regardless of the type of food, compliance with good management standards and good hygienic practices is a prerequisite in organic as well as conventional production, in order to ensure safe food. General farm management practices are important in reducing the risk of contaminating food with pathogens, an area that needs to be of constant concern to all food producers (Bourn&Prescott 2002). Magkos et al.(2006) suggested that demands on management practices are substantially greater in organic than in conventional systems, and the safety of organic foods are much more dependent on individual farmers than in conventional production.

Although a great majority of foodborne disease cases are sporadic, outbreaks are not uncommon. According to outbreak data reported as part of the EU Zoonoses Monitoring, there was an increase in the number of reported outbreaks, cases, hospitalizations and deaths associated with foods of non-animal origin from 2008 to 2011 (EFSA 2013). These trends occurred together with a decrease in the number of reported outbreaks, cases, hospitalizations and deaths associated with foods of animal origin. However, there are considerable limitations with outbreak output data which make interpretation uncertain. The monitoring system does not make a distinction between outbreaks caused by organically or conventionally produced food. Organic foods have been incriminated in several outbreaks, in EU and well as in other areas, but it is not possible to draw conclusions as to the relative importance of organic versus conventional food in causing outbreaks. In many outbreaks it remains unclear whether organic farming practices *per se* are to blame (Magkos et al. 2006).

In 2011 a serious foodborne outbreak of Shiga toxin-producing *Escherichia coli* (STEC) O104:H4 occurred in Europe, with the majority of cases being recorded in Germany (EFSA 2011b). About 4000 people were reported ill, about 900 developed hemolytic-uremic syndrome (HUS) and more than 50 died. Organically produced sprouted seeds were incriminated as the source of infection. The seeds were imported from Egypt, and the ultimate source of contamination was not identified.

Reviews of reported fresh-produce related outbreaks have been presented by Heaton & Jones (2008) and EFSA (2013). A number of major foodborne illness outbreaks where fresh produce were incriminated, has been directly linked to fecal contamination. Several authors have emphasized that the application of untreated manure carries a higher risk of contamination compared with composted manure (Beuchat&Ryu 1997, Tauxe et al. 1997, Magkos et al. 2006). Magkos and co-workers underlined that the use of manure is common in both organic and conventional agriculture (the prevalence of pathogens in different kinds of manure and faeces was reviewed by Olaimat & Holley (2012). Nevertheless, it may be argued that manure application in organic farmland is much more intensive and widespread than in conventional production where the use chemical fertilizers is not discouraged or prohibited (Magkos et al. 2006). Schmidt (1999) however, suggested that microbial contamination could occur just as easily on an organic farm as on a conventional farm and that the important issue is that proper production practices are pursued within both organic and conventional systems.

The contamination of food with *Escherichia coli* 0157:H7 resulting in severe illness and in some cases death has stimulated a debate on whether the use of animal manure in certified organic food production systems might confer any extra health risk for consumers. According to Bourn & Prescott (2002) this question has not been studied in a scientific manner and so is clearly an area for future research. They stated that organic certifying agencies generally require animal manures to be composted before use, which is likely to decrease the risk of pathogens from contaminating foods. The exact composting requirements vary from certifier to certifier, and it has been argued that some standards may not require a sufficiently long composting period or high enough temperature treatment in order to destroy *E. coli* 0157:H7 (Bourn&Prescott 2002). Studies investigating time/temperature treatments necessary to minimize the levels of *E. coli* 0157:H7, non-O157 serotypes and other emerging pathogens in the production of compost are necessary. Bourn & Prescott (2002) emphasized that organic certifying agencies need to constantly review their standards for composting in light of the developing knowledge in this area of food safety.

Johannessen et al. (2004) conducted an experimental field study to assess the influence of bovine manure on the bacteriological quality of organic iceberg lettuce grown on a Norwegian farm. The lettuce was fertilized with compost, firm manure and slurry. No significant difference in bacteriological quality could be shown in lettuce at harvest. The authors concluded that the use of manure as fertilizer does not have considerable impact on the bacteriological quality of lettuce at harvest grown under Norwegian conditions. They commented, though, that a number of factors might have influenced their results, such as climate, heavy rainfall, and a low level of pathogens. It should also be noted that when a small difference is expected as in Norway (see the next section), the number of observations required to identify that difference is correspondingly large.

It is conceivable that the probability that contamination with a given pathogen will take place, increases proportionally with the enzootic level of the pathogen in the animal population from which manure, meat, or other food products, are derived. Likewise, the probability increases with the frequency with which animal manure, outdoor husbandry and other factors contributing to contamination is employed in the production system in question. Several investigations have found higher prevalence of zoonotic and potentially zoonotic microbes in organically produced animals (see for example (Heuer et al. 2001, Hoogenboom et al. 2008, Petersen et al. 2010). In such a situation the difference between the two production systems as regards the risk of microbial contamination of the food products is enlarged, with the tacit presumption that the findings are real and not due to biased interpretation as a result of confounding factors (see the discussion below). Other investigations have found a higher prevalence in conventionally produced animals (see for example (Wingstrand et al. 2003, Alali et al. 2010). In such a situation the difference between the production systems as regards microbial contamination of foods decreases, but this effect is balanced against the frequency with which manure fertilization and other factors promoting contamination are used, and by the application of procedures intended to eliminate or reduce such contamination and prevent bacterial growth.

This section does not comprise an exhaustive discussion of all factors influencing contamination of foods with pathogens. The emphasis given to manure fertilization reflects the attention this factor has attracted in the literature, and does not necessarily represent its importance compared with other factors. The number of factors involved, and the probability of contamination associated with each factor, varies widely between, and within, production systems, depending on the certification standards used for organic production, and the general food safety regulations implemented in different countries. They also differ between individual farmers and processing units.

The probability that microbial contamination of a food product will occur as a result of a particular factor, increases with the frequency and intensity with which that factor is being employed. There is always a certain probability that procedures applied to reduce or eliminate contamination due to the factor are not fully effective, or that regulatory requirements intended to achieve this are not being followed. Moreover, the probability of contamination increases with the number of factors contributing to this outcome.

Foods may become contaminated with pathogens at any stage along the production and distribution chain, from farm to fork. The probability of contamination, and the magnitude of the contamination once it occurs, depends on many factors, of which some may differ between organic and conventional production systems. A general list of factors that may influence contamination is presented in the introduction to this report. Contamination of the final product with pathogens is the consequence of several pre-harvest, harvest, and post-harvest factors. These factors are not independent. There is usually a complex interaction in which one or more factors may increase, decrease or subvert the effect of other variables, and *vice versa*. It is, therefore, not warranted to state categorically whether or not a given factor is *independently* associated with increased or decreased risk of contamination, without controlling for the influence of confounding variables in the context concerned. This poses a methodological challenge in observational studies intended to examine differences in contamination rate between foods from organic and conventional production systems. The differences observed, as well as failure to demonstrate such differences, may be attributable to underlying confounders not directly related to the production systems *per se* (see the discussion of the literature review, below).

Even though no specific investigation of prions (or prion infectivity) in relation to organic food production or products versus conventional food production/products has been found, environmental contamination and persistence of prions has been studied to some extent. Prion infectivity remains in manure and sewage for prolonged periods of time (Maluquer de Motes et al. 2012), thus organic production, which relies more heavily on manure as fertilizer might theoretically be more exposed to prion contamination. However, it is important to emphasize that the risks related to prion infectivity is extremely low, regardless of organic versus traditional production.

Norwegian conditions

Contamination with human pathogens

In Norway, the enzootic levels of human pathogens in domestic and wild-living animal populations are comparatively low. As a consequence, the probability of contamination of food products, of animal as well as non-animal origin, is reduced proportionally.

Nevertheless, there is a considerable prevalence of:

- *Toxoplasma* in sheep and swine, and in cats
- Pathogenic *E. coli* among sheep
- *Yersinia enterocolitica* in swine
- *Campylobacter* in cattle, swine, sheep, dogs, cats, and poultry – and most conspicuously among wild birds
- *Salmonella* in gulls, passerines, and hedgehogs
- Human pathogenic *Cryptosporidium* in cattle and small ruminants
- Potentially zoonotic helminths in dogs and cats
- *Listeria* is ubiquitous

Annual reports from Norwegian surveillance and control programs for zoonoses and zoonotic agents in animals, food and feed are presented on www.vetinst.no.A detailed description of the occurrence of zoonotic agents in domestic and wild-living animals in Norway, with references to the literature, was presented in a previous report from VKM (Østerås et al. 2011). These reservoirs represent a potential source of microbiological contamination in organic as well as conventional production of both animal products and product of non-animal origin. However, for those agents which may be present in manure, organic farming confers an extra risk of contamination over that in conventional production for pure statistical reasons since manure fertilization is used much more frequently and intensively. Likewise, it is obvious that for pathogens with an appreciable enzootic level among wild-living animals, outdoor husbandry with free access to soil and water in the open, the probability of contamination increases with the frequency with which such a husbandry practice is being employed (e.g. *Trichinella* in pigs and *Campylobacter* in poultry). Free-ranging animals are also susceptible to transfer of pathogens from other domestic animals on the same farm, including cats and dogs (e.g. *Toxoplasma* from cats). On the other hand, the climatic conditions in Norway are less favorable for growth and survival of most bacterial pathogens in the environment, and discourage outdoor rearing of animals like poultry, a factor which contributes to decreased risk. In addition, the likelihood of contamination from untreated irrigation water is relatively small, given the low enzootic and endemic levels of pathogens.

Thus, when considering the comparatively low enzootic and endemic levels of pathogens, and the prevailing climate, it would be expected that the difference in contamination between organic and conventional food products in Norway is fairly modest. In most countries within as well as outside EEC the enzootic and endemic levels of pathogens are considerably higher than in Norway (EFSA-ECDC 2012). Therefore, imported foods pose an enlarged risk of human infection with such agents, compared to domestically produced foods.

In Norway, foodborne disease outbreaks are recorded by an online alert system (www.vesuv.no). In recent decades, an increasing number of foodborne outbreaks where fresh produce were identified as the source of infection, have been detected (Norwegian Institute of Public Health, www.utbrudd.no). In all but one outbreak, imported products were incriminated. Two outbreaks have been traced to foods from certified organic producers in Norway, one was caused by lettuce and the other involved soft cheese:

In 1999 an outbreak of EHEC infection was traced to organic lettuce from a Norwegian producer. Although EHEC could not be detected in lettuce samples collected at the farm (several weeks after the outbreak occurred), epidemiological evidence indicated that lettuce was the most probable source of infection, and a number hygienic failures were identified at the farm, which were plausible causes of contamination.

In 2007, an outbreak of listeriosis resulted in 19 cases, of whom five died, at two hospitals in Norway, including a cancer hospital (Norwegian Institute of Public Health, www.utbrudd.no). There were also three stillbirths. Organic camembert from a small dairy farm was incriminated as the source of infection, and up to 6×10^6 CFU of *Listeria* per gram were detected. The contamination was traced to the brine used for ripening of the cheese. It is likely that failure to maintain a robust internal control on such a small unit was the cause and not the organic production *per se*.

The regulations governing organic production in EEC, including Norway, establish a framework of harmonized Community rules on production, labeling and inspection of organic foods. In addition, all production, processing, distribution and sale of food in Norway, whether organic or conventional, is subject to the requirements pursuant to the Law on Food Production and Food Safety (MHCS 2003) that implements a number of provisions pertaining to biosecurity, food safety, food quality, consumer protection, animal health and welfare, environmental protection etc. at all stages of the food chain. Strict regulations and adoption of good management standards are a prerequisite in order to ensure safe food, but they do not eliminate failure to comply with the standards, and they do not preclude that errors may occur. In an investigation from 2012, the Norwegian Food Safety Authority (NFSA) found that 35 percent of the composting units inspected did not comply with the regulations as regards hygienisation (NFSA 2012). Although the investigation dealt with composting of waste (“avfallsbaserte gjødselvarer”)[1] and not manure or waste originating from organic production, it would seem appropriate to suspect that lack of compliance may occur just as easily when hygienisation of manure is considered, especially when performed on individual farms.

Antimicrobial resistance

According to the European Medicines Agency´s report (EMA 2011), compared with other European countries, the use of veterinary antimicrobial agents is lowest in Norway and 1½ - 12 times less than in other European countries listed in the EMA report (EMA 2011). Simply, the low use of veterinary antimicrobial agents in Norway is one of the reason for low prevalence of antibiotic resistant bacteria, isolated from food of animal origin in Norway (NORM/NORM-VET 2012). The other reason for low prevalence of resistance in Norway may be the administration route of antimicrobial agents in animals, which are usually

[1] This investigation is included as an example of failure to comply with regulations. No implications for organic production are intended. The term “organisk” when employed in the report cited refers to the original, chemical sense of the word, and does not pertain to organic production, organically produced waste or the composting procedures implemented in such production systems

injection rather than peroral administration. Peroral administration of antibiotics can cause severe alterations in the gut microbiota and promote development of antimicrobial resistance.

Data comparing the prevalence of antimicrobial resistance in different production systems in Norway are lacking. Since the use of antimicrobial agents and the prevalence of resistant bacteria in conventional production system in Norway is comparatively low, it would be expected that the difference between conventional and organic production systems would not be detectable or the difference may be insignificant.

The literature review

Microbial contamination

Since we have not identified investigations from Norway which directly compare the microbiological status of foods from different production systems, our assessment was based on investigations carried out in other countries, mainly EU and the USA, although the results cannot necessarily be extrapolated to Norwegian conditions.

Several comprehensive reviews have been published (Bourn&Prescott 2002, Magkos et al. 2006, Wilhelm et al. 2009, Smith-Spangler et al. 2012). The reviewers agree that the quantity and methodological soundness of primary research comparing the prevalence of pathogens in foods from organic and conventional production is limited. Overall, existing research does not consistently support, or refute, an association between prevalence of pathogens and production type. There is currently no firm evidence to support the assertion that organic products are more or less microbiologically safe than conventional food. The same conclusion was arrived at by the UK Food Standards Agency (FSA 2000) and the UK Ministry of Agriculture, Fisheries and Food (Nicholson et al. 2000).

However, it should be underlined that direct comparison of organic and conventional production as regards microbiological contamination of foods, is difficult to design, conduct and evaluate, because several extraneous factors that are unrelated to the production system, like geographic location, edaphic factors, climate and herd size, may influence the result and lead to biased interpretation (Adam 2001, Magkos et al. 2006). Such variables are difficult or even impossible to control in observational studies. Consequently, it remains almost unattainable to decide whether the differences observed, as well as failure to identify such differences, are due to the production systems *per se*, or are attributable to other variables. Biased interpretation may be introduced by a number of pre-harvest, harvest, post-harvest, and marketing factors that do not interfere with the organic status of a product (Magkos et al. 2006). A general list of factors that may influence the microbiological status of foods was presented in the introduction to this report.

As stated by Makos et al. (2006) many comparative studies on safety aspects of organic and conventional food suffer serious methodological limitations; hence their findings should be interpreted accordingly. For instance, most investigators provide only limited information about the actual production methods; the majority simply mentions that the samples tested were of ‘organic’ or ‘conventional’ origin. In some studies the number of observations is too low to justify meaningful comparisons, and most studies do not engage in multivariate analysis of factors in order to control confounding variables.

There is insufficient information at present to state categorically whether the risk of pathogen transfer on organic farms differs significantly from that associated with conventional farming practices (Nicholson et al. 2000). Conclusions remain tentative in the absence of adequate comparable data. However, it should be emphasized that absence of comparable data does not necessarily translate into absence of hazard (Smith-Spangler et al. 2012).

Most studies have not identified differences between production systems. Nevertheless, there are several investigations which do demonstrate significantly higher risk for contamination in organic products (see for example (Bailey et al. 1999, Doyle 2000, Mukherjee et al. 2003, Mukherjee et al. 2007, Smith-Spangler et al. 2012). Although the possibility of confounding cannot completely be ruled out, such findings indicate that further investigations are warranted. Interestingly, an analytic epidemiological study (case-case-study), a design which enable control of confounders, conducted in UK, found that consumption of organic meat in the winter was associated with increased risk of campylobacteriosis (Gillespie et al. 2003).

Well designed and executed research is clearly needed to investigate this question at various stages of organic and conventional production (Hoogenboom et al. 2008). Such research should include analyticepidemiological studies, where confounding factors are carefully controlled, to assess whether consumption of organic foods is independently associated with increased risk of disease. Likewise, experimental studies and field studies, like those presented by Johannessen (2005), Johannessen et al. (2004) and Johannessen et al. (2005), may be conducted to enable control of extraneous factors, and reduce biased conclusions.

Antimicrobial resistance

Due to lack of comparable data from Norway, our assessment was based on investigations carried out in other countries, although the results cannot necessarily be extrapolated to Norwegian conditions. The studies, presented in Table 3, were performed in Spain, Germany, USA, The Netherland, France, Mexico, and Australia; all are countries with high usage of veterinary antimicrobials and with high prevalence of antimicrobial resistance compared with Norway.

One of the limitations in the studies on antimicrobial resistance assessed in this report (Table 3) is that few studies examined resistance to the same antimicrobials on the same products. Furthermore the sample sizes were heterogeneous. Jacob et al. (2008) has also mentioned several other limitations in their review article; the breakpoints values assigned to resistant isolates were not always identical between the studies. Furthermore, similar concentrations were used to define a resistant or susceptible organism; however, not all studies should directly be compared. Due to heterogeneity of the studies it is difficult to combine similar trials in order to obtain a larger number of samples to improve the evaluation of whether statistically reliable differences exist between two production systems. Therefore, a good meta-analysis is not easy to perform.

Due to the above-mentioned limitations and limitations mentioned in the review articles of Smith-Spangler and co (2012) and Wilhelm and co (2009) it is not warranted to make firm conclusion regarding a putative association between prevalence of antimicrobial resistance and the production systems. Therefore, it is necessary to conduct more well-designed, executed and reported primary research, to investigate this question in various stages of organic and conventional production system. Both in the studies presented in the review articles (Jacob et al. 2008, Wilhelm et al. 2009, Smith-Spangler et al. 2012)and in the studies presented in this assessment; within a study comparison of antimicrobial susceptibility between production system and conclusion presented are valid because antimicrobial evaluated, methodology employed, and breakpoints assigned were identical.

Both in the individual studies presented in the review articles (Jacob et al., 2008; Smith-Spangler et al., 2012; Wilhelm et al., 2009) and in the studies presented in this assessment, the differences observed between production systems, or the failure to demonstrate such differences, are only valid if confounding variables are controlled, a task which has rarely been attempted.

Both the rate of bacterial contamination and the prevalence of antimicrobial resistance including multi-drug resistance presented in the Table 3 were in agreement with the findings in the published review articles (Jacob et al. 2008, Wilhelm et al. 2009, Smith-Spangler et al. 2012). It is known that the overuse of antimicrobial agents may favour the emergence, selection, and dissemination of antimicrobial resistance among bacterial pathogens and food-producing animals' endogenous fecal microbiota (Miranda et al. 2009) and resistant bacteria from food may colonize the human intestinal tract and pass on resistance genes horizontally to human endogenous bacteria (Chaslus-Dancla et al. 1987).

The majority of the studies presented in Table 3 indicate that there may be a favourable influence of organic production systems on antibiotic resistance. It is conceivable that this putative favourable influence is due to low use of antimicrobial agents in organic production systems. However, it is most likely that not only restriction in antibiotic application, but also in-house produced feeding stuff and fertilization with antibiotic-free manure contribute effectively to prevent a carry-over of antibiotics and antibiotic resistance genes (Schwaiger et al. 2008). Theoretically, the restricted use of antimicrobial agents in organic production system may result to low prevalence of antimicrobial resistant bacteria. However, due to the lack of well-designed studies, no firm conclusion can be drawn from the available studies presented in the Table 3.

The public health consequences of a possible high rate of bacteria in organic products or high prevalence of resistant bacteria in conventional products have not been assessed in the studies presented in Table 3. Although foodborne infections rarely require treatment with antimicrobial agents, the resistance genes may be disseminated to other bacteria (Jacob et al. 2008).

Conclusion

- Contamination of the final food product with human pathogensis the consequence of a complex interaction between several pre-harvest, harvest, and post-harvest factors, which may confer positive as well as negative effects on the outcome. Foods may become contaminated with pathogens at any stage along the production and distribution chain, from farm to fork. The probability of contamination, and the magnitude of the contamination once it occurs, depends on many factors, of which some may differ between organic and conventional production systems. The number of factors involved, the probability of contamination associated with each factor, and the interaction between them, varies widely between, and within production system. They also differ between individual farmers and processing units.
- It would be expected that the difference in prevalence of pathogens between organic and conventional foods produced in Norway is fairly modest, because the enzootic levels of human pathogens in domestic and wild-living animal populations are comparatively low. Moreover, the climatic conditions in Norway are less favorable for outdoor rearing and for the growth and survival of most pathogens in the environment, a factor which contributes to decreased risk. In addition, the likelihood of contamination from untreated irrigation water is relatively small, given the low enzootic and endemic levels of pathogens.
- However, it should be emphasized that several pathogens are indeed enzootic in Norway, sometimes at an appreciable level. This fact needs to be a constant concern to all food producers. Such pathogens include *Toxoplasma* in sheep, swine, and cats, pathogenic *E. coli* among sheep, *Yersinia enterocolitica* in swine, *Campylobacter* in cattle, swine, sheep, dogs, cats, poultry and among wild birds, *Salmonella* in gulls, passerines, and hedgehogs, human pathogenic *Cryptosporidium* in sheep and cattle, and potentially zoonotic helminths in dogs and cats. *Listeria* is ubiquitous.
- In Norway, imported foods represent a higher risk of human infection compared with domestically produced foods, regardless of whether the products are organic or conventional, because the enzootic and endemic levels of many pathogens are higher in most other countries, within and outside the EU. The same argument applies to antimicrobial resistance.
- Other factors being equal, proper production practices are especially important, including sufficient composting of manure as required in organic production. Failure to comply with safe food production practices may confer a higher risk of contamination with pathogens than in conventional systems due to more frequent use of animal manure, outdoor husbandry, and other variables contributing to contamination
- We have not identified investigations from Norway that compare the prevalence of pathogens in foods from different production systems. Thus, our assessment is based on investigations carried out in other countries, although the results cannot necessarily be extrapolated to Norwegian conditions.
- Several comprehensive reviews have been published. The reviewers agree that the quantity and methodological soundness of primary research comparing the prevalence of pathogens in foods from organic and conventional production, is limited. Overall, existing research does not consistently support, or refute, an association between prevalence of pathogens and production type. However, it should be emphasized that absence of comparable data does not necessarily translate into absence of hazard. There is

currently no firm evidence to support the assertion that organic products are more or less safe than conventional food in terms of the risk of infections.

- Data comparing the prevalence of antimicrobial resistance in different production systems in Norway is lacking. Our literature review is based on investigations carried out in countries where the use of antimicrobials in animal husbandry is substantially higher than in Norway. The results indicate that the prevalence of antimicrobial resistance is lower in organic foods than in conventional foods, which is plausible in countries where antimicrobial usage in conventional production is high. However, the majority of available research suffers from methodological problems. Based on these studies, it is therefore not warranted to make firm conclusion regarding an association between prevalence of antimicrobial resistance and production systems.
- Nevertheless, it would be expected that in Norway the difference between organic and conventional foods as regards prevalence of antimicrobial resistant bacteria, is small or insignificant, because the use of antimicrobial agents and the resulting presence of resistant bacteria is comparatively low.

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Annex 1

Table 3 A list of the selected articles on antimicrobial resistance

Reference	Country	Food	Sample size Conventional	Sample size Organic	Pathogen (Genus)	Resistance against antimicrobial agents
Cui *et al*., 2005	USA	Chickens	n= 61 samples The samples were randomly collected from three organic and three conventional retail stores, respectively (September 2002 – August 2003)	n=198 samples	*Campylobacter* *Salmonella*	Chloramphenicol Ciprofloxacin Erythromycin Tetracyclines Amikacin, Amoxocillin-clavulanic acid, Ampicillin, Apramycin, Ceftiofur, Ceftriaxone, Cephalotin, Chloramphenicol, Ciprofloxacin, Florfenicol, Gentamicin, Kanamycin, Nalidixic acid, Streptomycin, Sulfamethoxazole, Tetracycline Trimethoprim- Sulfamethoxazole
Luangtonkum *et al*., 2006	USA	Poultry (broiler, turkey)	n=345 broilers n= 360 turkeys originating from 10 broilers and 10 conventional turkey farms	n=355 broilers n= 230 turkeys from a state- inspected organic processing plant	*Campylobacter* spp.	Ampicillin, Tetracyclin, Gentamicin, Kanamycin, Clindamycin, Erythromycin, Ciprofloxacin, Norfloxacin, Nalidixic acid
Miranda *et al*., 2007	Mexico	Chickens and turkey meat	n=30 reared chicken samples n=30 reared turkey samples	n=30 reared chicken samples	*Enterococcus* spp.	Ampicillin, Chloramphenicol, Doxycycline, Ciprofloxacin, Erythromycin, Gentamicin, Nitrofurantoin, Vancomycin
Miranda *et al*., 2008	Spain	Poultry meat	n=61 samples	n=55 samples	*E. coli,* *S. aureus* *L. monocytogenes*	Ampicillin, Cephalotin, Chloramphenicol, Ciprofloxacin, Doxycycline, Fosfomycin, Gentamicin, Nitrofurantoin, Streptomycin, Sulfisoxazole
Lestari *et al*., 2009	USA	Chicken	n=141	n=53	*Salmonella*	Amikacin, Ceftriaxone, Ciprofloxacin, Quinolones, Extended –spectrum cephalosporins
Cohen- Stuart et al., 2012	The Netherlands	Chicken meat	n=60	n=38	Enterobacteriaceae	Antimicrobial agents which are degraded by Extended-Spectrum Beta-Lactamase (ESBL) bacteria Extended-spectrum β-lactamases (ESBLs) are enzymes, which are capable of hydrolyzing penicillins, cephalosporins of the first, second, third, and fourth generations and the monobactam antibiotic aztreonam.

Melendez *et al.*, 2010	USA	Free-range 8organic) or pastured poultry	59 isolates were collected from two pastured poultry farms (n = 164; pens, feed, water and insect traps) and retail carcasses (n = 36) from a local natural foods store and a local processing plant.		*Sallmonella*	Tetracycline, Kanamycin, Neomycin, Sulfisoxazole, Novobiocin, Nalidixic acid, Ampicillin, Streptomycin, Gentamicin, Chloramphenicol, Ciprofloxacin
Álvarez-Fernández et al., 2012	Spain	Eggs (from supermarked)	The shells of 240 table eggs. Eggs from six sources (40 samples in each) were analyzed: chicken eggs from five different housing systems (conventional battery cages, barn, free range, organic, and domestic breeding) and quail eggs (cages).		Aerobic bacteria, Fecal coliforms, Psychrotrophes, Enterobacteriacea, *Pseudomonas* spp, *Enterococcus* spp, *Staphylococcus* spp, Moulds and Yeasts. Only *E. coli* isolates (n=120) were tested for susceptibility against antimicrobial agents.	Gentamicin, Ampicillin-sulbactam, Amoxocillin-clavulanic, Piperacillin-tazobactam, Cefotaxime, Sulfamethoxazole –Trimethoprim, Chloramphenicol, Tetracycline, Ciprofloxacin, Nalidixic acid, Nitrofurantoin, Phosphomycin
Thibodeau *et al.*, 2001	Canada	Chicken	Antimicrobial resistance data from The Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS).	A total of 10 lots of chickens. 1 bird out of 10 from each lot for sample analysis. Ceacum was taken from 30 chickens from each lot. From each lot, 3 samples of 10 g fecal matter).	*C. jejuni*	Tetracycline, Erythromycin, Chloramphenicol, Gentamicin, Ciprofloxacin, Nalidixic acid, Clindamycin, Ampicillin, Azithromycin, Bacitracin, Ceftiofur (CIPARS)
Kola *et al.*, 2012	Germany	Chicken meat	399 chicken meat samples from nine supermarket chain: four organic food stores and one butcher´s shop in two geographically distinct regions (Berlin and Greifswald). Antibiotic co-resistances were determined and strain typing was performed using PCR-based phylogenetic grouping and XbaI-PFGE.		Enterobactericeae	Antimicrobial agents which are degraded by Extended-spectrum β-lactamase (ESBL), bacteria, Tetracycline, Co-trimoxazole, Ciprofloxacin (PCR-analysis) Extended-spectrum β-lactamases (ESBLs) are enzymes, which are capable of hydrolyzing penicillins, cephalosporins of the first, second, third, and fourth generations and the monobactam antibiotic aztreonam.
Miranda *et al.*, 2009	Spain	Beef	n=75 samples	n=75 samples	*E. coli, S. aureus, L. monocytogenes, Salmonella*	*E. coli:* Ampicillin, Chloramphenicol Ciprofloxacin, Azetronam Sulfisoxazole, Doxycycline Cephalotin, Gentamicin Chloramphenicol,Fosfomycin, Nitrofurantoin Nitrofurantoin Streptomycin, *S. aureus:*

						Clindamycin, Ciprofloxacin Doxycycline, Erythromycin Sulfoisoxazole, Gentamicin Oxacillin, Penicillin, Rifampin *L. monocytogenes:* Cephalotin, Chloramphenicol, Doxycycline, Enrofloxacin, Erythromycin, Gentamicin, Rifampin, Sulfisoxazole, Vancomycin
Barlow *et al.,* 2008	Australia	Beef	198 samples from three separate cattle production systems (grass-fed, grain-fed, and certified organic cattle production system) were tested by PCR for the presence of class 1 and class 2 integrons. Integron-containing bacteria were readily isolated from pen faeces and hide samples regardless of production system. Lower numbers of integron-containing bacteria were isolated from the remaining sample types.		*Aeromonas caviae* *Morganella morganii* *Proteus vulgaris* *E. coli* *Providentia stuarti* *Pantoea agglomerans* *Aeromonas veronii* (biovar sobria) *Alcaligans feacalis* *Commamonas testostroni*	Different integrons are associated with different resistance; Tripethoprim, Ampicillin, Spectinomycin, Streptomycin. Integrons are mobile DNA element that can capture and carry genes, particularly those responsible for antibiotic resistance.
Ruimy et al., 2009	France	Fruit sand vegetables	n= 218 samples 54,6%	n= 181 samples 45,4%	Gram-negative bacteria pathogenic to human, most of these originate from soil and environment	Amoxocillin+clavulanic acid, Amoxocillin, Ceftazidime, Imipenem, Cefotaxime, Piperacillin, Ticarcillin+clavulanic acid, Tiracillin, Piperacillin+tazobactam