



Vitenskapskomiteen for mattrygghet
Norwegian Scientific Committee for Food Safety

Comparison of organic and conventional food and food production

Overall summary: Impact on plant health, animal health and welfare, and human health

Opinion of the Scientific Steering Committee of the Norwegian Scientific Committee for Food Safety

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Summary

The Norwegian Scientific Committee for Food Safety performed the present assessment of the differences between organic and conventional foods and food production on plant health, animal health and welfare and human health at the request of the Norwegian Food Safety Authority. The work was divided into five parts: (I) Plant health and plant production, (II) Animal health and welfare, (III) Human health - nutrition and contaminants, (IV) Human health – hygiene and pathogens and (V) Human health - pesticide residues.

The assessments are based on review of the scientific literature. Separate literature searches were performed and one or two expert reviewers from the five working groups examined the literature. Detailed descriptions of the searches and the publication selection are included in the five reports. In addition, relevant assessments for the purpose, prepared by international and national scientific bodies, were included.

There are few Norwegian studies on organic food production and food products and their impact on plant health, animal health and welfare, and human health. The assessments therefore had to rely on scientific studies from abroad. The relevance of these studies for conditions under which Norwegian food and feed production take place varies. There were large variations in study design, exposure (both type and time of exposure), and the measured outcomes among the studies included. Apart from the Norwegian monitoring program on pesticide residue in food, there is no systematic national surveillance on the content of nutrients and contaminants in food and feed from organic and conventional food production. This precludes any assessment of possible differences on the intake of nutrients and contaminants of Norwegian consumers from food of the two production systems.

For plant health and plant production, most studies concluded that crop losses due to plant diseases, plant pests and weeds are higher in organic than in conventional production. Richness and abundance of pollinating insects and natural enemies of harmful insects are higher in organic than in conventional farming. In general, there are small differences in content of nutrients, secondary plant metabolites, and other plant constituents, except for organic berries and fruits where higher levels of dry matter, ascorbic acid and antioxidant activity have been found. In conventionally grown wheat, there are higher levels of protein than in organically grown wheat. Contamination of cereals with *Fusarium*-mycotoxins is widespread. Results from comparison of mycotoxin contamination in organic and conventional cereals vary. While most studies found no difference in DON content, the majority of the remaining studies reported lower levels in organic than in conventional cereals. Most studies showed that organically produced cereals contained lower levels of the T-2 and HT-2 toxins than conventionally grown cereals. Some studies showed higher mycotoxin contamination in organic than in conventional apple products, while other studies reported similar level of contamination. Only few comparative studies of quality in organic and conventional seeds and seed potatoes have been published. Therefore, it is not possible to conclude on quality differences

For animal health and welfare, it was concluded that the differences between animal health and welfare regulations in Norway for organic and conventional animal production are less than in most other countries. The presence of antimicrobial resistant bacteria in both organic and conventional production systems is very low in Norway. The difference between the two production systems in proportional rate of antimicrobial resistant bacteria is small and insignificant.

There are no differences in disease occurrence between organic and conventional farming except for less clinical mastitis and more milk fever in organic dairy herds.

For cattle, the increased access to pasture and outdoor areas, the use of group housing for milk feeding calves and the increased space allowance for growing cattle is positive for animal welfare in organic production. However, grouping of young calf, suckling for three days, as well as pasturing, could have some hygienic challenges due to more exposure for pathogens and parasites.

For sheep and goats, the differences in animal health and welfare are small.

For pigs, the access to outdoor area and provision of roughage is positive for animal health and welfare in organic production, but prevention and control of parasites and pathogens from wildlife, as well as predators may be a challenge.

For poultry, the increased space allowance in organic production for broilers and layers, use of slow growing breeds, the use of roughage and natural light is beneficial for both health and welfare. There are no data to support positive effects on welfare and health of small flock sizes. Access to outdoor areas is positive for animal welfare, but increases the risk of parasites, predators and infectious diseases or subclinical infections with zoonotic agents (example: influenza and Newcastle disease).

For honey bees, the ban in organic farming against feeding bee colonies with pollen supplements in periods with low pollen availability, as well as the ban (EU regulation) against the disinfection of equipment with caustic soda, produces welfare challenges compared to conventional honey production.

Concerning feed, the nutrient contents, bioactive secondary plant compounds, as well as contaminants such as mycotoxins and pesticide residues may differ between organically and conventionally produced plants for feed. The impact on animal health and welfare is sparsely documented.

For human health, the main conclusions are that consistent evidence of clear positive or negative effects on human health as a result of consuming an organic diet, in comparison with a conventional diet has not been presented. There are reported indications of health benefits from organic food on risk of atopic diseases in children and a positive impact of organic diets on general health in animal models. The evidence is not sufficient to draw any conclusion. None of the studies on human health reported negative health effects from organic food consumption compared with conventional foods. There are some differences in concentrations of nutrients and other bioactive compounds in organic, compared with conventional foods. However, differences are mostly small and no differences have been found in e.g. biomarkers of antioxidant status, hence the relevance for health in humans on a well-balanced diet is uncertain. There is currently no firm evidence to conclude that organic products are more or less microbiologically safe than conventionally produced foods, and it may be assumed that any possible differences between organic and conventional productions concerning the prevalence of pathogens or antimicrobial resistance in Norway will be small or insignificant. Organic foods contain lower amounts of pesticides than conventional food, and lower urinary concentrations of pesticide metabolites in children have been observed from abroad. In Norway, the estimated exposure to pesticide residues in conventional food is low, and well below what is likely to result in adverse health effects. The finding of pesticide residues which exceeds established regulatory limits in a minority of tested samples, is not considered to result in adverse health effects. Available data suggest that the combined exposure to multiple pesticide residues is not likely to result in increased human health risk.

Sammendrag

Vitenskapskomiteen for mattrygghet (VKM) har på oppdrag fra Mattilsynet gjennomgått og sammenstilt forskning om økologisk og konvensjonell mat og matproduksjon. VKM har sammenlignet de to produksjonsformene og vurdert hva forskjellene har å si for plantehelse, dyrs helse og velferd og for menneskers helse. Arbeidet ble delt i 5 deler: (I) Plantehelse og planteproduksjon, (II) Dyrehelse og dyrevelferd, (III) Human helse - næringsstoffer og fremmedstoffer, (IV) Human helse – hygiene og smittestoffer, og (V) Human helse – rester av plantevernmidler.

Rapportene er basert på vitenskapelig litteratur som ble funnet i litteratursøk, og deretter gjennomgått og vurdert av ett eller to medlemmer i arbeidsgruppene. Detaljerte beskrivelser av hvordan dette er gjort finnes i delrapportene. I tillegg er relevante vurderinger utarbeidet av internasjonale og nasjonale vitenskapelige organisasjoner lagt til grunn.

Det finnes få norske studier av økologisk mat og matproduksjon hvor betydning for plantehelse, dyrs helse og velferd, og befolkningens helse er studert. Vurderingene er derfor i stor grad basert på vitenskapelige studier fra andre land. Utenlandske studiers relevans for produksjon av mat og fôr i Norge vil variere. Blant studiene var det stor variasjon når det gjaldt studiedesign, eksponering (både type eksponering og eksponeringslengde) og utfall. Bortsett fra det norske overvåkingsprogrammet for rester av plantevernmidler i mat, er det ingen systematisk nasjonal overvåking på innholdet av næringsstoffer og fremmedstoffer i mat og fôr fra økologisk og konvensjonell matproduksjon. Det er derfor ikke mulig å vurdere hvilken betydning konsum av økologisk eller konvensjonelt produsert mat har for inntaket av næringsstoffer og fremmedstoffer for norske forbrukere.

Innen plantehelse og planteproduksjon konkluderer de fleste studier med at avlingstap på grunn av plantesjukdommer, skadedyr og ugras er større i økologisk enn i konvensjonell dyrking. Det er større arts mangfold og mengde av pollinerende insekter og naturlige fiender til skadeinsekter i økologisk enn i konvensjonell plantekultur. Generelt er det små forskjeller i næringsinnhold, sekundære plantemetabolitter og andre innholdsstoff i planter, med unntak av økologisk frukt og bær som har høyere innhold av tørrstoff, askorbinsyre og antioksidantaktivitet. Konvensjonelt dyrket hvete har gjennomgående høyere proteininnhold enn økologisk hvete. Forurensning av korn med *Fusarium*-mykotoksiner (DON, T-2 og HT-2) er utbredt. Det er varierende resultater fra sammenligning av økologisk og konvensjonelt dyrket korn. I de fleste studier er det ikke funnet forskjeller i innhold av DON. I de studiene hvor det er funnet forskjeller er det flere som rapporterer at det er et lavere innhold av DON i økologisk korn. De fleste undersøkelser finner lavere innhold av T-2 og HT-2 i økologisk enn i konvensjonelt dyrket korn. Det er få studier hvor økologiske og konvensjonelle såvarer og settepoteter sammenlignes, og det er derfor ikke mulig å trekke noen konklusjoner om kvalitetsforskjeller.

Forskjellene mellom regelverket som regulerer økologisk og konvensjonell husdyrproduksjon i Norge er mindre enn i de fleste andre land. Både ved økologisk og konvensjonell drift er det lav forekomst av antibiotikaresistente bakterier, og forskjellene mellom de to produksjonssystemene er små og ikke signifikante.

Med unntak av lavere forekomst av jurbetennelse og mer melkefeber i økologiske storfebesetninger, er det ikke funnet forskjeller i sykdomsforekomst mellom dyr i økologiske og konvensjonelle besetninger.

For storfe er økt tilgang til beite og uteområder, bruk av gruppebinger for diende kalver og økt plasstilgang for voksende storfe positivt for dyrevelferd i økologisk produksjon. Men gruppering av unge kalver som får die i tre dager, så vel som beiteforhold, kan medføre hygieniske utfordringer på grunn av høyere eksponering for patogener og parasitter.

For sauer og geiter er forskjellen i dyrehelse og dyrevelferd liten.

For griser er tilgangen til uteareal og grovfôr i økologisk produksjon positivt for dyrehelse og dyrevelferd, mens økt eksponering for parasitter, patogener og rovdyr kan være en utfordring.

For fjørfe vil økt plass for slaktekylling og verpehøns, bruk av saktevoksende raser, bruk av grovfôr og tilgang til naturlig lys være positivt for både dyrehelse og dyrevelferd. Det foreligger ikke studier som kan si om mindre flokkstørrelse er av positiv betydning for helse og velferd. Tilgang til utearealer er positivt for dyrevelferd, men øker risikoen for parasitter, rovdyr, smittsomme sykdommer og zoonotiske infeksjoner (for eksempel influensa og Newcastle disease).

I økologisk honningproduksjon er det ikke tillatt å fôre bier med pollentilskudd i perioder hvor biene ikke har naturlig tilgang på pollen, og i EU-regelverket er det heller ikke tillatt å bruke kaustisk soda for å desinfisere produksjonsutstyr. Dette gir utfordringer for dyrevelferden i økologisk honningproduksjon.

Innholdet av næringsstoffer og bioaktive forbindelser, og fremmedstoffer som soppgifter og sprøytemiddelrester, kan variere i økologisk og konvensjonelt produsert fôr. Det er lite dokumentasjon om mulige effekter på dyrehelse og dyrevelferd.

Basert på eksisterende forskning, er det ikke grunnlag for verken å si at økologisk mat er bedre eller dårligere for menneskers helse enn konvensjonelt produsert mat. I noen studier er det indikasjoner på at økologisk mat kan ha en positiv effekt på risiko for atopiske sykdommer (for eksempel eksem) hos barn og på generell helsetilstand i noen dyremodeller, men funnene er for få og for sprikende til at det kan trekkes noen konklusjon. Ingen av studiene rapporterte negative helseeffekter.

Det er rapportert enkelte forskjeller i konsentrasjon av næringsstoffer og andre bioaktive stoffer (bl.a. antioksidanter) mellom økologisk og konvensjonelt produsert mat. Forskjellene er imidlertid små, og det heller er ikke funnet forskjeller hos mennesker i biomarkører for antioksidantstatus. Det er derfor usikkert om forskjellene er av betydning for helse hos folk med et godt og variert kosthold. Det er ikke vitenskapelig grunnlag til å si at økologiske produkter er mer eller mindre mikrobiologisk trygge enn konvensjonelt produserte matvarer. Det kan antas at eventuelle forskjeller i forekomst av patogener og antibiotikaresistente mikrober i økologisk eller konvensjonell drift i Norge er små og ikke av betydning. Økologiske matvarer inneholder lavere mengder av plantevernmidler enn konvensjonelt produsert mat, og det er i utenlandske studier funnet lavere konsentrasjoner av plantevernmiddel-metabolitter i urin fra barn som spiser økologisk mat. Beregninger viser at norske forbrukere får i seg lite plantevernmiddelrester fra konvensjonell mat, og inntaket ligger godt under nivåene som antas å kunne gi økt risiko for helseskade. Funn av plantevernmiddelrester som overskrider fastsatte grenseverdier i et lite antall prøver, anses ikke for å kunne gi helseeffekter. Tilgjengelige resultater tyder ikke på at kombinert eksponering for flere typer plantevernrester samtidig resulterer i økt helserisiko for befolkningen.

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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 of 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 should also be reported.

Part I. Plant health – plant production

NFSA requests VKM to compare plant properties and plant health using organic production systems versus conventional production systems. We are particularly interested in products that also are produced in Norway: Seeds, potatoes including seed potatoes, grass, grains, fruits (apples, plums, cherries), berries (strawberries, red raspberries, black currant) and vegetables (carrot, brassica, onion, tomatoes, cucumber, salad).

NFSA requests VKM to identify and/or assess:

- differences between levels of various nutrients (e.g. vitamins, antioxidants, bioactive substances, minerals, protein, fat and carbohydrates), plant pests, contaminants (heavy metals, other environmental toxins), and mycotoxins found in organically produced raw materials and conventionally produced raw materials.
- differences in quality (purity, germination capacity, health etc.) between organic and conventional seed potatoes and seeds.

Part II. Animal health – animal welfare and feed

NFSA requests VKM to evaluate the impact of different production factors on animal health, animal welfare and feed for cattle, poultry, swine, sheep, goat and bees when organic production systems are used compared to conventional production systems. For the evaluation of animal welfare the method described by EFSA Panel on Animal Health and Welfare (AHAW) would be recommended, Guidance on Risk Assessment for Animal Welfare, Scientific Opinion, Draft version, EFSA Journal 2011).

NFSA requests VKM to identify and/or assess:

- consequences on animal welfare and animal health of feed and feeding practices using an organic production system compared to a conventional production system
- differences in animal welfare and health for various species of livestock under an organic versus conventional production system
- differences in animal welfare and health for bees under organic versus conventional production systems.
 - May the prohibition of feeding with pollen replacement /protein have any negative consequences?

Part III, IV and V. Human health

NFSA requests VKM to evaluate the impact on human health in Norway of eating organic versus conventionally produced food. The assessment is for practical reasons divided into three parts.

Part III. Human health - nutrition and contaminants

NFSA requests VKM to identify and/or assess:

- if consumption of organic food versus conventional food has a positive and/or negative influence on human health? Specification of substances that may be connected to reported health effects is wanted and also possible differences in levels of these substances (between conventional and organic products).

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.

Part V. Human health - pesticide residues

NFSA requests VKM to identify and/or assess:

- the difference in levels and intake of pesticide residues from organic versus conventional products, and the influence on human health.
For the evaluation, Norwegian monitoring data (Bioforsk/Mattilsynet) and data from Europe (EFSA) should be used.
- consequences of combination effects of multiple pesticide residues 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 from 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 (assessed by Panel on Animal Health and Welfare)
- III) Human health - nutrition and contaminants (assessed by 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)

All parts have been delivered as separate reports and then assessed and adopted by the respective Panel and the Scientific Steering Committee. (For further details on working groups involved, see page 24).

Separate literature searches were performed for each of the five reports, and the literature was examined by one or two expert reviewers from the five working groups. Detailed descriptions of the searches and the publication selection are included in the five reports.

In addition, assessments relevant for the purpose, made by international and national scientific bodies, were included.

General limitations

Literature

Generally, there are few studies from Norway on organic food production and food products and their impact on plant health, animal health and welfare, and human health. The present assessment therefore had to rely on scientific studies from other countries. The relevance of these studies for Norwegian food and feed production was taken into account when considered necessary.

The available studies showed a large variability in design, in exposure (both type and time of exposure), and in the measured outcomes.

Norwegian surveillance data and exposure assessment

Apart from the Norwegian monitoring program on pesticide residues in food, there has been no systematic national surveillance on the content of nutrients and contaminants in food and feed from organic and conventional food production providing data which would allow comparisons between organic and conventional food production. This applies to both Norwegian and imported products.

Lack of such monitoring data makes it impossible to assess the impact of intake of nutrients and other substances, including contaminants from organic and conventional foods, to the consumers in Norway. Some information on occurrence of nutrients and contaminants in organic versus conventional food and feed has been found in the literature, but the data are too scarce and of uncertain relevance for estimation of true occurrence values for nutrients and contaminants present in organic and conventional food. For this reason, it has been impossible to carry out a dietary exposure assessment for humans consuming organic or conventional food. The exception is a dietary exposure assessment for some pesticide residues in foods based on data from the Norwegian programme on pesticide residues in vegetables and fruits.

Uncertainties

Due to the small number of Norwegian studies comparing organic and conventional plant health and production the evaluations of nutrient contents, plant health and environmental contaminants are mainly based on studies performed in other European countries and North America. Differences in climate, soil types and varieties between Norway and these countries where the studies used in this report were performed constitute major sources of uncertainty.

The evaluation of contamination with human pathogens and bacteria in organic and conventional produced food is mainly based on studies performed in other European countries and USA. The production practices and other conditions cannot necessarily be extrapolated to Norwegian conditions. For example, the use of antibiotics to farm animals is considerably lower in Norway compared with countries outside Scandinavia.

Contamination of food with pathogens is a consequence of a complex array of interactions between many factors, differing widely both between and within production system and also between individual farmers and processing units. This array of partly unpredictable

interactions and variations may give rise to considerable methodological problems when comparing the two production systems.

There were few human studies and the outcomes were mostly incomparable. Some feeding studies using rodents, chicken and fruit flies have been conducted, comparing organic and conventional food. Results from the animal studies cannot be directly extrapolated to humans.

Main results

Plant health – plant production

In 2012, organic plant production covered 50 200 ha which is 5.1% of the total agricultural area of Norway. The country is on the northern frontier for commercial plant production with short growing season, low summer temperatures and in some districts, precipitation above the optimum for crops. However, many hours of daylight during the summer months are positive for growth and plant production. Very few Norwegian studies have compared organic and conventional plant production. Therefore, the evaluations of nutrient contents, plant health and environmental contaminants are mainly based on scientific publications from other countries in Europe and North America. The main uncertainties in the evaluation are the differences in climate, soil types and varieties cultivated in Norway and in the countries where comparative studies of organic and conventional agriculture have been performed.

Plant health

- Most studies conclude that crop losses due to plant diseases, plant pests and weeds are higher in organic than in conventional production. There are small differences in cereal diseases, while potato late blight, apple scab and grey mould on strawberries are more severe in organic than in conventional farming. Higher damages due to insects and mites are expected in organic compared to conventional farming. Most studies conclude that organic farming increases weed species richness and weed density compared to conventional farming. The most probable explanation for these differences is that the control methods available to organic farmers are less efficient than those used in conventional farming. Better crop rotation increases weed species richness in organic farming, while higher nitrogen levels in conventional farming reduces weed richness..
- Richness and abundance of pollinating insects and natural enemies of harmful insects are higher in organic than in conventional farming. Higher heterogeneity of landscapes and absence of pesticides in organic farming are the most likely reasons for the difference.

Plant contents

Nutrients, secondary plant metabolites, and other constituents

- The evaluation shows that the protein content is commonly lower in organically produced wheat than in conventional wheat. High protein content is important for the baking quality of wheat flour.
- Dry matter and starch contents are higher in organic than in conventionally produced potato. Higher nutrient levels in the soil support rapid growth of the potato tuber at the expense of dry matter and starch content in conventional farming. In most studies the nitrate content is higher in conventional than in organic potato due to higher soil nitrogen availability in conventional than in organic farming.

- Most studies report on higher levels of dry matter, ascorbic acid and antioxidant activity in organic than in conventional apples. Organically grown berries may have higher sensory quality and content of secondary plant metabolites with antioxidant activity and some minerals than conventional berries.
- For vegetables the results were variable and less clear. In some studies vegetables grown in organic production systems have higher content of some nutrients and secondary plant metabolites with antioxidant activity, while in other studies there is no effect of the growing system.

Mycotoxins

- Contamination of cereals with *Fusarium* mycotoxins is widespread. Results from comparison of mycotoxin contamination in organic and conventional cereals are variable. Most studies found no difference in DON content and the majority of the remaining studies reported on lower levels in organic than in conventional cereals. Most studies showed that organically produced cereals contained lower levels of T-2 and HT-2 toxin than conventionally grown cereals. Organic cereal farmers practice wider crop rotation, more ploughing, and they apply less fertilizer which gives lower plant density than on conventional farms. DON producing fungi are partly controlled by fungicides in conventional farming, while there are no approved fungicides for control of T-2 and HT-2 producing fungi. Some studies showed higher mycotoxin contamination in organic than in conventional apple products, while other studies reported similar contamination. The difference may be due to more efficient disease control in conventional orchards, which reduces the mycotoxin producing fungi in apple fruits.

Environmental contaminants

- The uptake in plants of most organic chemical contaminants from soil is very low or negligible. Differences in organic contaminants in soil are probably mostly related to sources that are not influenced by organic and conventional practices.
- Due to high human consumption, cereals and vegetables are important sources for dietary intake of heavy metals. The data do not provide basis for a conclusion on differences in levels of metals between organically and conventionally grown food plants.

Seeds and seed potatoes

- Only few comparative studies of quality in organic and conventional seed and seed potatoes have been published, and it is not possible to conclude on quality differences. In some studies a higher proportion of seed borne diseases were found in organic than in conventional seeds.

More details can be found in Part I: Plant health and plant production

Animal health and welfare

The Norwegian animal welfare regulations for conventional animal production are strict compared to those of other countries in Europe, possibly with the exception of Sweden and Switzerland. Hence, the differences between animal welfare regulations in Norway for organic and conventional animal production are smaller than in most other countries. The assessment is based on both differences in regulations and farming practices.

It is also important to be aware that the authorities' regulation of the distribution of medicine for use in animal production is very different between the Nordic countries and the rest of Europe and overseas countries as only veterinarians are allowed to prescribe antibiotics for animal use. This is probably, together with freedom from several of the main serious infectious diseases in animal production, the reason why the use of antibiotics is considerably lower in Norway compared with countries outside the Nordic countries.

The difference in proportional rate of antimicrobial resistant bacteria between the two systems is small and insignificant. The presence of antimicrobial resistant bacteria in both production systems is very low in Norway compared to other countries in Europe and overseas countries.

The main differences in the regulations for organic and conventional farming related to animal health and welfare were found to be space allowance, access to pasture and outdoor areas, feeding practices, use of organic grown feed, use of concentrate, fertilizers (organic manure), double withdrawal time after use of medications and some restrictions on the frequency of use of medication for the same animal.

Cattle

- For cattle, the requirement in organic farming that calves should suckle their own mother may increase the risk of insufficient supply of colostrum and may be a risk factor both for the failure of passive transfer (FPT), as well as exposure of serious pathogens. However, good farm management can overcome this. There are no data to document any effect of milk feeding period on animal health and welfare. The ban on single boxes for calves in organic production is positive for animal welfare but might increase the risk of infectious diseases. The pasture period is longer in organic farming and some conventional farmers will probably choose the outdoor yard alternative. For dairy cows, the difference in space allowance between organic or conventional production seems to be negligible. For calves, the required space allowance is somewhat higher in organic compared to conventional production, but it is unclear if this limited difference will have any significant effect on animal welfare. For growing cattle > 300 kg live weight, the differences in required space allowance between organic and conventional production is higher, and data suggests that this will have a significant effect on animal welfare. The use of less concentrates and more roughage in organic production probably explains the reduced milk yield production and the lower level of clinical mastitis.
- Research may indicate that alternative therapy, as homeopathic therapy, which can be used in organic farming, has no better effect than the self-cure rate

Sheep

- For sheep, data indicate that the higher required space allowance in organic production entails a better animal welfare than in conventional production, but without clear effects

on animal health. When considering solid lying floor, access to pasture, access to outdoor area, length of the suckling period, the proportion of roughage in the diet and veterinary treatments, the differences between conventional and organic production in Norway are negligible.

Goats

- For goats, data indicate that the higher required space allowance in organic production entails a better animal welfare than in conventional production, but there is probably no effect on animal health. Access to a solid lying area is beneficial for animal welfare in uninsulated buildings with slatted floor pens at low temperatures. For access to pasture and outdoor area the differences in the regulation for organic and conventional production are small. Concerning the length of the suckling period, proportion of roughage and veterinary treatments, no relevant literature on the comparison between organic and conventional farming was found.

Pigs

- For pigs in Norway, the age at weaning is higher than the required minimum both in conventional and organic production. The available data do not show differences in animal health and welfare between the production systems. The difference in indoor space is small, but the access to an outdoor area in organic production is positive for animal welfare. However, it is more difficult to control pathogens from wildlife and visitors, and predators might be a problem when pigs have access to outdoor areas. In general, provision of roughage is beneficial for the welfare and gastric health of pigs, and the difference in animal welfare between organic and conventional production depends on the amount of straw and/or roughage that is used in conventional pig production.

Poultry

- For poultry, organic production systems for layers were compared with conventional free range production systems, and furnished cages were not considered. The increased space allowance in organic production for broilers and layers, use of slow growing strains and use of roughage and natural light are beneficial for both health and welfare. There are no data to support positive effects on welfare and health of small flock sizes. On the other hand, access to outdoor areas in organic production is positive for animal welfare but increases the risk of parasites, infectious disease or subclinical infections with zoonotic agents (example: influenza and Newcastle disease). There might also be an increased risk of death caused by predators.

Feed

- The influence of differences of organic and conventional feed production concerning use of pesticides, fertilizers, chemically synthesized solvents, flavours and colours and synthetic amino acids on animal health and welfare remains to be shown. The contents of nutrients, bioactive secondary plant compounds as well as contaminants such as mycotoxins and pesticide residues may differ between organically and conventionally produced plants for feed but the influence on animal health and welfare is sparsely documented.

Honeybees

- For honeybees there is a main concern regarding welfare in organic versus conventional culture related to the ban in organic farming against feeding bee colonies with pollen supplements in periods with low pollen availability. Pollen is the only source bees have for fat, protein, several vitamins and minerals. The risks of errors in bee development with a chance of impaired longevity due to physiological deficits are high with poor nutrition.
- Another main problem for organic beekeeping is the ban against using caustic soda to disinfect equipment. Disinfection with caustic soda and soap is known to kill spores of foulbrood, whereas flaming is not as efficient. By allowing caustic soda, previously allowed in organic bee keeping for cleaning and disinfecting equipment, the chance of spread of disease and infection will diminish.

More details can be found in Part II. Animal health – animal welfare and feed

Human health – nutrition and contaminants

This part of the assessment addresses the question whether consumption of organically produced versus conventionally produced foods has a positive and/or negative influence on human health. A specification of the substances which may be connected to the reported health effects are outlined where possible. Comments have been included for differences in levels of nutrients and other bioactive compounds in organic food compared with conventional food.

The evaluation is based on comprehensive literature searches. However, few relevant studies were found. Studies with humans (9 papers), animal model studies (9 papers) and biomarker studies (13 papers) reporting one or more health outcomes were included. Studies only describing levels of various nutrients or other bioactive compounds in conventional foods versus organic foods were not included. Only studies with organic food production similar to the European member state regulation were included.

There were several methodological challenges in studies investigating organic food and the effect on human health. A frequent problem was inadequate descriptions of the foods which were tested in the various studies, also in terms of production conditions. Another major problem was the lack of a suitable design, both for experimental studies, but perhaps even more so for clinical trials. The included animal studies were well-designed and investigated relevant endpoints and selection of biomarkers.

Clinical outcomes

- The following clinical health outcomes were investigated in the included human studies: atopy, eczema, respiratory disease, semen quality, hypospadias and risk factors for cardiovascular disease. The studies are so far scarce and have several limitations, and the clinical health outcomes studied have been investigated in too few studies to allow for firm conclusions. No conclusion could therefore be drawn regarding semen quality, hypospadias or risk factors for cardiovascular diseases. For immune-associated outcomes,

there are some indications that organic food consumption may have a more beneficial effect than conventionally produced food.

- None of the included studies on human health reported negative health effects from organic food consumption compared with conventional food. However, the studies were not specifically designed to investigate safety.

Animal studies

- In the nine included animal studies, various general health parameters were tested, but all studies included some immune parameters. The animals studied were rats (six studies), mice, chicken and fruit flies (one study each). Results from these studies might indicate a positive effect on some outcomes; however, the relevance of extrapolating from animal studies to humans remains a challenge. Organically produced plant foods in some well performed animal studies show a positive effect on animal physiology which may have an impact on animal health, i.e. immune parameters, hormonal balance and activity level. Not all studies substantiate these findings. Possible explanations for the discrepancies might be found in the differences in study design, including animal breed, plant food used, growing seasons and geographical location.

Biomarkers

- Thirteen included papers investigated changes in biomarkers of antioxidant capacity, specific fatty acids, copper and zinc bioavailability and pesticides from consumption of organic foods compared with conventional foods. The study designs and biomarkers measured in these investigations studies varied.
- The overall impression of the biomarker studies in humans is that there is probably no difference in antioxidant capacity between consumption of organic and conventional foods, but better designed studies are needed. There are some indications of increased concentrations of anti-inflammatory and growth stimulating trans-fatty acids in human milk from mothers using predominantly organically produced dairy and meat products. In children in the USA, a lower urinary concentration of pesticides was found in children consuming an organic diet compared to a conventional diet. The findings were not investigated in relation to health.

Nutrients and other bioactive compounds in food

- There are mostly small some differences in concentrations of nutrients and other bioactive compounds in organically compared to conventionally produced foods. However, the relevance for health in humans on a well-balanced diet is uncertain.

Contaminants in food

- Pesticide exposure is lower with use of organic food compared to conventional food. There are in a Norwegian setting no documented advantageous health outcomes related to the lower pesticide exposure with organic compared with conventionally produced food .

- Levels of trichothecene mycotoxins (DON, T-2 and HT-2) are similar or lower in organic than in conventional produced cereals. This may be of importance for infants and children who have a high consumption of cereals.
- No negative or positive effect on human health can be inferred based on differences in contaminant concentrations based on cultivation system.

More details can be found in Part III: Human health – an evaluation of human studies, animal models studies and biomarker studies

Human health – hygiene and pathogens

This part of the assessment address differences in contamination of foods from conventional and organic production with human pathogens and whether the bacteria have different levels of antimicrobial resistance. However, as adequate comparative data from Norway are lacking, the present assessment is based on investigations carried out in other countries, mainly in EU and USA, where the production practices and other conditions cannot necessarily be extrapolated to Norwegian condition.

Contamination of final food products with pathogens is a consequence of a complex array of interactions between many factors, differing widely both between and within production system and also between individual farmers and processing units. This array of partly unpredictable interactions and variations may give rise to considerable methodological problems when comparing the two systems.

- Several comprehensive reviews have been published on contamination with pathogens as a function of conventional versus organic food production. The authors of these reviews generally 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 conventionally produced food.
- The majority of available research concerning antimicrobial resistance suffers from methodological problems and firm conclusions regarding a possible association between prevalence of antimicrobial resistance and production systems cannot therefore be reached. However, the literature review of microbial contaminants in the two production systems indicates that the prevalence of antimicrobial resistance may be somewhat lower in organic foods than in conventional foods.
- The enzootic levels of most human pathogens in domestic and wild-living animal populations in Norway are usually low compared to EU and USA where the studies were undertaken. The same is true for the use of antimicrobial agents. Although relevant data is lacking, it may therefore be assumed that any possible differences between organic and conventional productions concerning the prevalence of pathogens or antimicrobial resistance in Norway will be small or insignificant.

More details can be found in Part IV: Human health – hygiene and pathogens

Human health – pesticide residues

The present report on pesticide residues in organic and conventional food is based on data published by EFSA (EFSA 2010), the Norwegian monitoring programmes 2007-2012 and other reported data.

It is a challenge to perform quantitative estimates and comparative studies of residue levels due to large variation in the measured levels, and the large number of different pesticides present in the samples. Thus, the focus is on the frequency of observed contaminations in relation to regulatory limits and to present examples to illustrate the variation in residue values and number of detected substances.

Pesticide residues in conventional and organic products

- Of the 12,168 samples in the 2010 EU-coordinated programme, 1.6 % exceeded the respective maximum residue level (MRL) values, and 47.7 % had measurable residues above the limit of quantification (LOQ), but below or at the MRL. Of the 1168 samples analysed in Norway in 2012 (from both imported and domestic products), 1.9 % exceeded MRL and 53 % contained measurable pesticide residues. Direct comparison of these values is not possible since different types of food samples and different numbers of pesticides were analysed.
- When conventional and organic samples from fruit, vegetables and other plant products in the 2010 EU-coordinated programme were compared, 4.2 % of the conventional and 1.0 % of the organic samples exceeded the MRL values. Furthermore, 43.2 % of the conventional and 10.8 % of the organic samples had measurable residues below or at the MRL value. Most of the pesticide residues detected in organic samples are not permitted for use in organic farming.
- Of the 624 organic samples analysed in Norway between 2007 and 2012, 0.2 % (one sample) had residues exceeding MRL, while measurable residues were detected in 1.8 % of the samples (11 samples).
- Conventional products were often found to contain multiple pesticides while most organic samples were found to contain few or only one type of pesticide.
- Lack of data on pesticide residue levels of organic samples in the EU-coordinated programme, and the few Norwegian samples, do not allow for a quantitative comparison of pesticide residue levels in organic and conventional samples. Comparative estimation of pesticide residues faces a number of challenges and uncertainty. However, it seems unquestionable, based on available data, that organic plant products contain fewer and substantially lower amounts of pesticide residues than conventionally products.

Health risks associated with pesticide residues

- In Norway, the general level of pesticide residues in both conventional and organic food is very low, and well below what is likely to result in adverse health effects. This conclusion is based on the comparison of estimated dietary exposure with toxicological reference values i.e. ADI for chronic effects, and ARfD for acute effects. The finding of pesticide residues that exceeds established regulatory limits in a minority of tested samples is not considered to result in adverse health effects.
- When dietary exposure estimated in six different food commodities in the 2010 EU-coordinated programme was compared with their relevant reference values, EFSA concluded that for 79 of 18243 conventionally grown fruit and vegetable samples a short-term acute consumer health risk could not be excluded. The conclusion was based on the exceeding of ARfD. None of these 79 samples were organic. Exceeding the acute reference value only occurred in 0.4 % of the samples and the scenario used for acute intake assessment is conservative, suggesting that the toxicological implications are limited. This is also reflected in the chronic exposure assessment, where none of the samples were found to exceed the toxicological reference value ADI.
- Dietary exposure assessments on the basis of Norwegian samples of apples, tomatoes, carrots, strawberries and lettuce did not show any values exceeding the toxicological reference value.

Combined exposure and cumulative risk assessment

- No generally accepted methodology is presently established for a cumulative risk assessment of combined exposure to pesticide residues. Available data suggest however that combined exposure is not likely to result in enhanced human health risk.

More details can be found in Part V: Human health – pesticide residues

Overall conclusions

General aspects

- There are few studies from Norway on organic food production and food products and their impact on plant health, animal health and welfare, and human health. The assessment therefore had to rely on scientific studies from abroad. The relevance of these studies for conditions under which Norwegian food and feed production take place varies.
- In general, among the studies included there were large variations in study design, in exposure (both type and time of exposure), and the measured outcomes. In addition, adequate controls were not always included.

- Apart from the Norwegian monitoring program on pesticide residue in food, there has been no systematic national surveillance on the content of nutrients and contaminants in food and feed from organic and conventional food production providing data which would allow comparisons between organic and conventional food production. This applies to both Norwegian and imported products.

Plant health – plant production

- Most studies conclude that crop losses due to plant diseases, plant pests and weeds are higher in organic than in conventional production. Richness and abundance of pollinating insects and natural enemies of harmful insects are higher in organic than in conventional farming.
- In general, there are small differences in content of nutrients, secondary plant metabolites, and other constituents in plants, except for organic berries and fruits where higher levels of dry matter, ascorbic acid and antioxidant activity have been found. In conventional wheat there are commonly higher levels of protein than in organically grown wheat. High protein content is important for the baking quality of wheat flour.
- Contamination of cereals with *Fusarium*-mycotoxins is widespread. Results from comparison of mycotoxin contamination in organic and conventional cereals are variable. Most studies found no difference in DON content, and the majority of the remaining studies reported lower levels in organic than in conventional cereals. Most studies showed that organically produced cereals contained lower levels of T-2 and HT-2 toxin than conventionally grown cereals. Some studies showed higher mycotoxin contamination in organic than in conventional apple products, while other studies reported no differences in contamination.
- Plant uptake of most organic chemical contaminants from soil is very low or negligible. Differences in organic contaminants in soil are probably mostly related to sources that are not influenced by organic and conventional farming practices. Due to high human consumption, cereals and vegetables are important sources for dietary intake of some heavy metals. The data do not provide basis for a conclusion on different levels of metals between organically and conventionally grown food plants.
- Only few comparative studies of quality in organic and conventional seeds and seed potatoes have been published, and it is not possible to conclude on quality differences.

Animal health and welfare

- The differences between animal health and welfare regulations in Norway for organic and conventional animal production are smaller than in most other countries.
- The frequency of medication of animals are found to be lower in organic compared to conventional farming for many diseases, except for milk fever in dairy cattle. However, looking at objective subclinical measures which are not imposed by farmers' attitude to call for veterinary assistance, like somatic cell count and metabolic parameters, and after adjusting for confounding factors, the conclusions are that there is no difference in

objective disease occurrence between organic and conventional farming except for less clinical mastitis and more milk fever in organic herds.

- For dairy cattle, the difference between the two systems in proportional rate of antimicrobial resistant bacteria is small and insignificant. The presence of antimicrobial resistant bacteria in both production systems are very low in Norway compared to other countries in Europe and overseas countries.
- For cattle, the increased access to pasture and outdoor areas, the use of group housing for milk feeding calves and the increased space allowance for growing cattle is positive for animal welfare in organic production. However, grouping of young calf, suckling for three days, as well as pasturing, could have some hygienic challenges due to more exposure for pathogens and parasites, but these challenges can be overcome with good management. The practise of suckling in three days makes a large challenge to control that the calves get sufficient amount of colostrum.
- For sheep and goats, the difference in animal health and welfare is small. Both predators and prevention of parasites on these animals out on pasture are a huge challenge in animal welfare and health for both systems.
- For pigs, the access to outdoor area and provision of roughage is positive for animal health and welfare in organic production. On the other hand, prevention and control of parasites and pathogens from wildlife as well as predators may be a challenge for pigs with access to outdoor areas. These challenges can however be overcome by good management practice.
- For poultry, the increased space allowance in organic production, the use of slow growing breeds, the use of roughage and natural light is beneficial for both health and welfare. Access to outdoor areas is positive for animal welfare but increases the risk of parasites and infectious diseases. There might also be an increased risk of death caused by predators. These challenges connected to access to outdoor areas may however to a great extent be overcome by good management practice.
- Concerning feed, the contents of nutrients, bioactive secondary plant compounds as well as contaminants such as mycotoxins and pesticide residues may differ between organically and conventionally produced plants for feed, but the influence on animal health and welfare is sparsely documented.
- For honey bees, the ban in organic farming against feeding bee colonies with pollen supplements in periods with low pollen availability, as well as the ban against caustic soda to disinfect equipment, causes welfare challenges compared to conventional honey production.

Human health

- Consistent evidence of clear positive effects on human health as a result of consuming an organic diet in comparison with a conventional diet has not been presented.

- There are reported indications of health benefits from organic food on risk of atopic diseases in children and of positive impact on general health of organic diets in animal models. The evidence is not sufficient to enable a conclusion.
- An organic diet was found to give higher concentrations of transfatty acids (different from industrially produced transfatty acids, i.e. vaccinic- and conjugated linoleic acid, which has been associated with beneficial effects) in breastmilk of lactating women. The relevance of these findings for human health in Norway is uncertain.
- None of the studies on human health reported negative health effects from organic food consumption compared with conventional foods.
- There are some differences in concentrations of nutrients and other bioactive compounds in organic in comparison with conventional foods. However, differences are small and the relevance for health in humans on a well-balanced diet is uncertain.
- There is currently no firm evidence to support the assertion that organic products are more or less microbiologically safe than conventionally produced food.
- In the absence of relevant data, based on low enzootic levels of most human pathogens in domestic and wild-living animal populations in Norway and the low use of antimicrobial agents, it may be assumed that any possible differences between organic and conventional productions concerning the prevalence of pathogens or antimicrobial resistance in Norway will be small or insignificant.
- Organic foods contain far lower amounts of pesticides than conventional food, reflected in lower urinary concentrations of pesticide metabolites in children. However, in Norway, the estimated exposure to pesticide residues in conventional food is low, and well below what is likely to result in adverse health effects. The finding of pesticide residues which exceeds established regulatory limits in a minority of tested samples, is not considered to result in adverse health effects. Available data suggest that combined exposure to multiple pesticide residues is not likely to result in increased human health risk.

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Persons working for VKM, either as appointed members of the Committee or as external 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.

Organisation of the work

Five project groups were established to answer the request from NFSA. The outcome of this work is five separate reports answering the questions in the terms of reference.

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