Assessment of food safety in organic farming

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Abstract: Public concern about food safety in Europe has grown in response to the BSE scandal and problems with Salmonella and Campylobacter, etc. Such health and safety considerations are among the most important incentives for buying organic food, and have helped to promote rapid growth in the organic sector.

Against this background the present article reviews food safety from an organic perspective. To our knowledge this has not been done previously. A novel definition is introduced which incorporates safety aspects of both the product and the agri-food-system. A Driving force-State-Impact-Response (DSIR) framework, that incorporates recent findings relating to organic products, is employed to analyse processes that control the safety of food. The safety of the agri-food-system is still poorly understood, but an introduction to the concept is given because of its relevance in an holistic organic setting.

It is generally felt that safety is greater with organic than with conventional foods, mainly because of the precautionary principle followed in the formulation of organic regulations and in the assessment of food safety. High standards of product safety in organic foods are promoted by a) lower nitrogen applications (which reduce nitrate concentrations), b) the ban on pesticides (which results in almost no pesticide residues), and c) the ban on prophylactics and the requirement for double retention times in animal production systems (to ensure low concentrations of medicine residues). These effects may minimise the incidence of cancer and the transfer of resistance genes from animal production systems to human pathogens.

Examples of reduced product safety in organic products can also be found, for example: a) mycotoxins in organic cereals exposed to inappropriate storage conditions, and b) Salmonella and Campylobacter infections caused by the extended exposure of animals to out-door conditions. It is however possible to reduce these risks. In particular, regulation of the processing of organic foods results in higher product safety due to a limit of no more than 5% non-organic components, and the ban on irradiation, colouring agents, sweeteners, synthetic additives, flavouring, GMOs and trans fatty acids. There seems to be a trend towards higher agri-food-system safety in organic compared to conventional farming systems due to a) the provision of more information through the labelling of organic food, and b) lower impacts on the environment.

Keywords: food safety; product safety, agri-food-system safety, organic farming; Driving force-State-Impact-Response (DSIR) framework,

INTRODUCTION

Within the EU, consumer interest in food safety has grown markedly in recent years. In 1997, the European Commission conducted a Eurobarometer study that focused specifically on consumer attitudes. This revealed that 67.9% of consumers were concerned about the safety of foodstuffs.[1] These findings motivated the introduction of an information campaign on food safety (1998-1999) which revealed that consumers were principally concerned about: I) labelling (particularly E numbers and other food safety elements), II) the traceability of foodstuffs, and III) genetically modified organisms.

Public worries about food safety relate mainly to the different specific agri-food-environment problems that have recently been encountered in Europe. These include:

- the discovery of animals with BSE,
- the increased occurrence of Salmonella in meat and eggs,
- the increased occurrence of Campylobacter in meat,
- the finding of Listeria in some dairy products,
- the increased occurrence of dioxins in food and feed,
- excessive amounts of pesticides, antibiotics, additives, etc. in food,
- the presence of toxic fungi in stored foods,
- criminal activity: the discovery of wine containing wood alcohol, polluted cooking oil etc.,
- the pollution of drinking water with pesticides and nitrate,
- GMO-polluted organic food products, and
- deception in the sale of conventional foods as organic products.

In response to the increasing consumer demands and Government policy initiatives, organic farming has developed rapidly throughout Western Europe. The market share of organic products is increasing, albeit differently, in each of the European Union (EU) countries. It is predicted that by 2005 these products will account for 5 to 10 per cent of market share, with opportunities for every category of product.[2] In absolute terms, Germany is the largest market in the EU. In percentage terms, however, the proportion of the domestic market is biggest in Denmark, Switzerland, Austria and Sweden. Market growth is most rapid in Great Britain (25-30%). Highest consumption levels tend to occur in northern Europe, while the lowest levels tend to be in the south.[2] In some countries the rate of growth in organically farmed land between 1993 and 2000 has been very high, rising from 2.4 to 8.0% in Austria, 1.1 to 6.3 % in Sweden and 0.8 to 6.2% in Denmark.[3]

Organic farming is distinguished from conventional agriculture by exercising particular respect for human values, the environment, nature, and animal welfare, etc. This regard is incorporated in the basic principles of organic farming, as formulated by the International Federation of Organic Agriculture Movements (IFOAM). The main principles for organic farming and food processing include:[4]

- the production of food of high quality in sufficient quantities,
- operation within natural cycles and closed systems as far as possible, drawing upon local resources,
- the maintenance and long term improvement of the fertility and sustainability of soils,
- the creation of a harmonious balance between crop production and animal husbandry,
- the securing of high levels of animal welfare,
- the fostering of local and regional production and supply chains, and
- the provision of support for the establishment of an entire production, processing and distribution chain that is both socially and ecologically justifiable.

These basic principles provide organic farming with a platform for ensuring high levels of food safety, even though the safety of food is not directly specified in the principles.

In Denmark, health and/or environmental concerns reflect a lack of trust in conventional products. They constitute the main reason for buying organic produce, which are widely associated with the concepts of food quality and safety. [5] The same pattern is seen in Switzerland (Coop NATURAplan) where health concerns also receive top priority. [6] Organic foods are exceptional in that consumer risk perceptions play an important role in determining demand, [7] high levels of concern being related to the frequency of organic purchases. [8-12] In general, pesticide residues are of greatest concern, [13-16] and a household which associates conventional foods with a high level of health risk should be willing to pay more for organic food that contains no pesticides. One study [17] suggests that worries about natural biodiversity may be an important factor in the assessment of the attributes of food products. In a wider context, several studies have found that environmental considerations are an important motivation for buying organic produce.[11, 18, 19] Concern for the welfare of domestic animals may be another factor that leads to consumer preference for organic products.[20]

In view of the continuing public concerns about food safety, perceived health advantages of organic products, and the recent expansion in organic farming, there is a need to evaluate food safety throughout the organic system. The present article provides a novel definition of food safety which covers both product safety and the safety of the agri-food-system. Subsequently different food safety aspects are identified and selected using a DSIR (Driving force, State, Impact and Response) framework. The state of product safety and the safety of the agri-food-system is then assessed in organic compared to conventional production, and driving forces and impacts are identified. Finally, the DSIR framework is used to discuss different responses and reactions to food safety.

DEFINITION OF FOOD SAFETY

Traditionally, food safety is defined in a narrow sense. Safe food is produce that one can eat without becoming ill. It is also food that is rich in health-promoting substances, all essential components of which are shown in a declaration (e.g. Danish authorities[21]). In Table 1 these features are referred to as 'product safety'.

As mentioned, a broader and more differentiated definition of food safety is also given in this paper. This incorporates wider aspects of food safety, as seen from an holistic organic point of view. In this context food safety relates to the safety / security of the production system, as inferred by the key words: supply, distribution, transparency, proximity, information and consumer influence, as well as the lack of negative production impacts on humans and other living organisms, the environment, and climate etc. (Table 1).

ASPECTS OF FOOD SAFETY

In the present review, the DSIR framework is used to organise these various aspects of food safety. The model is based on the DSR framework developed by the OECD [22], including some aspects from the DPSIR scheme developed by EEA..[23] The DSR model was originally developed to ensure consistency between environmental and agricultural policies, and to promote a sustainable development in agriculture. The framework has been used in several investigations; for example, where interest has focused on an assessment of the environmental impact of organic farming.[24, 25]

The DSIR framework consists of a chain of causal links, ranging from *Driving force* to changes in the *State* of food safety, and leading to *Impacts* on human health or environment and nature. Finally these three aspects of food safety bring about different *Responses* and visa versa.

PRODUCT SAFETY

As shown in Fig. 1 and Table1, the concentrations of natural and synthetic chemical compounds in food contribute to product safety. It is possible to quantify the traditional nutrients, heavy metals, pesticides and various other constituents, but there still exist unknown and unidentified chemical compounds in food. Current knowledge about the health qualities of organic foods is very limited and inconclusive.[26] Single health effects of individual constituents and multiple health effects of several components in food may occur, but in the latter case scientific documentation is very sparse.[27] It therefore seems reasonable to follow the precautionary principle when assessing food safety. Recently the possible implications of organic food for health have been reviewed.[26] The findings and conclusions from that work are used in this paper to describe the safety of the organic food product.

Both national and EU regulation of organic farming is meant to secure high levels of food safety. The labelling of organic products is part of organic product safety. The EU has its own logo (regulation (EF) No. 331/2000) but national and private organic labels also exist.

Effects of regulation of organic plant production

The regulations for organic plant production are comprehensive and detailed. An EU regulation released in 1991 (2092/91) contains parts which relate directly to the composition of organic plant products. The more important aspects of this regulation include:

- a ban on genetic engineering and GMOs
- lower nitrogen levels: maximum limits for manure application of 170 kg N $ha^{-1}yr^{-1}$
- a ban on synthetic pesticides
- a ban on synthetic mineral fertilisers
- a ban on growth promoters

In the following the significance of these different aspects for food safety will be described.

Ban on GMOs

In organic farming it is forbidden to use genetic engineering and GMOs. Consequently, organic products may normally be assumed to be free of GMOs. However, organic products may become polluted by GMOs originating from conventional farming. This may occur through I) atmospheric spread and deposition, II) the use of polluted storage containers, and III) the feeding of conventional GMO-containing feeds to animals. In Denmark, it is currently permitted to include respectively 20% and 10% conventional feed in pig and cattle diets. However, after 2005 Denmark will be subject to the EU regulation demanding 100% organic feed in organic agriculture.

The ban on GMOs in organic food reflects the fact that their long-term effects on humans and nature are still unknown. For this reason the precautionary principle has been applied.

Lower nitrogen levels

In general, total applications of nitrogen (N) are lower in organic than in conventional farming systems. A comparison of different types of well-managed farming systems in Denmark showed that on average N inputs in organic farming (104-216 kg N ha^{-1} yr^{-1}) were lower than in conventional farming systems (146-311 kg N ha^{-1} yr^{-1}).[28]

Low levels of N application in organic farming are expected to be the principal driving force behind changes in dry matter, protein, C-vitamin, carotene and nitrate concentrations in different types of organic vegetables and milk (Table 2). On average, a 5-40% higher content of dry matter [29-31], a 10-20% lower content of protein[32-35], a 5-90% higher content of C-vitamin[31, 36, 37], a lower content of carotene [38], and a 30-90% lower content of nitrate [30, 31, 36, 39] has been found in organic compared with conventional products (Table 2).

The observed differences in the content of dry matter, protein, C-vitamin, and carotene in organic products have probably no consequences for health.[26] However, the well-documented lower concentration of nitrate in organic products [40, 41] may have positive effects.[26] Nitrate exists naturally in all plant products due to its role in protein synthesis, but its concentration is affected by the level of N application. The toxicity of nitrate in food is low, but this radical can be transformed to nitrite in the food and in the stomach/intestinal canal. Nitrite can be converted to nitrosamines that are strongly carcinogenic.

Ban on pesticides
For the Danish population, food is the most important route for exposure to pesticides. Thus, the intake of pesticides with drinking water, animal products and fish is minimal. The most seriously affected sources of pesticides are berries, fruit, vegetables, and cereals (Table 3).[42] Generally, residues of one or more pesticides, at legally permitted concentrations, are found in about one third of all conventionally grown plant materials in Denmark. The permitted maximum limit is exceeded in 1-2% of the crops examined.[43]

The ban on pesticide usage in organic production means that organic foods do not contain these compounds, or that they are present in only trace amounts (Table 4).[44-46] However, only a few investigations on this issue have been undertaken.[26]

It is known that some pesticides can have harmful effects on reproduction, and that others have effects that resemble those of oestrogen. Residues of pesticides are suspected of being implicated in a range of different illnesses and diseases, such as neurological disease, damage to the immune system, and the promotion of cancer. Even in low concentrations they are thought to influence the development of sebaceous cells in the body and thereby the tendency for obesity. However, these hypotheses are not scientifically documented.[26]

The ban on pesticides and the lower applications of N in organic production may change or increase the concentration of secondary compounds (non-nutrients) in organic plant products (Table 4). It has frequently been claimed that organic plant production methods can yield foods with higher concentrations of these compounds.[47] However there exist only a few scientific investigations relating to the occurrence of secondary compounds in food. Some of these compounds are thought to help reduce the incidence of cancer and cardiovascular diseases.[26]

Indirectly, the ban on pesticides can be expected to influence the incidence of fungal attacks on food products, and thereby the production of mycotoxins (Table 4). The latter compounds are mainly found in cereals, seeds, nuts and dried fruit that have been attacked by moulds, the problem most frequently appearing in association with wet summers, late harvests and unsatisfactory drying conditions.[26] In Denmark, between 1993-1997, there was an increase in the level of ochratoxin A in organic as opposed to conventional products, especially in rye. The source of the problem appeared to be poor storage conditions in the out-dated drying systems of smallholdings. This problem has now been reduced (Susanne Elmholt, person. comm.). On the other hand, the increased use of fungicides in conventional

farming has raised concerns about their inability to control the growth of certain mycotoxin-producing fungi (Fusarium) in extended plant growing seasons.[26]

One investigation has found that conventionally produced milk contained aflatoxin M_1 during the winter period, when the equivalent organic product contained none.[37] This was probably due to the composition of the feed consumed by the animals.

Mycotoxins can affect the liver, the kidneys, and the nervous system, and some may be carcinogenic.[48]

Ban on synthetic fertilisers and growth regulators
The regulations for organic farming include a ban on synthetic fertilisers and sludge. This is because applications of these fertilisers can introduce heavy metals to agricultural soils (e.g. cadmium in phosphor fertilisers).[26] Although these metals exist naturally in soils (depending on soil type, geological parent material, climate, pH, atmospheric environment etc.), lower concentrations of them are expected in organic plant products (Table 5).[26]

Growth regulators have been found in more than 30% of all conventional plant products.[26] A Danish study undertaken in 1999 identified these compounds in 64 of 77 tests of conventionally grown grains in concentrations that were within the accepted limits.[49] Growth regulators are prohibited in organic farming, so it is expected that organic foods do not contain these compounds.

It is suspected that these plant hormones can have negative effects on animal reproduction.[50, 51] Several experiments with pigs have shown a negative effect of straw reducers on the ability to reproduce.[52-54]

Effects of regulation on organic animal production
The regulation of organic animal production is comprehensive, and influences aspects of feeding, housing, demarcation, care, medical treatment and slaughter. An EU regulation on organic animal husbandry was released in 1999 (1804/99), different aspects of which are expected to directly affect the composition of organic animal products. This regulation provides for:

- extended access to out-door areas with a lower stocking density
- restrictions on animal feeds
  - compulsory use of roughage feeds
  - ban on antibiotics, growth promoters and additives
  - ban on GMOs
  - ban on meat and bone meal
- double retention time after medicine treatment

In the following the effects on food safety of extended access to out-door areas, the compulsory use of coarse fodder, and the restrictions on medicine use will be described.

Extended access to out-door areas
Infections (zoonoses) can be transmitted from animals to human beings through the consumption of food. In conventional agriculture attempts have been made to control zoonoses through the use of hygiene barriers. Knowledge about the influence of different production systems on the occurrence and distribution of microbes in food is still very limited. However, in comparison with conventional farming practice, the extended access to out-doors areas encouraged in organic production systems more greatly exposes animals to disease-promoting soil microbes (Table 6). Furthermore, the presence of rats, mice and birds increases the risk of animals being infected with Salmonella or Campylobacter bac-

teria, [55] especially in poultry production (Ole Heuer pers. Com.).[56] Parasites also exist in nature and can cause infections (e.g. tapeworm), particularly in out-door pig production systems.[26]

However, in out-door organic animal production systems the density of livestock per hectare is relatively low. This may decrease the pressure of infection and help to neutralise the risk of zoonoses.[26]

Compulsory use of roughages
Feed composition can reduce the incidence of zoonoses in organic as compared to conventional production systems (Table 6), the compulsory use of roughages in organic systems reducing the occurrence of harmful intestinal bacteria.[26]

A significantly higher content of conjugated linolic acid (CLA) has been observed in organic compared to conventional milk.[58] This may reflect the higher content of grass in animal diets on organic farms (Table 6). A higher content of CLA in organic milk could have positive consequences for health, because CLA may help to control the onset of cancer and arteriosclerosis.[26]

Restricted use of medicine
In accordance with EU directives, all EU countries monitor their animal products for the presence of residues of medicines. In the Danish controls of 1999 [59] only limited amounts of these compounds were detected. Residues of medicine were found in 0.03% of pig meat and 0.09% of cattle meat, but nothing was found in the meat from poultry, venison, breeding fish, and milk and honey. In 1996, about 68% of the antibiotics used in conventional agriculture in Denmark were used as growth promoters (mainly to pigs), while only 31% was used directly for the treatment of different diseases.[60] However, the use of antibiotics as growth promoters for pigs was prohibited in 1999.

The restricted use of medicine in organic farming may be expected to produce a lower incidence of residues in organic animal products (Table 6), partly because of the double retention time imposed following medical treatment. However, no results are yet available from Danish controls on organic animal products.[26]

The restricted use of antibiotics could have a positive effect on health by reducing the risk for transfer of resistance genes from animal to human pathogens.[61, 62]

Effects of processing on organic production
The processing of organic food aims to maintain nutritional value and limit the number and quantity of additives and processing aids in food products.[4] The regulations for organic processing in relation to food safety prohibit:

- the use of more than 5% non-organic constituents,
- irradiation, colouring agents, sweeteners,
- synthetic additives,
- the flavouring of animal products and artificial flavouring in vegetable food products,
- GMOs,
- artificial trans fatty acids

These exclusions directly affect the composition and nutritional value of food products, and thereby the state of food safety. However potential impacts are still unknown.

AGRI-FOOD-SYSTEM SAFETY

The safety / security of the agri-food system is an important but poorly understood aspect of food safety in general. It relates principally to the concepts of supply, distribution, transparency, proximity, information and consumer influence, and must ensure that production systems have no negative impacts on humans, other living organisms, the environment, climate etc.

Effect of technological and structural development on organic production, processing and marketing

There are no specific regulations for the technological and structural development of organic production, processing and marketing, although there exist several basic principles for the area.[4] These include:

- the production of food of high quality in sufficient quantities,
- the fostering of local and regional production and supply chains,
- support for the establishment of a comprehensive production, processing and distribution chain that is both socially and ecologically responsible

There exist no specific regulations on the storage of organic products, and no national or EU regulations relating to the wrapping of these products. However, the Codex Alimentarius Commission advises the use of biodegradable and recyclable wrapping for organic products.[63]

Supply and distribution

Adequate supplies of agricultural products result from ample primary production as well as efficient distribution chains. They are therefore linked to the structural development of agriculture, from production and processing to the marketing of products.

The primary distribution routes for organic products are I) supermarkets chains, II) specialist retailers, and III) direct distribution outlets. The increase in sales by supermarkets has greatly affected the size of the market for organic produce in Europe.[26]

The question of supply of organic food products can be discussed at the local, regional, national and global levels. At the national level, the Bichel Committee [61] undertook an extensive analysis of the implications for the Danish Ministry of Food of a 100% transition to organic farming in Denmark. They concluded that a total transition to organic farming would produce a reduction of 1-3% in the gross national product and a decrease in private consumption of 1900-4700 DKK (2-5%) per year per inhabitant. Although this constitutes a considerable economic reduction, the analysis shows that it is possible to have 100% organic farming in Denmark, depending on consumer demand.

At the global level, food supply can be discussed from two basically different perspectives of sustainability – resource sufficiency or functional integrity.[84] Resource sufficiency emphasises the use of resources and the production and distribution of food, focusing first and foremost on the relationship between input and output in the systems under consideration. A sustainable development infers that agriculture can satisfy the requirements for food and textiles etc. for current and future generations, such that the most productive systems are also the most sustainable. This concept has been the dominating one in modern conventional agriculture. From the perspective of resource sufficiency organic farming results in lower food safety than that achieved by conventional agriculture.

Sustainability in the sense of functional integrity sees agriculture as a complex system of values and relationships, and emphasises the frailty of the system that results from our lack of understanding of interactions between production methods and ecological and social survival. The basic assumption is that the system is vulnerable, and that some of its fundamental elements recur over a period of time in

a way or at a rate that depends on the condition of the system at an earlier date. The genetic characteristics of specific farm animals and crops, for example, and treatments that change the fertility of the soil can be critical to production over the longer term. In general, nature is seen as an inseparable aspect of society's sustainability or functional integrity, and this understanding underpins strategies to oppose and avoid irreversible changes. Caution is thus a valuable approach to avoid negative consequences in our relationships with nature. From this perspective organic farming results in higher food safety than that encountered in conventional agriculture.

Transparency, information and consumer influence
Consumer information is an integral part of food safety. The more transparent the agricultural production process, the safer the consumer feels. To the consumer, trustworthy and adequate information is basically a way to minimise risk, e.g. the risk of getting ill from food, the risk of buying environmentally degrading products, or the risk of buying products that do not ensure the well-being of animals.

For food products in general, information is to some extent ensured by the product declaration, which is meant to inform consumers about its individual components. However, for most conventional products, there is no information on the production process, e.g. the use of pesticides, antibiotics etc. An exception is information on animal welfare in the production of e.g. eggs, chicken, pork etc, which is often typed onto the product itself. One way to improve transparency and to summarise the various types of information is to attach a label. Today, there exist many different labels for different kinds of food products, including conventional quality labels. One of the most comprehensive types is the organic label, which incorporates the whole set of principles and regulations for this type of farming, including field management, animal care, environmental care as well as the processing of the products.

Labelling is a means for providing information about various product attributes, and thus, if consumers value these attributes, for increasing sales of the products that bear the label. However, the prerequisites for using labelling as an effective tool are that consumers (1) recognise, (2) understand, and (3) trust the label.

Quality labels attached to conventional food products represent a variety of types and incorporate a very varied amount of information. Consumer knowledge and understanding of these labels is mainly affected by the success of previous marketing strategies. However, in so far as the information is provided by the producers themselves with no additional public control scheme, it can carry the risk of not being trusted.

This also holds for organic products. Since it is impossible for consumers to check the authenticity of such products, it is necessary to build up a control system with clearly defined rules for production methods and the labelling of certified products. Consumer studies suggest that trustworthy labels guaranteeing organic production are very important.[19, 64, 65] The results indicate that clear and unambiguous labelling is an important factor in the buying of organic foods.[19, 64, 66]

Some countries, such as Denmark, Sweden, The Netherlands, France, Germany, Switzerland and Austria have a national organic label. The Danish certification label, which is controlled by the State, is clearly recognised by between 50 and 75 per cent of consumers. Danish consumers have great confidence in this control system, [67-69] and that is one of the reasons why Denmark has probably the highest per capita consumption of organic food in the world.[5] In some countries, however, there are many competing labels. This poses a problem for consumers trying to distinguish pseudo-organic and "environmentally friendly" products from authentic organic products. This has been a problem in Germany

and USA, for example, where consumers have had great difficulty identifying the authenticity of organic products.[70-73]

Information on the origin of food products is of special interest to consumers. In all European countries, consumers prefer products produced within the country.[74] This holds for organic products too, as national products are perceived to be the most trustworthy. Credibility weakens with distance from source, mainly for the following two reasons: firstly, consumers have little confidence in foreign certification and control; and secondly, consumers believe that long transportation distances conflict with the principles underlying organic food production (according to [68, 75, 76]). Origin from foreign countries is, however, a smaller problem when organic foods are distributed through supermarkets, since in this situation consumers are less aware of the origins of the products.[76]

Consumer perceptions of origin may be further narrowed to local production. In some countries (e.g. Germany, The Netherlands, Austria) products bought directly from the farmer or at local markets are considered to be the most trustworthy in the eyes of consumers. Thus, the question of origin is closely related to sales channels. This holds for conventional as well as organic food types.[77-80] For food products purchased in supermarkets, consumers are only given information of the country of origin. Organic certification does not guarantee proximity. Additional information on producer characteristics, e.g. geographical location or production system, can be provided by the producers themselves. However, for both organic and conventional foods such information is not controlled by public authorities.

Consumer influence can be maintained in two ways: firstly, by choosing to buy or not to buy the product, and secondly, to state concerns and interests through consumer councils and organisations. In this regard, there are only a few differences between conventional and organic products. Organic grower organisations often have consumers represented on steering boards etc., ensuring that the development of rules also mirrors consumer concerns. However, these members are often appointed or elected within the organisations themselves, such that full consumer representation may not occur.

Impacts of organic production systems

The safety of the agri-food-system incorporates a lack of negative production impacts on humans and other living organisms, and the environment. In general, the risk of harmful environmental impacts is lower with organic than with conventional farming methods.[24, 25] With regard to soil biology, organic farming is usually associated with a significantly higher level of biological activity (bacteria (*Monera*), fungi (*Mycota*), springtails (*collembola*), mites (*Arachnida*), earthworms (*Lumbricus terrestris*)), due to its versatile crop rotations, reduced applications of nutrients, and the ban on pesticides. In most cases there is also a lower surplus of nutrients and less leaching with organic than with conventional farming. Of particular importance, with organic farming there is no leaching of pesticides to the ground-water.[25]

ORGANIC FARMING AND FOOD SAFETY

Organic principles and regulation

As stated earlier, organic farming can be distinguished from conventional farming by virtue of its special regard for human values, the environment, nature, and animal welfare. Its basic principles provide a platform that ensures high levels of food safety, many of which are based on the precautionary approach. According to these principles, responsibility for future generations demands that the natural basis for life must be preserved, and that irreversible damage must be avoided. In this context, the use of industrially produced pesticides and other environmentally alien compounds it not permitted in organic farming. By virtue of these prohibitions the risk of pesticide contamination in food is minimised. Likewise genetically modified organisms are not permitted. These bans can be considered as an alterna-

tive and more extensive desire for caution and care in our relations with nature than the assessment of risk that underlies the use of, for example, pesticides in conventional agriculture. The regulation of organic farming is meant to ensure that this type of agriculture lives up to its basic principles. To a large extent the regulation of organic farming and processing results in higher levels of food safety in organic products.

Assessment of food safety

There is no undisputable scientific evidence that organic food is healthier than conventional food (e.g. see reviews: [40, 41, 47]), and to our knowledge a review of food safety in relation to organic farming and processing has not been attempted previously. From the perspective of food safety, however, organic food has several advantages over its conventional counter-part. The absence of GMOs from organic food products increases their safety, while the lower concentrations of nitrate in organically produced vegetables and animal products may reduce the risk of cancer by reducing the danger of nitrosamine formation. The ban on pesticides in organic farming also improves safety by guaranteeing the absence of pesticide residues from organic foods. The ban on pesticides and the lower applications of N in organic farming may also increase the occurrence of such secondary compounds as phenols in organic plant products. This may induce higher levels of food safety because some secondary compounds are thought to prevent the onset of cancer. However, a potentially negative outcome of the ban on pesticides is that it could support higher levels of mycotoxins in cereals, rendering them more toxic. Finally, the bans on synthetic fertilisers and growth regulators should increase food safety by reducing the concentrations of heavy metals and the residues of growth regulators in organically grown plant products.

Extended access to out-door areas for organically produced animals could have positive or negative effects on food safety. Safety may be reduced through the higher risk of zoonoses, caused by the transfer of infections from the soil, parasites, rats, mice and birds. In contrast, food safety could be improved by the lower stocking rates and lower infection pressures that tend to neutralise the risk of zoonoses in organic farming. In addition, the compulsory use of roughages may reduce the numbers of harmful intestinal bacteria. Roughages (e.g. grass) are expected to provide higher concentrations of CLAs in organic as compared to conventional milk, thereby increasing food safety by reducing the risks of cancer and arteriosclerosis. The restricted use of medicine in organic animal production improves food safety by lowering the incidence of residues in animal products and reducing the risk of transfer of resistance genes from animals to human pathogens.

Of particular importance, the regulation of processing results in higher product safety in organic foods, due to the 5% limitation on non-organic constituents, and the ban on irradiation, colouring agents, sweeteners, synthetic additives, flavourings, GMOs, and trans fatty acids. With regard to the safety of agri-food-systems (i.e. supply, distribution, transparency, proximity, information, consumer influence, and the lack of negative production impacts), although basic safety principles apply to organic farming in all its forms, these have not been translated into regulations. However, the organic label provides the consumer with more information about the whole production process, thereby indicating higher safety with organic products.

Concerning food supply at the global level there exist two perspectives of sustainability.[84] The resource sufficiency perspective points to a lower level of food safety with organic than with conventional products while the functional integrity perspective shows the opposite. In general, the risk of harmful environmental impacts is lower with organic than with conventional methods, resulting in a higher level of food safety.

RESPONSES TO CHANGES IN FOOD SAFETY

As shown in Fig. 1, the DSIR framework can be used to explain the various aspects of food safety. The driving forces relate to product safety through I) the usage of GMOs, nitrogen, pesticides, fertilisers and growth regulators, II) animal housing, feeding and medical treatment (use of medicine, hormones, out-door areas, feed composition etc.), and III) food processing (additives, technology and specialisation). The driving forces can also link to the safety of the agri-food-system through I) the use of technology, II) the distribution chains, and III) the structural development of agricultural production, processing and marketing. The changes in (or state of) product safety can be identified directly in the food by measuring the content of its constituents. In contrast, the state of safety of the agri-food-system can be assessed by evaluating I) the security of supply and the distribution of agricultural products (sustainable production) and II) the level of transparency, information and consumer influence associated with the type of agricultural product (labels/control). The DSIR framework also incorporates the impact of the state of food safety on human health (disease or health and the impact of production on humans) and the environment and nature (nature conservation, protection of surface and ground-water quality etc.).

These impacts and the state of food safety can produce responses by different groups in society. Firstly the authorities can respond by changing food and agricultural policies, including the regulation of organic farming and food processing, subsidies to farmers, and the move to public staff restaurants. The agri-food industry can also react by the voluntary adoption of standards of safety and quality.

Consumers play a central role in the question of food safety. Clearly, conditions of illness and health in the consumer are influenced by the composition of the diet, even though it may be difficult to identify a direct effect for an individual component or food product. A review of the relevant social science literature reveals that considerable health benefits appear to accrue from the consumption of organic foods due to associated changes in food consumption patterns or diet composition.[26] It is documented that changes in diet composition for "heavy users" of organic foods do occur.[26] For example, there exists a desire among consumers of organic foods to eat fewer meat products and more vegetables for environmental and ethical reasons arising from the demands of sustainable development. The composition of the organic diets of consumers can also have considerable and positive implications for health. This increases the safety of organic products. Consumer perceptions also influence food safety. Psychological and sociological research has established that meals make a very important contribution to the quality of daily life. On this basis it may be assumed that the consumption of organic foods may help to alleviate feelings of insecurity,[26] thereby increasing the perceived safety of organic foods.

Finally, different NGOs may also respond to the state and impact of food safety assessments in organic production. For example, farmer associations and other organisations may change the regulations for farming.

CONCLUSION

In organic farming, holistic ways of thinking have illustrated the need for a broader perception of food safety than is traditionally used. It has been shown that the DSIR framework is a very useful tool for providing a broader understanding of the concept of food safety.

In general, the safety of food is greater with organic than with conventional products. However, various opportunities exist for improving it in both types of farming in the future. It is important to take a precautionary approach to new technologies, in order to reduce their negative effects on humans, the environment and nature. If labelling, control and certification function properly, the attachment of labels to

food products improves food safety; and in this context the organic label has significant advantages. Nevertheless, there are opportunities for improving the organic label, for example by including controlled information about the origin of products. Similarly, organic regulations and food safety could be improved by introducing rules governing the processing, distribution and marketing of organic products. More generally, the safety of food could be improved by raising consumer influence on food production above that dictated by the purse.

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Table 1. Definition of food safety. The definition is broad, including aspects of both product safety and agri-food-system safety.

FOOD SAFETY	
Product safety[1]	**Agri-food-system safety**
• Safety, non-toxicity of the food • Safety, nutritious food • Safety of the declaration (all components of the food are shown on a declaration) • Safety of the label (the organic food is truly organic)	• Safety of supply • Safety of distribution • Safety of transparency and proximity • Safety of consumer influence on food production • Safety of information on the whole food production process (e.g. by using labels) • Safety, no negative impacts of production practices on humans and other living organisms, the environment, climate etc.

1: The traditional definition (e.g. given by the Danish authorities: [21])

Table 2. Effect of lower nitrogen (N) levels on product safety in organic farming (compared to conventional farming). (Modified from [26]).

Constituent	Potential effects on human health	PRODUCT SAFETY IN ORGANIC PRODUCTS				
		Product	Driving force	State: Concentration of constituent	Impact on human health	References
Dry matter	None	Leaf vegetables and potatoes	Lower N-levels than in conventional product	5-40% higher than in conventional product	None	[29-31]
Protein	?	Cereals	Lower N-levels than in conventional product	10-20% lower than in conventional product	None	[33-35]
C-vitamin	?	Vegetables, milk	Lower N-levels than in conventional product	5-90% higher than in conventional product	None	[31, 36, 37]
Carotene	?	Carrots	Lower N-levels than in conventional product	Lower than in conventional product	None	[38]
Nitrate	Carcinogenic (nitrosamines)	Spinach, potatoes, beetroots	Lower N-levels than in conventional product	30-90% lower than in conventional product	Positive	[30, 31, 36, 39]

Table 3. Estimated average pesticide consumption in domestic and foreign food products in Denmark (μg day^{-1}).[42]

Product type	DK	From abroad	Total
Fruit and vegetables	58	104	162
Cereal and cereal products	21	5	27
Animal food products	<1	<1	<1
Fish and fish products	<1	<1	<1
Drinking water	<1	<1	<1
Total	80	110	190

Table 4. Effect of ban on pesticides on product safety in organic farming (compared to conventional farming). (Modified from [26]).

Compounds	Potential effects on human health	PRODUCT SAFETY IN ORGANIC PRODUCTS				
		Product	**Driving force**	**State: Concentration of compounds**	**Impact on human health**	**References**
Pesticide residues	Reproduction, the nervous system and immune system: carcinogenic	Fruit, vegetables, cereals	Ban on pesticides	None or very low concentrations in organic food	Positive, especially for children, pregnancy /embryo	[44-46]
Phenol (flavoler, resveratrol)	Preventive against cancer and cardiovascular disease	Apples and vine	Lower N-levels than in conventional product: Ban on pesticides	Higher than in conventional product	?	[81-82]
Mycotozins (Ochratozin)	Liver, kidney, the nervous system: carcinogenic	Cereals	Bad storage (ban on pesticides)	Higher than in conventional product	Negative	[48]
Mycotozins (aflatoxin)	Liver, kidney, the nervous system: carcinogenic	Milk	? (ban on pesticides)	Absent from organic food (12-25 ppt in conventional.)	Positive	[37]

Table 5. Effect of ban on synthetic fertilisers and growth regulators on product safety in organic plant production (compared to conventional farming). (Modified from [26]).

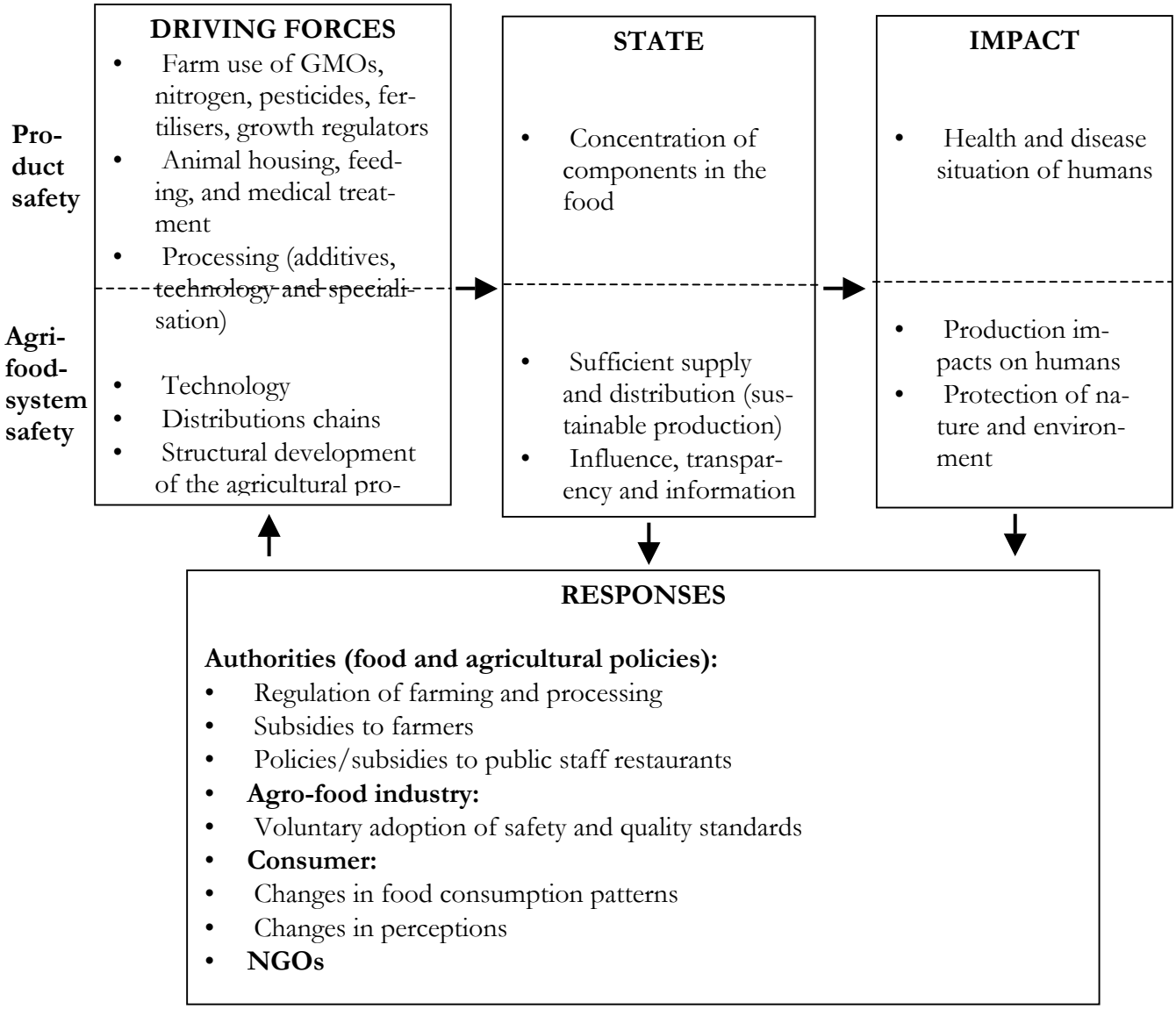
Elements or Compounds	Potential effects on human health	PRODUCT SAFETY IN ORGANIC PRODUCTS				
		Product	Driving force	State: Concentration of elements or compounds	Impact on human health	References
Heavy metals	?	Cereals, carrots, potatoes	Ban on synthetic fertilisers	Same or lower than in conventional products	Positive	[30, 34, 83]
Residues of growth regulators	Reproduction	Cereals	Ban on growth regulators	Not present in organic foods (present in 64 of 77 conventional samples)	Positive	[49]

Table 6. Effect of regulation on product safety in organic animal production (compared to conventional farming). (Modified from [26]).

Compound or organism	Potential effects on human health	PRODUCT SAFETY IN ORGANIC PRODUCTS			
		Driving force	**State: Concentration of compound or organism**	**Impact on human health**	**References**
Conjugated linolic acid (CLA) in milk	Preventive against cancer and arteriosclerosis	More grass fodder	Higher than in conventional product	Positive	[58]
Salmonella, Campylobacter	Infections	Extended use of out-doors areas. Compulsory use of roughages	Lower/higher than in conventional product	Both positive and negative	Ole Heuer pers. com.; Frank Aarestrup, pers. com.; [57]
Medicine residues	Transfer of resistance genes from animals to humans pathogens	Restricted use of medicine, double retention time	Possibly lower than in conventional product	Positive	[61]

Legends:

Fig. 1. The DSIR-framework for understanding different aspects of food safety. (Modified from [22]).


DRIVING FORCES
Product safety
Farm use of GMOs, nitrogen, pesticides, fertilisers, growth regulators
Animal housing, feeding, and medical treatment
Processing (additives, technology and specialisation)
Agri-food-system safety
Technology
Distributions chains
Structural development of the agricultural pro-
STATE
Concentration of components in the food
Sufficient supply and distribution (sustainable production)
Influence, transparency and information
IMPACT
Health and disease situation of humans
Production impacts on humans
Protection of nature and environment
RESPONSES
Authorities (food and agricultural policies):
Regulation of farming and processing
Subsidies to farmers
Policies/subsidies to public staff restaurants
Agro-food industry:
Voluntary adoption of safety and quality standards
Consumer:
Changes in food consumption patterns
Changes in perceptions
NGOs