

Animal health in organic livestock production systems: a review

A. Kijlstra* and I.A.J.M. Eijck

Animal Sciences Group, Wageningen University and Research Centre, P.O. Box 68, NL-1200 AB Lelystad, The Netherlands

* Corresponding author (fax: +31-320-238094; e-mail: aize.kijlstra@wur.nl)

Received 22 September 2005; accepted 2 March 2006

Abstract

Organic livestock production is a means of food production with a large number of rules directed towards a high status of animal welfare, care for the environment, restricted use of medical drugs and the production of a healthy product without residues (pesticides or medical drugs). The intentions of organic livestock production have been formulated by the International Federation of Organic Agriculture Movements (IFOAM) and were further implemented by EU regulation 2092/91 in the year 2000. The consequences of these rules for the health of the animals were not yet fully anticipated at the time these regulations were made and it has become clear that in some cases the rules are not clear enough, thereby even hampering the development of the production system. In this review we shall discuss the implications of these rules for animal health, whereby we shall focus on pig, poultry and dairy production systems. Disease prevention in organic farming is based on the principles that an animal that is allowed to exhibit natural behaviour is not subject to stress, is fed optimal (organic) feed, and will have a higher ability to cope with infections than animals reared in a conventional way. Fewer medical treatments would thus be necessary and if an animal would become diseased, alternative treatments instead of conventional drugs should be preferred. Although homeopathy or phytotherapy are recommended according to prevailing regulations, not many organic farmers use this treatment regimen because of lack of scientific evidence of effectiveness. Important health problems in organic livestock farming are often related to the outdoor access area, exposing the animals to various viral, bacterial and parasitic infections some of which may only influence the animals' own welfare whereas other ones may also endanger the health of conventional livestock (e.g. Avian Influenza) or pose a food safety (*Campylobacter*, *Toxoplasma*) problem to the consumer. Many preventive measures can be taken, such as using better animal breeds, optimized rearing conditions, pre- and probiotics, and addition of acids to the drinking water. In case of infectious disease, tight vaccination schedules may prevent serious outbreaks.

Additional keywords: organic production, homeopathy, infectious disease

Characteristics of organic livestock production

Pressure from society and from within the farming community itself has resulted in a movement towards a system of animal food production that incorporates a better treatment and welfare of the animals, takes care of our resources and environment and at the same time results in products that do not contain unwanted chemical residues. To prevent confusion concerning different brands of organically grown or reared products and to provide a uniform translation of the biological principles, the EU has set up a unique organic food chain that is firmly regulated.

Organic production is regulated throughout the EU by EU regulation (EEC) 2092/91, whereby the animal food production chain came into effect in the year 2000. All member states have to comply with these rules. Some countries, including the Netherlands, have added some rules. In the Netherlands the Ministry of Agriculture has assigned the inspection of compliance with these rules to a separate organization named Skal. This organization also takes care of certification and informs farmers and processors within the food chain about legislation. Certified producers are allowed to use the so-called EKO quality symbol. The EKO prefix (e.g. EKO-pigs; EKO-milk) is legally protected and can only be used after written permission from Skal.

Organic livestock production differs from conventional systems. In organic systems the animals are allowed a larger housing area (including outdoor access), have obligatory straw bedding, and are fed organic feed and roughage (sows). In view of the shortage in supply of organic feeds there is still an allowance to use a certain percentage of conventional feed for a few years (cattle until 31 December 2007; poultry and pigs until 31 December 2011). The use of antibiotics is restricted, the waiting times before delivery of products after medical treatments are longer, weaning periods (pigs) are longer, tail, teeth and beak clipping are prohibited and broiler systems use slower growing breeds. These measures ultimately lead to a product (milk, eggs, meat) obtained from animals grown under higher welfare conditions and containing fewer residues (pesticides, medical drugs) than the products from conventional rearing systems. The organic movement throughout Europe is thus well defined, but its boundaries are not so strict. This has resulted in different types of individual organic farmers, each with their own ideas and practices. This fact should be taken into account when comparing organic livestock systems with conventional ones. The consequences of the EU regulations on organic farming for the health of the animals reared under these conditions are not well known and form the subject of this review paper. We have limited this overview to organic pig, poultry and dairy production systems.

Legislation and animal welfare in organic systems

Disease prevention in organic livestock production is based on the assumption that feeding, housing and care of the animals is such that they have an optimal natural resistance to combat disease. As will be mentioned later there is little scientific evidence today neither to support nor to dismiss this assumption.

In case disease does occur, the EU regulations state the following:

“(a) Phytotherapeutic (e.g. plant extracts (excluding antibiotics), essences, etc.), homeopathic products (e.g. plant, animal or mineral substances) and trace elements and products listed in Part C, section 3 of Annex II, shall be used in preference to chemically synthesised allopathic veterinary medicinal products or antibiotics, provided that their therapeutic effect is effective for the species of animal, and the condition for which the treatment is intended; (b) If the use of the above products should not prove, or is unlikely to be, effective in combating illness or injury, and treatment is essential to avoid suffering or distress to the animal, chemically synthesised allopathic veterinary medicinal products or antibiotics may be used under the responsibility of a veterinarian.”

Interpreting these rules, an organic farmer is inclined to use phytotherapeutic or homeopathic medicines as a first line of treatment and will only use conventional veterinary medicines if the alternative treatments are not effective. Correct interpretation of the EU rules shows that these so-called ‘alternative’ medicines should only be used if their effect has been proven for the species concerned and for the disease the animal is suffering from. As yet insufficient scientifically sound data are available that indicate the therapeutic effects of the agents listed in the directives of the EU regulations (Hammarberg, 2001). Furthermore, it is not clear whether for instance homeopathic drugs that are currently used by organic farmers comply with EU regulations stating that these drugs should be registered (EU regulation 1992/74). In some countries (Sweden) the use of homeopathy to treat diseased animals is forbidden (Hammarberg, 2001). Also in the Netherlands a discussion is going on whether the recognition of veterinary homeopaths should be withdrawn. Analysis of the medicines used by organic livestock farmers shows that not many farmers use alternative or complementary treatments in view of lacking scientific evidence (Kijlstra & Van Der Werf, 2005).

Preventive use of chemically synthesized pharmaceuticals and antibiotics is not allowed in organic farming. The use of hormones, coccidiostatics and other growth or production stimulants is not allowed either. Only a limited number of conventional treatments or treatment courses are allowed per animal per year, with the exception of compulsory treatments implied by law, vaccinations and anti-parasitic treatments. The withdrawal period after the use of a conventional treatment has to be doubled, but in some countries longer waiting times are compulsory.

As mentioned above, the current EU legislation for organic animal farming was implemented in the year 2000. In the meantime it has become clear that a number of subjects are not adequately covered and some even hamper the further development of the organic production system. At present the EU is updating the regulations.

General aspects of diseases and animal welfare in organic livestock

Organic standards offer a good framework for animal health and welfare management. In these fields it is nevertheless necessary to solve certain grey areas among the organic farming objectives (Hovi *et al.*, 2003). A review of the literature by Worthington (1998) states that animals fed organically grown feed showed better growth and repro-

duction than animals fed conventionally grown feed. It is generally assumed that animals have a better immune response towards prevailing pathogens under organic conditions than under conventional conditions but this has not yet been formally proven. Important aspects of organic farming, like genetic background, nutrition, environmental exposure, weaning age and stress may affect the immune response of the animals and should preferably be analysed separately.

Breeding

Disease prevention in organic livestock production is preferably based on the principle that appropriate breeds or strains of animals should be selected. Magnusson (2001) has recently reviewed a number of breeding strategies for improved disease resistance in organic livestock production. These include (1) the recording of disease incidence in the progeny and the selection of parents that produce progeny with the lowest incidences, (2) the use of breeds possessing certain major histocompatibility-complex antigens known to be associated with resistance to certain infections, and (3) the identification of a set or combination of immune parameters crucial for resistance to infections and using parameters with high heritability in breeding programmes. The feasibility of these approaches is hampered in most countries by the small numbers of organic livestock, but also by the fact that including many disease resistance factors in the breeding might result in the loss of productivity. Genetic control of parasitic diseases is an option that has been shown to be operational in sheep (Windon, 1996) and poultry (Gauly *et al.*, 2002). Selection for certain immune response traits relevant to organic farming has not yet been approached but should be feasible since examples from 'regular' farming are available (Edfors-Lilja, 1998).

Feeding

Investigations on the effect of organic feed on immunological defence in organic livestock have not been reported in literature. Nutrition affects the immune status of animals and humans. Almost all nutrients in the diet play a crucial role in maintaining an 'optimal' immune response, such that deficient and excessive intakes can have negative consequences for the immune status and the susceptibility to a variety of pathogens (Field *et al.*, 2002). Zinc, iron and vitamin A deficiencies and protein-energy malnutrition in humans influence the individual's immune status. Several selected nutrients such as glutamine, arginine, fatty acids, vitamins E and C, zinc and selenium have also been shown to affect the immune response. Intestinal nematode parasites have deleterious effects on the host nutritional status, but only recently it was shown that malnutrition in turn may predispose the animal to intestinal nematode infection (Koski & Scott, 2001). As mentioned later in this review, organic feed used in organic livestock production may be deficient in some of the above-mentioned nutrients. Unravelling of the nutrients essential in the immune response against a variety of pathogens encountered in organic livestock production is badly needed.

Outdoor versus indoor housing

As yet only one research group has analysed the effect of outdoor versus indoor housing on the immune status of regular pigs. Kleinbeck & McGlone (1999) showed that pigs reared outdoors had similar serum IgG concentrations in their blood as animals grown indoors. Pigs reared outdoors had lower white blood cell counts and lower Natural Killer cell responses than pigs kept indoors. Pigs raised outdoors had higher neutrophil levels but lower lymphocyte levels than pigs raised indoors. The authors concluded that under the experimental conditions, outdoor pigs showed signs of stress-induced immunosuppression. It is unlikely that the conditions used in these experiments equalled those expected in organic pig production and extrapolation of these data to the effect of organic production systems on the immune status of animals is not valid.

The housing conditions and the access to straw bedding used in organic animal farming might lead to the conclusion that the animals would be less stressed than conventionally kept animals. Stress affects the immune response of both humans and animals (Khansari *et al.*, 1990), but to date the effect of potentially lower stress conditions in organic animal farming on the immune response of the animals has not yet been dissected.

Outdoor rearing of livestock will increase the risk of animals coming into contact with a broad range of environmental pathogens. Whether this results in an infection depends on the infectious load and both the nutritional and immune status of the animal. Below we shall review the available literature on the incidence of infectious disease in organic livestock.

Species-specific aspects of diseases and animal welfare

Characteristic aspects of organic farming that may affect animal health and welfare include (1) outdoor rearing, (2) limited use of curative and preventive conventional medicines, (3) organic feed, and (4) incorporation of biological cycles within the farm. Most aspects will be dealt with in the following species-specific sections. One aspect that will not be dealt with in depth is the fact that the principle of biological cycles, which includes the use of organic manure within a farm, may carry the risk of re-circulating infectious pathogens. Animal manure frequently contains enteric pathogenic micro-organisms and its use as fertilizer for organic crops can lead to pathogen entry into the food chain (Pell, 1997). In veterinary medicine, the prevention of the transfer of infectious diseases, such as parasitic diseases or bacterial diseases (*Listeria monocytogenes*, *Escherichia coli* O157:H7, *Salmonella* spp., and *Mycobacterium paratuberculosis*) is based on the breaking of cycles. The use of manure from farm animals as a fertilizer for crops that are fed to the same animals is a risk that has not yet been addressed. Composting and drying of manure may decrease the number of viable pathogens (Pell, 1997).

Poultry

Animal welfare is an important desired feature of organic livestock production. Several studies have nevertheless indicated severe health problems, e.g. in organic poultry production in Denmark (Thamsborg, 2001). Besides health problems, the risk of zoonotic disease affecting food safety is an issue often mentioned in the literature. In the sections below we shall list the current literature on disease incidence in organic poultry, and wherever possible indicate the factors that are directly related to 'organic' management. We shall also indicate therapies and the effects of feeding and housing systems on poultry health.

Viral infections

No reports are available on comparisons of viral poultry disease prevalence between organic and conventionally reared chickens. Concerns have been expressed about the risk of free-ranging chickens becoming infected with influenza viruses due to contact with wild birds and other animals. The contact with domestic ducks, which may be acting as a silent reservoir for the Avian Influenza virus, may play a role in the transmission of the virus to other poultry, to mammals and to humans as well (Anon., 2004).

Bacterial infections

Providing chickens with access to an outdoor area may increase the risk of poultry becoming infected with *Salmonella* and *Campylobacter* due to contact with wild birds and other animals and their faeces. In a recent review Engvall (2001) mentioned that almost 100% of the organically farmed flocks in Sweden might be infected with *Campylobacter*, compared with only 10% of the conventionally reared flocks. These findings were confirmed in recent Danish and Dutch studies (Heuer *et al.*, 2001; Rodenburg *et al.*, 2004). Rodenburg *et al.* (2004) typed the *Campylobacter* strains and found that in organic broilers 27% was *C. jejuni* and 73% *C. coli*. In conventional broilers about 70% of the strains were *C. jejuni* and 30% were *C. coli*. The Dutch data on *Campylobacter* are different from the Danish ones where no difference in strains was found between organic and conventional systems (Heuer *et al.*, 2001). *C. coli* is only responsible for 7% of human campylobacteriosis cases (Rodenburg *et al.*, 2004). *Campylobacter* is not a direct health problem for chickens.

Recent studies have shown that approximately 80% of the cases of pasteurellosis (*Pasteurella multocida*) in Danish poultry occurred in flocks that had access to outdoor areas (Christensen *et al.*, 1998). *P. multocida* infections may occur as a superinfection in chickens infected with *Ascaris galli* (Dahl *et al.*, 2002).

Prevalence of *Salmonella* in organic poultry systems was recently investigated in the Netherlands (Rodenburg *et al.*, 2004). The incidence of *Salmonella* infections in organic broilers was 13% in 2003, a percentage similar to that found in conventionally reared broilers. In the Netherlands many organic laying-hen farms vaccinate their chickens against *Salmonella* (T. Fiks-Van Niekerk; personal communication).

Parasitic diseases

Outdoor production of poultry poses a higher risk to parasitic infection, which in combination with the rules of organic farming – where preventive antiparasitic control is not allowed – may result in higher parasitic infection levels. Nutritional imbalance due to an insufficient protein balance in organic poultry feed may also lead to a higher susceptibility to parasite infection. Only few of the above raised hypotheses have formally been addressed in the peer-reviewed literature.

Permin *et al.* (1999) carried out a cross-sectional prevalence study of gastrointestinal helminths in Danish poultry production systems on 16 farms during 1994 and 1995. In the free-range/organic systems the following helminths were detected: *Ascaridia galli* (63.8%), *Heterakis gallinarum* (72.5%), *Capillaria obsignata* (53.6%), *Capillaria anatis* (31.9%) and *Capillaria caudinflata* (1.5%). In the deep-litter systems the results were: *A. galli* (41.9%), *H. gallinarum* (19.4%) and *C. obsignata* (51.6%), in the battery cages *A. galli* (5%), *Raillietina cesticillus* and *Choanotaenia infundibulum* (3.3%) were found, in the broiler/parent system *C. obsignata* (1.6%), and in the backyard systems *A. galli* (37.5%), *H. gallinarum* (68.8%), *C. obsignata* (50.0%), *C. anatis* (56.3%) and *C. caudinflata* (6.3%). The authors conclude that there is a higher risk of helminth infections in free-range and backyard systems but prevalence may also be high in deep-litter systems. Such parasite infections can lead to reduced growth rate, weight loss and decreased integrity of the intestinal mucosa, predisposing animals to secondary infections. *A. galli* can function as a vector for *Salmonella* (Chadfield *et al.*, 2001).

Thamsborg (2001) has suggested a number of measures to control parasites, including biological control of helminths by using certain strains of fungi (larvae-trapping fungi, egg-destroying fungi, *Duddingtonia flagrans*), frequent rotation, lower stocking rates or alternate grazing with other species. Further research is needed to validate these concepts. Recently, various research groups (Permin *et al.*, 2001; Gaulty *et al.*, 2002) have shown that resistance to some of these parasites (*A. galli*) is genetically determined and these authors suggest selection of poultry strains based on parasite resistance.

A higher prevalence of *Toxoplasma* infections has been reported in free-ranging chickens but no data are available on the presence of *Toxoplasma* infections in organic chickens (Dubey *et al.*, 2004). *Toxoplasma* does not pose a direct health problem to chickens but is an important food safety issue (Mead *et al.*, 1999).

The prevalence of external parasites like mites is expected to be higher in organic poultry systems than in conventional systems (Permin & Nansen, 1996). A Swedish study showed that *Dermanyssus gallinae* was the only mite present in poultry systems, with high prevalence in deep-litter (33%) and backyard (67%) flocks, compared with only 4% in battery systems (Hoglund *et al.*, 1995). No published data are available on mites in organic poultry systems.

Veterinary medicine, alternative therapies and vaccinations

Vaccination of young 'conventionally derived' pullets is a strategy to prevent infection in chickens that are later transferred to an 'organic' system. These include standard vaccinations against Marek's disease, avian encephalitis and infectious bronchitis

(Berg, 2001). In Sweden, organic egg producers buy their pullets from a conventional farm when the animals are 16 weeks old. After a transition period of 6 weeks the eggs are sold as 'organic'. Coccidiosis for instance can be prevented by vaccination of these young pullets that are later used for organic egg production. The use of GMO-based vaccines is under discussion, whereby the EU rules allow these types of vaccine if no alternatives are available.

No published data are available on differences in the use of therapeutic drugs between conventional and organic poultry systems. As in other organic animal husbandry systems it has been argued whether the increased withdrawal periods and the risk of losing the 'organic' status of a treated animal may not lead to an under-treatment of sick animals thereby leading to needless suffering.

Feeding, housing systems and poultry health

Synthetic amino acids or vitamins are not allowed in organic poultry feed, which can result in a nutritional imbalance leading to increased disease susceptibility and behavioural problems like cannibalism and feather picking (Damme, 2000; Berg, 2001).

Such unwanted behaviour may also be expressed by poultry kept in loose-housing systems. A questionnaire sent out to Swedish organic egg producers showed that almost half of the farmers reported cannibalism or feather picking (Berg, 2001). These problems are not specific to 'organic' management but are also observed in conventional systems with loose housing. Factors involved in this type of behaviour include genetic aspects, housing environment, feed composition and the presence of external parasites (Savory, 1995; Berg, 2001; Bestman & Wagenaar, 2003). In Denmark the Animal Ethics Council has previously (1996) concluded that extreme feather picking is unacceptable. Organic egg producers have noted that severe outbreaks of cannibalism could be handled by changing from a brown hybrid to a white hybrid (Berg, 2001). Studies from the Netherlands have shown that stimulation of the use of the outdoor run can reduce feather picking (Bestman & Wagenaar, 2003).

Keutgen *et al.* (1999) studied gross pathologic and histologic changes in animals from free-range stocks, deep-litter stocks, and from caging systems. Pododermatitis, deformation of the keel bone and amputated beaks occurred primarily in free-range hens. Also deep-litter hens suffered from pododermatitis, keel bone deformation and amputated beaks in addition to pecking wounds. Caged hens showed severe fatty liver syndromes, injuries of the claws and inflammation of the feather follicles. Injuries and fractures due to handling and transport were almost exclusively found in caged hens, indicating that loose-housed poultry have improved bone strength (Berg, 2001).

Pigs

Organic pig production is of major benefit to the welfare of pigs because of the larger living areas per pig, the later age (7 weeks) at which piglets are weaned and the animals' access to an outdoor area. The latter change in housing may predispose animals to various infectious micro-organisms, normally no longer present indoors because of the strict hygienic measures that are taken. Especially parasitic infections have increased in organic swine production systems. In the sections below we shall sum-

marize current data published in the peer-reviewed literature on respiratory problems, gastrointestinal problems, claw and skin problems, piglet mortality, amino acid imbalance, phosphorus intake and parasites, in combination with personal experience.

Respiratory problems

A small study of Feenstra (2000), who evaluated pulmonary health on four organic pig farms, showed that lung health was generally good with the exception of one herd with acute pleuropneumoniae of multifactorial origin. Serological screening showed positive results for *Mycoplasma hyopneumoniae* in all four herds. Serotypes 6 and 12 of *Actinobacillus pleuropneumoniae* were found in two and three herds, respectively, whereas serotypes 2, 5, and 7 were not detected. Antibodies to Porcine Reproductive and Respiratory Syndrome virus were found in three herds. Data from Austria obtained at slaughter indicate that pulmonary health was better in organic pigs than in regular pigs (Baumgartner *et al.*, 2003). The Austrian study showed that 24% of organic pigs displayed pneumonic lesions at slaughter. In the Netherlands in the years 2001 and 2002, pneumonia was detected in 19.2% of 'organic' slaughter pigs compared with 4.5% in regular pigs (J. Kampshof, personal communication). Further studies in 2003 showed that *Mycoplasma hyopneumoniae* could be one of the causes of pneumonia, and avoiding the mixing of groups of pigs or the relocation of animals from the sick bay might play an important role in decreasing the lung problems on organic pig farms (M. Mul, personal communication).

The obligatory use of straw bedding in swine household management may lead to higher dust and bioaerosol levels in pigsties. Endotoxin levels may increase from 40 ng endotoxin per mg dust to 80 ng endotoxin per mg dust when straw bedding is used in the pigsty. At the same time also the absolute amount of dust increases dramatically, leading to very high respirable endotoxin levels (N. Stockhofe and A.J.A. Aarnink, personal communication). Strategies to decrease the amount of dust during straw chopping include the use of lignosulfate (Breum *et al.*, 1999), but it remains to be seen whether this treatment complies with the rules of organic farming. The pig lung is extremely sensitive to endotoxin (Olson *et al.*, 1995) and levels of endotoxin in bioaerosols in livestock buildings where chopped straw is used, may well lead to pulmonary problems.

Gastrointestinal problems

Small-scale Danish studies have shown that neonatal diarrhoea was uncommon in organic pig production, possibly due to routine vaccination with *Clostridium perfringens* and *C. enteritis* (Feenstra, 2000). Austrian studies, however, revealed diarrhoea in 30% of the finishing pigs (Baumgartner *et al.*, 2003). Comparison of homeopathy with conventional antibiotic treatment and a placebo showed that homeopathy was not effective in the treatment of post-weaning diarrhoea (Eijck & Binnendijk, 2003).

Claw and skin problems

Vaerst *et al.* (2000) noted that physical injuries causing lameness, skin traumas and sunburn were prominent findings in sows in an on-farm study performed in Denmark whereby four organic herds were studied. Damage to the outdoor area due to driving

resulted in deep tracks, causing injuries to the animals when walking. Skin traumas were considered an important cause of death in piglets (Vaarst *et al.*, 2000). Analysis of claw and skin problems at slaughter in the Netherlands did not reveal differences between conventional and organic pigs (J. Kampshof, personal communication).

Piglet mortality

High piglet mortality has been observed in organic swine herds but exact figures were not published (Vaarst *et al.*, 2000). Detailed analysis of the causes of pig mortality in one herd revealed that trauma due to crushing was the major cause (65%) of death (Feenstra, 2000). Data from the Dutch Organic Pig farming group (Biovar) for the year 2001 showed a markedly higher mortality of piglets until weaning in organic (mean 21%; range 14–39%) than in conventional (mean 12.7%) systems (J. Kampshof & M. Steverink, personal communication). Piglet mortality after weaning was 4.9% (range 0.6–11.2%) on organic compared with 2.2% on conventional farms (Kampshof & Steverink, 2001).

Amino acid imbalance

Organic feedstuffs may be insufficient to meet the protein requirements for growing pigs, leading to amino acid imbalance, growth retardation, susceptibility to disease and increased pollution due to excretion of excess amino acids (Jongbloed & Lenis, 1992). Since synthetic amino acids are not allowed under the organic rules a search has been started for plant foods with high protein levels. Sundrum *et al.* (2000) carried out experiments with growing pigs, using alternative sources of protein such as peas, lupines and faba beans. Three organic barley/wheat-based diets were compared with an isocaloric conventional diet supplemented with synthetic amino acids. Protein sources in the organic diets were either (1) faba beans, supplemented with potato protein to the same amino acid level as the control diet, (2) peas and lupines, or (3) faba beans and lupines. Diets (2) and (3) were not supplemented leading to a lower level of amino acids. The organic diets with potato protein showed the same performance as the conventional diet supplemented with synthetic amino acids, although crude protein levels differed markedly. Pigs fed an organic diet in the absence of amino acid supplementation showed reduced performance (growth and food intake) compared with pigs fed a conventional diet or an organic diet supplemented with amino acids. The latter treatment resulted in an increase in intramuscular fat content, which is considered a negative eating quality characteristic. These findings are in agreement with earlier studies showing that amino acid-deficient diets can produce substantial increases in intramuscular fat levels (Sundrum, 2005). Digestibility of protein from legumes may be enhanced by removal of anti-nutritional factors, which also leads to a better nitrogen utilization (Jongbloed & Lenis, 1992). Currently, various groups in Europe are developing varieties of legumes that have little or no problems with anti-nutritional factors.

Phosphorus intake

Pigs need phosphorus for general metabolism and formation of the skeleton. One third of the phosphorus in plant feed diets is available as inorganic phosphate, the

rest is present in an organic form bound to phytic acid (Kemme *et al.*, 1997). The latter phosphorus can be released by the enzyme phytase, present in wheat and barley. Heating of the diets, however, leads to the destruction of the plants' phytase and conventional diets thus contain supplemented bacterial phytase. This supplementation is not allowed in organic farming. As yet it is not known whether phytase levels in organic feed are sufficient to allow optimal utilization of organic phosphorus thereby also leading to less environmental pollution.

Parasites

Borgsteede & Jongbloed (2001) reviewed the literature on the risks of parasitic diseases in outdoor pig rearing. They have drawn attention to an increased incidence of *Ascaris suum* infection in pigs reared outdoors as evidenced by a strong increase of livers displaying so-called 'white spots'. No evidence is available for a possible increase in the incidence of *Sarcoptes scabiei* infections. The incidence of *Toxoplasma gondii* in pigs reared outdoors significantly increased compared with conventionally reared pigs where no infected pigs could be detected (Kijlstra *et al.*, 2004a). Access of cats to the farm premises, the use of compost and goat whey, and inappropriate rodent control were identified as possible risk factors that should be addressed (Kijlstra *et al.*, 2004b).

Data on parasitic infections found in former days when pigs were kept outside, like *Hyostrongylus rubidus*, *Strongyloides ransomi*, *Oesophagostomum* and *Trichuris suis*, have not yet been reported as re-emerging infections in organic pig systems. Some of these infections are quite common in wild swine (*Sus scrofa* L.) and pig farms bordering areas where wild swine is present may contract infections via transfer from these areas.

Carstensen *et al.* (2002) recently investigated parasitic infections in nine organic pig herds in Denmark. They measured faecal excretion (weaners, fatteners and sows) and pasture contamination by parasite eggs or larvae between March and October 1999. The following results were obtained: *Ascaris suum* (28% of weaners, 33% of fatteners, 4% of sows), *Trichuris suis* (4% of weaners, 13% of fatteners, <1% of sows) and *Oesophagostomum* spp. (5% of weaners, 14% of fatteners, 20% of sows). No infections with *Hyostrongylus rubidus*, *Metastrongylus* spp. or *Strongyloides ransomi* were detected. None of the pigs showed clinical signs of scabies or lice.

Analysis of soil samples in the above study revealed very few *Trichuris* eggs, whereas *Ascaris* eggs were observed in 14% of the soil samples from sow pastures and in 35% of the soil samples from slaughter-pig pastures. The first infective eggs were recorded in July and the largest number in August. Infective *Oesophagostomum* larvae were found in increasing numbers in the grass samples taken from May to October. Exceptionally high parasite infection levels in a few of these Danish herds could be ascribed to herd management procedures.

Important management procedures to prevent parasitic infection as suggested by Carstensen *et al.* (2002) include the following:

1. Start organic pig production with helminth-free sows, i.e., animals originating from intensive indoor herds and pre-treated with anthelmintics.
2. Keep the accumulation and transmission of helminth eggs/larvae at a minimum by using a low stocking rate.

3. Maintain a strict pasture rotation and avoid permanent pastures as well as pigsties with low hygiene.
4. If clinical infections do occur, the pigs should be treated with anthelmintics and transferred to clean areas.

Even higher parasite infection prevalence than observed in Denmark was reported in a recent study from the Netherlands, which further showed more helminth infections on pig farms with outdoor facilities than on conventional farms (Eijck & Borgsteede, 2005). Similar findings were also reported from Austria (Baumgartner *et al.*, 2003).

Research is needed on the prevention of parasitic infections of organic pigs, including disinfection strategies, genetic predisposition and novel plant-derived anthelmintics (Waller *et al.*, 2001).

Dairy cattle

Herd health problems on organic dairy farms are similar to those seen on conventional farms. Main problems in descending order are: mastitis, fertility disorders and hoof diseases, whereas metabolic disorders such as acetoaemia and milk fever are less frequent (Krutzinna *et al.*, 1995). Below, problems with mastitis, bacteria and parasites as well as the veterinary treatment of organic dairy herds are discussed.

Mastitis

Mastitis, one of the diseases routinely treated with antibiotics, may pose an important problem in health management of organic dairy herds. No differences in the incidence of mastitis or somatic cell counts were reported in a Danish study whereby 27 organic and 57 conventional herds were compared (Vaarst & Bennedsgaard, 2001). A Norwegian study showed that the incidence of mastitis was lower in organic ($n = 31$) than in conventional ($n = 93$) herds but no differences were observed in the milk somatic cell counts (Hardeng & Edge, 2001). In this study, also ketosis and milk fever were less common in organic than in conventional herds. Several explanations were suggested by the authors, including a different attitude and disease management resulting in lower disease reporting in organic dairy farming, higher skill and performance of organic farmers or an inherent positive property of organic husbandry towards animal health (see also Sundrum, 2001). Subclinical mastitis as evidenced by high milk cell counts seems to be more prevalent in organic dairy herds than in conventional herds (Hovi *et al.*, 2003). Within the current regulations, organic farmers can cope with mastitis because a cow can receive two conventional treatments per year and the treatment of a disease episode of mastitis is seen as one treatment procedure.

Comparisons of other disorders such as milking fever, infertility, metabolic diseases and lameness between conventional and organic dairy herds are contradictory (Hovi *et al.*, 2003). No major health problems have been noted among organic beef producers (Nielsen *et al.*, 2002).

Bacteria

To date no studies have been published on comparative studies between conventional and organic dairy herds with relation to the incidence of certain bacterial infections. In

the Netherlands a study was recently carried out whereby the risk factors and prevalence of paratuberculosis was evaluated (Kijlstra, 2005). Despite a higher risk to contract paratuberculosis due to farm management, the actual number of infected farms (36%) or animals (1.4%) in the Netherlands is not different between organic and conventional farms. Organic farmers mainly differed from conventional farmers in their calf management. Since young animals are extremely susceptible to becoming infected, prevention starts at the time of calving. Farmers are advised to use separate clean rooms for calving and to separate the calves from their mothers immediately after birth. Calves are allowed to drink colostrum (collected by the farmer) from their own mother but should not drink raw milk. Raw milk from infected cows can harbour the bacterium but can also be contaminated with small amounts of faeces. In the study mentioned above, organic farmers differed from conventional farmers in that a lower percentage of organic farmers use a separate space for calving. Only 20% of organic farmers remove their calves from the mother after birth, compared with 45% for conventional farmers. Comparing management of calves until weaning showed that 50% of the conventional farmers feed their calves with artificial milk against only 4% of the organic farmers. The results of calf management after weaning showed that more organic farmers than conventional farmers keep their animals on grassland used earlier that season by cattle or goats. Organic farmers are also less strict as to allowing their calves on pastures that have been fertilized the same season with cattle or goat manure. On the interviewed organic farms the calves come into contact with cattle older than two years more often than on conventional farms. Furthermore, organic farmers more often buy animals from a farm with an unknown paratuberculosis status and often use manure from other farms (with unknown paratuberculosis status).

Parasites

Since the prophylactic use of antihelminthics is not allowed in organic dairy production management of parasite infection may be a problem. A Swedish study indeed reported a high incidence of lung worms (*Dictyocaulus viviparus*) in organic calves (Hoglund *et al.*, 2001). Grazing management incorporating varying grass pasture species, forage crops containing condensed tannins, and rotation may offer a challenge towards a system whereby parasites can be controlled without the use of antihelminthics (Niezen *et al.*, 1996).

Veterinary treatment of herds

Only few studies have been reported about clinical trials in organic dairy herds. A double-blind, placebo-controlled clinical trial of a homeopathic treatment of neonatal calf diarrhoea showed no clinically or statistically significant difference between the two groups (De Verdier *et al.*, 2003). Calves treated with Podophyllum had an average of 3.1 days of diarrhoea compared with 2.9 days for the placebo group. The authors concluded that their results support the widely held opinion that scientific proof for the efficacy of veterinary homeopathy is lacking and that such treatments may cause a considerable risk for animal welfare. A small study in Norway, comparing homeopathic with antibiotic and placebo treatment of clinical mastitis did not show an efficacious effect of homeopathy compared with the placebo group (Hektoen *et al.*, 2004).

Conclusions

Organic livestock production differs from conventional systems in many respects:

1. Animals are allowed a larger housing area (including outdoor access) and straw bedding.
2. Animals are fed organic feed.
3. There is a restricted use of antibiotics.
4. Preventive medical treatments are not allowed.
5. Prolonged waiting times before delivery of products after medical treatments.
6. Longer weaning periods (pigs), no tail, teeth or beak clippings.
7. Slower growing breeds are used (broilers).

These measures ultimately lead to a product (milk, eggs, meat) obtained from animals grown under higher welfare conditions whereby the product contains lesser residues (pesticides, medical drugs) compared with conventional rearing systems. The effects of organic livestock production on the health of the animals not being well known were the motive for this review paper.

The principle that organically held animals are in a better condition concerning their health than conventionally held animals has not yet been proven. Well-controlled studies are needed to show the effects of organically held animals on innate and adaptive immune responses and disease susceptibility.

The conditions in organic livestock production lead to novel challenges concerning social interactions, physical requirements, climatic conditions and infectious burden, which require certain breeds of animals that may differ considerably from the conventionally held animals. More research is needed to identify these breeds whereby selection criteria specific for organic conditions and principles should be used.

Important health problems like infestation with parasites have been noted in organic poultry and pig production. Outdoor access is recognized as an important predisposing factor but as yet little is known how to prevent and treat these infections. Although widely recommended, homeopathy does not have any demonstrated efficacy in managing helminths and the use of herbs is still in its infancy. A multidisciplinary approach is needed to address these questions. Investigations should deal with aspects such as rotation, stocking density, disinfection strategies, genetic predisposition and novel (plant derived or biological) antihelminthics.

Compared with organic poultry and pig production, organic dairy farming is not confronted with major health issues that are related to the organic principles. Mastitis is still a frequent problem in organic dairy production where its prevalence is not largely different from conventional herds. Although the (theoretical) risks of contracting paratuberculosis are higher on organic farms, actual measurement of the serology of organic herds showed that its prevalence was similar to that in conventional herds.

More knowledge is needed on the effects of alternative treatments in organic livestock production. As long as alternative treatments have not formally been proven to be effective, conventional treatments should be preferred. Studies are needed on the welfare aspects of disease and insufficient or postponed treatment in organic animal production systems.

Organic livestock production and other farming systems with outdoor runs can

lead to an increase or re-emergence of certain zoonotic diseases (*Campylobacter*, *Toxoplasma*). Consumers regard organic products to be healthier than conventional foods. To ensure food safety of organic products, further research on the prevalence of certain zoonotic infections, risk factors, farm management, post slaughter decontamination and consumer perception/education is badly needed.

Biological cycles such as the utilization of manure from organic farms may potentially lead to the creation and cycling of infectious micro-organisms. Current veterinary medicine tries to prevent disease by breaking cycles of material or animals that contain infectious micro-organisms. Research is needed to further describe this risk and strategies should be devised to attack this problem.

Little is known about the role of pests in the occurrence of disease in organic livestock production. Research is needed on the efficacy of alternative pest control strategies since current pest control methods are not in agreement with organic production principles (e.g. use of anticoagulants for rodent control).

The obligatory use of straw bedding in pig household management leads to higher dust and bioaerosol (endotoxin) levels in pigsties. This may affect susceptibility to lung disease (farmer and animal) and investigations into measures to reduce dust and bioaerosol levels are needed. Current literature on this subject is not concordant and true differences may exist between management systems from different countries.

Piglet mortality is an important problem in organic production systems and research on genetic and housing aspects is currently done but not yet reported in the peer-reviewed literature.

Amino acid imbalance and research into novel feed sources with a high protein content is needed. More knowledge is required on possible anti-nutritive factors in these feeds and the effects of these new nutrients on gut health of the animals.

References

- Anonymous, 2004. Laboratory Study of H5N1 Viruses in Domestic Ducks: Main Findings. WHO Report <http://www.who.int/csr/disease/avian_influenza/labstudy_2004_10_29/en/> Accessed 1 March 2006.
- Baumgartner, J., T. Leeb, T. Gruber & R. Tiefenbacher, 2003. Husbandry and animal health on organic pig farms in Austria. *Animal Welfare* 12: 631–635.
- Berg, C., 2001. Health and welfare in organic poultry production. *Acta Veterinaria Scandinavica, Supplementum* 95: 37–45.
- Bestman, M.W.P. & J.P. Wagenaar, 2003. Farm level factors associated with feather pecking in organic laying hens. *Livestock Production Science* 80: 133–140.
- Borgsteede, F.H.M. & A.W. Jongbloed, 2001. Organic pig farming: what about parasitic infections? *Tijdschrift voor Diergeneeskunde* 126(2): 39–42.
- Breum, N.O., B.H. Nielsen & M. Lyngbye, 1999. Dustiness of chopped straw as affected by lignosulfonate as a dust suppressant. *Annals of Agricultural and Environmental Medicine* 6: 133–140.
- Carstensen, L., M. Vaarst & A. Roepstorff, 2002. Helminth infections in Danish organic swine herds. *Veterinary Parasitology* 106: 253–264.
- Chadfield, M., A. Permin, P. Nansen & M. Bisgaard, 2001. Investigation of the parasitic nematode

- Ascaridia galli* (Shrank 1788) as a potential vector for *Salmonella enterica* dissemination in poultry. *Parasitology Research* 87: 317–325.
- Christensen, J.P., H.H. Dietz & M. Bisgaard, 1998. Phenotypic and genotypic characters of isolates of *P. multocida* obtained from backyard poultry and from two outbreaks of avian cholera in avifauna in Denmark. *Avian Pathology* 27: 373–381.
- Dahl, C., A. Permin, J.P. Christensen, M. Bisgaard, A.P. Muhairwa, K.M.D. Petersen, J.S.D. Poulsen & A.L. Jensen, 2002. The effect of concurrent infections with *Pasteurella multocida* and *Ascaridia galli* on free range chickens. *Veterinary Microbiology* 86: 313–324.
- Damme, K., 2000. Nutritional requirements of poultry of different genetic background: possibilities and limits in biofarms. *Tierärztliche Praxis Ausgabe Grosstiere Nutztiere* 28: 289–292.
- De Verdier, K., P. Ohagen & S. Alenius, 2003. No effect of a homeopathic preparation on neonatal calf diarrhoea in a randomised double-blind, placebo-controlled clinical trial. *Acta Veterinaria Scandinavica* 44: 97–101.
- Dubey, J.P., H. Salant, C. Sreekumar, E. Dahl, M.C. Vianna, S.K. Shen, O.C. Kwok, D. Spira, J. Hamburger & T.V. Lehmann, 2004. High prevalence of *Toxoplasma gondii* in a commercial flock of chickens in Israel, and public health implications of free-range farming. *Veterinary Parasitology* 121: 317–322.
- Edfors-Lilja, I., E. Wattrang, L. Marklund, M. Moller, L. Andersson-Eklund, L. Andersson & C. Fossum, 1998. Mapping quantitative trait loci for immune capacity in the pig. *Journal of Immunology* 161: 829–835.
- Eijck, I.A.J.M. & G. Binnendijk, 2003. Homeopathic Treatment of Weaning Diarrhoea in Piglets not (yet) Ready for Veterinary Practice. <<http://www.biofoon.nl/biobieb/PraktijkKompas/200307020021.pdf>> (in Dutch)
- Eijck, I.A.J.M. & F.H.M. Borgsteede, 2005. A survey of gastrointestinal pig parasites on free-range, organic and conventional pig farms in the Netherlands. *Veterinary Research Communications* 29: 407–414.
- Engvall, A., 2001. May organically farmed animals pose a risk for Campylobacter infections in humans? *Acta Veterinaria Scandinavica, Supplementum* 95: 85–87.
- Feenstra, A., 2000. A Health Monitoring Study in Organic Pig Herds. Darcof Report 2/2000, pp. 107–112. <http://www.darcof.dk/publication/rapport/dar_2.pdf>
- Field, C.J., I.R. Johnson & P.D. Schley, 2002. Nutrients and their role in host resistance to infection. *Journal of Leukocyte Biology* 71: 16–32.
- Gauly, M., C. Bauer, R. Preisinger & G. Erhardt, 2002. Genetic differences of *Ascaridia galli* egg output in laying hens following a single dose infection. *Veterinary Parasitology* 103: 99–107.
- Hammarberg, K.E., 2001. Animal welfare in relation to standards in organic farming. *Acta Veterinaria Scandinavica, Supplementum* 95: 17–25.
- Hardeng, F. & V.L. Edge, 2001. Mastitis, ketosis, and milk fever in 31 organic and 93 conventional Norwegian dairy herds. *Journal of Dairy Science* 84: 2673–2679.
- Hektoen, L., S. Larsen, S.A. Odegaard & T. Loken, 2004. Comparison of homeopathy, placebo and antibiotic treatment of clinical mastitis in dairy cows - methodological issues and results from a randomized-clinical trial. *Journal of Veterinary Medicine Series A* 15: 439–446.
- Heuer, O.E., K. Pedersen, J.S. Andersen & M. Madsen, 2001. Prevalence and antimicrobial susceptibility of thermophilic Campylobacter in organic and conventional broiler flocks. *Letters in Applied Microbiology* 33: 269–274.
- Hoglund, J., H. Nordenfors & A. Uggla, 1995. Prevalence of the poultry red mite, *Dermanyssus*

- gallinae*, in different types of production systems for egg layers in Sweden. *Poultry Science* 74: 1793–1798.
- Hoglund, J., C. Svensson & A. Hessel, 2001. A field survey on the status of internal parasites in calves on organic dairy farms in southwestern Sweden. *Veterinary Parasitology* 99: 113–128.
- Hovi, M., A. Sundrum & S.M. Thamsborg, 2003. Animal health and welfare in organic livestock production in Europe: current state and future challenges. *Livestock Production Science* 80: 41–53.
- Jongbloed, A.W. & N.P. Lenis, 1992. Alteration of nutrition as a means to reduce environmental pollution by pigs. *Livestock Production Science* 31: 75–94.
- Kampshof, J. & M. Steverink, 2001. Year Results Biovar Study Group 2001. <<http://www.platformbiologica.nl/varkens/>> Accessed 6 December 2004. (in Dutch)
- Kemme, P.A., A.W. Jongbloed, Z. Mroz & A.C. Beynen, 1997. The efficacy of *Aspergillus niger* phytase in rendering phytate phosphorus available for absorption in pigs is influenced by pig physiological status. *Journal of Animal Science* 75: 2129–2138.
- Keutgen, H., S. Wurm & S. Ueberschar, 1999. Pathologic changes in end-of-lay hens with regards to different housing systems. *Deutsche Tierärztliche Wochenschrift* 106: 127–133.
- Khansari, D.N., A.I. Murgo & R.E. Faith, 1990. Effects of stress on the immune-system. *Immunology Today* 11: 170–175.
- Kijlstra, A., O.A. Eissen, J. Cornelissen, K. Munniksmä, I. Eijck & T. Kortbeek, 2004a. *Toxoplasma gondii* infection in animal-friendly pig production systems. *Investigative Ophthalmology and Visual Science* 45: 3165–3169.
- Kijlstra, A., 2005. No difference in paratuberculosis seroprevalence between organic and conventional dairy herds in the Netherlands. In: M. Hovi, J. Zastawny & S. Padel (Eds), *Enhancing Animal Health Security and Food Safety in Organic Livestock Production*. Proceedings of the 3rd SAFO Workshop, 16–18 September 2004, Falenty. University of Reading, Reading, pp. 51–56.
- Kijlstra, A. & J. Van Der Werf, 2005. Analysis of disease prevalence and medical treatments in organic dairy herds in the Netherlands. In: M. Hovi, M. Walkenhorst & S. Padel (Eds), *Systems Development: Quality and Safety of Organic Livestock Products*. Proceedings of the 4th SAFO Workshop, 17–19 March 2005, Frick. University of Reading, Reading, pp. 157–164.
- Kijlstra, A., B.G. Meerburg & M.F. Mul, 2004b. Animal-friendly production systems may cause re-emergence of *Toxoplasma gondii*. *NJAS – Wageningen Journal of Life Sciences* 52: 119–132.
- Kleinbeck, S.N. & J.J. McGlone, 1999. Intensive indoor versus outdoor swine production systems: genotype and supplemental iron effects on blood hemoglobin and selected immune measures in young pigs. *Journal of Animal Science* 77: 2384–2390.
- Koski, K.G. & M.E. Scott, 2001. Gastrointestinal nematodes, nutrition and immunity: breaking the negative spiral. *Annual Review of Nutrition* 21: 297–321.
- Krutzinna, C., E. Boehncke & H.J. Herrmann, 1996. Organic milk production in Germany. *Biological Agriculture & Horticulture* 13: 351–358.
- Magnusson, U., 2001. Breeding for improved disease resistance in organic farming – possibilities and constraints. *Acta Veterinaria Scandinavica, Supplementum* 95: 59–61.
- Mead, P.S., L. Slutsker, V. Dietz, L.F. McCaig, J.S. Bresee, C. Shapiro, P.M. Griffin & R.V.O. Tauxe, 1999. Food-related illness and death in the United States. *Emerging Infectious Diseases* 5: 607–625.
- Nielsen, B. & S.M. Thamsborg, 2002. Dairy bull calves as a resource for organic beef production: a farm survey in Denmark. *Livestock Production Science* 75: 245–255.
- Niezen, J.H., W.A. Charleston, J. Hodgson, A.D. Mackay & D.M. Leathwick, 1996. Controlling internal parasites in grazing ruminants without recourse to anthelmintics: approaches, experiences and

- prospects. *International Journal for Parasitology* 26: 983–992.
- Olson, N.C., P.W. Hellyer & J.R. Dodam, 1995. Mediators and vascular effects in response to endotoxin. *British Veterinary Journal* 151: 489–522.
- Pell, A. N. 1997. Manure and microbes: public and animal health problem? *Journal of Dairy Science* 80: 2673–2681.
- Permin, A. & P. Nansen, 1996. Parasitological problems in organic poultry production. Beretning Fra Statens Husdyrbrugsforsog No 729, Danish Institute of Animal Science, Tjele, pp. 91–96. (in Danish)
- Permin, A. & H. Ranvig, 2001. Genetic resistance to *Ascaridia galli* infections in chickens. *Veterinary Parasitology* 102: 101–111.
- Permin, A., M. Bisgaard, F. Frandsen, M. Pearman, J. Kold & P. Nansen, 1999. Prevalence of gastrointestinal helminths in different poultry production systems. *British Poultry Science* 40: 439–443.
- Rodenburg, T.B., M.C. Van Der Hulst-Van Arkel & R.P. Kwakkel, 2004. *Campylobacter* and *Salmonella* infections on organic broiler farms. *NJAS – Wageningen Journal of Life Sciences* 52: 101–108.
- Savory, C.J., 1995. Feather pecking and cannibalism. *World Poultry Science Journal* 51: 215–219.
- Staiger, D., 1986. The Influence of Conventional and Biologically/Dynamically Developed Feeds on Fertility, All Around Health and Meat Quality in Domestic Rabbits. Inaugural address University of Bonn, Faculty of Agriculture, Bonn, 146 pp. (in German)
- Sundrum, A., 2001. Organic livestock farming – A critical review. *Livestock Production Science* 67: 207–215.
- Sundrum, A., 2005. Carcass yield and meat quality of organic pig production. In: M. Hovi, M. Walkenhorst & S. Padel (Eds), *Systems Development: Quality and Safety of Organic Livestock Products*. Proceedings of the 4th SAFO Workshop, 17–19 March 2005, Frick. University of Reading, Reading, pp. 77–86.
- Sundrum, A., L. Butfering, M. Henning & K.H. Hoppenbrock, 2000. Effects of on-farm diets for organic pig production on performance and carcass quality. *Journal of Animal Science* 78: 1199–205.
- Thamsborg, S.M., 2001. Organic farming in the Nordic countries – animal health and production. *Acta Veterinaria Scandinavica, Supplementum* 95: 7–15.
- Vaarst, M. & T.W. Bennedsgaard, 2001. Reduced medication in organic farming with emphasis on organic dairy production. *Acta Veterinaria Scandinavica, Supplementum* 95: 51–57.
- Vaarst, M., A. Roepstorff, A. Feenstra, P. Høgedal, V.A. Larsen, H.B. Lauritsen & J.E. Hermansen, 2000. Animal Health and Welfare Aspects of Organic Pig Production. Darcoff Report No 2/2000, pp. 77–78. <http://www.darcof.dk/publication/rapport/dar_2.pdf>
- Waller, P.J., G. Bernes, S.M. Thamsborg, A. Sukura, S.H. Richter, K. Ingebrigtsen & J. Hoglund, 2001. Plants as de-worming agents of livestock in the Nordic Countries: historical perspective, popular beliefs and prospects for the future. *Acta Veterinaria Scandinavica* 42: 31–44.
- Windon, R.G., 1996. Genetic control of resistance to helminths in sheep. *Veterinary Immunology and Immunopathology* 54: 245–254.
- Worthington, V., 1998. Effect of agricultural methods on nutritional quality: a comparison of organic with conventional crops. *Alternative Therapies in Health and Medicine* 4: 58–69.