ELSEVIER

Veterinary Parasitology 106 (2002) 253–264

veterinary parasitology

www.elsevier.com/locate/vetpar

Helminth infections in Danish organic swine herds

Lone Carstensen [a,*], Mette Vaarst [a], Allan Roepstorff [b]

[a] *Department of Animal Health and Welfare, Danish Institute of Agricultural Sciences (DIAS), P.O. Box 50, DK-8830 Tjele, Denmark*

[b] *Danish Centre for Experimental Parasitology, The Royal Veterinary and Agricultural University, Dyrlægevej 100, DK-1870 Frederiksberg C, Denmark*

Received 3 October 2001; received in revised form 27 February 2002; accepted 4 April 2002

Abstract

In nine organic swine herds, faecal excretion and pasture contamination by parasite eggs/larvae were studied in a period from March to October 1999. It was shown that the organic pigs were infected with *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) whereas no infections with *Hyostrongylus rubidus*, *Metastrongylus* spp. or *Strongyloides ransomi* were detected. Moreover, no pigs showed clinical signs of infestations with scabies or lice. In the soil samples, very few *Trichuris* eggs were found throughout the season, whereas *Ascaris* eggs were found in 14% of the soil samples from sow pastures and in 35% from slaughter pig pastures, with the first infective eggs being recorded in July and the maximum number in August. Infective *Oesophagostomum* larvae were found in the grass samples in increasing numbers from May to October. Single herd cases of exceptionally high parasite infection levels are described in relation to herd management procedures. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Pig-helminths; Organic husbandry; Outdoor production; *Ascaris suum*; *Trichuris suis*; *Oesophagostomum* sp.

1. Introduction

The industrialization of the Danish swine production during the last 50 years has caused an elimination of some helminth species and a decrease in the prevalence and intensity of others (Nansen and Roepstorff, 1999; Roepstorff and Jorsal, 1989). Now, reintroduction of systems with outdoor pig production implies a risk of increased infection levels with the present worm parasites (e.g. Jolie et al., 1998) possibly leading to growth retardation or

* Corresponding author. Tel.: +45-89-99-13-07; fax: +45-89-99-15-00.
E-mail address: lone.carstensen@agrsci.dk (L. Carstensen).

PII: S0304-4017(02)00080-8

even clinical infections in growing pigs, if not handled appropriately. Moreover, there is a risk of reintroducing helminth species, like *Hyostrongylus rubidus* and *Metastrongylus* spp. which have not been found in domestic pigs in Denmark for decades.

In this respect, organic swine production may run a particularly high risk, as legislation includes a set of rules for organic husbandry, which may have an impact on parasite infections. In 1999, the Danish rules for certified organic pig production thus included: access to grazing at least 150 days each year (except for slaughter pigs, given that they have access to an outdoor area); straw bedding; access to roughage; no prophylactic medication (including anthelmintics); a withdrawal period after curative medical treatment which is three times longer than in conventional herds; weaning after 7 weeks of age (Law no. 479, 1996).

The aim of this study was to investigate the occurrence and level of parasite infections in organic pig herds in Denmark and to describe how preventive management procedures were handled in practice.

2. Materials and methods

2.1. Participating herds

The study was conducted as repeated cross-sectional sampling in nine private organic pig herds from various locations in Denmark. The farms had produced organic pigs for a few months up to 8 years and herd size ranged from 12 to 258 sows (Table 1). All but two farms had both sows and fatteners.

Table 1
Production and management characteristics of the participating herds

Herd	Outdoor pig production prior to organic pigs (years)	Organic pig production	Total grazing area for pigs per year (ha)	Number of sows	Weaning age (weeks)	Weaners/ fatteners on pasture[a]	Weaners/ fatteners indoor[a]	Use of permanent pastures[a]
1	–	2 years	10	74	7	−	+	−
2	–	7 months	8	59	7	−	+	+
3	–	2 years	19	258	7	−	+	−
4[b]	–	3 months	5	70	8	NA	NA	+
5[c]	–	5 years	11	0[c]	7–9	+[d]	+[d]	+
6	10	1 year	17	70	7	+[e]	+[e]	+
7	4	3 years	15	50	10	+	−	+
8	–	2 years	8	75	7–10	+	−	+
9	–	8 years	5	12	7–8	+	−	−

NA: no animals of these age categories present.
[a] The symbols − and + indicate that the management form was not in use or was in use, respectively.
[b] Piglets were sold at 25 kg.
[c] Originally 30 sows, but production was in liquidation.
[d] Moving pigs in and out during the fattening period.
[e] Fatteners were on pasture until only 1–2 months prior to slaughtering, whereafter they were finished in an open stable in deep litter.

2.2. Farm visits

All farms were visited within a period of 10 days every 6 weeks from March to October (i.e. five visits) in 1999. At the first visit, the farmer was interviewed about the production and management routines and soil samples were collected from the pastures that were going to be used for grazing from April and onwards by dry sows and fatteners, respectively. At the 2nd–5th visit faecal samples and soil samples were collected routinely. Grass samples were collected from dry sow pastures in all herds at visit 2 and thereafter only from the farms, on which strongylid eggs had been detected coprologically at the previous visit. Recordings were made on pasture appearance and clinical observations on the sampled pigs. The latter included recording of signs of ectoparasites, i.e. scabies and lice.

2.3. Faecal samples

At each visit, faecal samples were collected rectally from four groups of 10 pigs: 12 week-old piglets, 90 kg fatteners, dry sows, and lactating sows. All samples were immediately cooled and sent to the laboratory, where they were stored in a refrigerator until examination, which took place within a few days. Faecal egg counts (FECs) were determined by the concentration McMaster technique (Roepstorff and Nansen, 1998) with a lower detection limit of 20 eggs per gram faeces (epg) using saturated NaCl with 500 g glucose per litre as a flotation fluid. Coccidia oocysts were registered as "few, medium or many".

Faecal samples containing strongylid eggs were cultured for 8 days in vermiculite at room temperature, after which they were mixed with agar and infective larvae were recovered by baermannization and 200 L3 larvae were identified to genus according to Alicata (1935).

2.4. Soil samples

A pooled soil sample was collected by walking a W-route across the pasture, collecting approximately 5 g of soil from the upper 3 cm, every 15–20 steps. Two such pooled samples were collected from each pasture and analyzed separately. After thorough mixing in the laboratory, 5 g of soil was soaked in 0.5 M NaOH overnight, and flotated in several McMaster slides using the above mentioned flotation medium, as described by Roepstorff and Nansen (1998), thereby gaining a lower detection limit of 0.2 epg.

2.5. Herbage samples

Two replicate herbage samples (200–300 g) were collected randomly by hand every 15–20 steps when walking two W-routes across the pasture. The herbage samples were washed and after sieving (1000 μm) and sedimentation, the sediment was embedded in agar-gels and incubated overnight, before the larvae that had migrated out of the gels were harvested (Mwegoha and Jørgensen, 1977). The identification of the L3 larvae was similar to the method used for the cultured L3 larvae from the faecal samples.

2.6. Pasture appearance

The pastures were visually evaluated for the grass cover percentage as well as the percentage of bare soil, and the percentage of the pasture, which had been turned over by the foraging of pigs. The grass height on each pasture was registered as an average of five measurements with a sward stick.

2.7. Necropsy

Post mortem registrations for superficial liver white spots (ws) were conducted at the local abattoirs when the fatteners were slaughtered. The ws were classified into low (1–4 ws), medium (5–14 ws), and high (more than 14 ws) numbers.

2.8. Calculations and statistics

Helminth prevalences and FEC values were calculated as means of the herd prevalences.

Statistical analyses were performed by the generalized linear models (GLM) procedure PROC GENMOD in SAS Release 6.12 (SAS Institute Inc., 1989, 1996). The model used a binomial distribution of the response variable, being the helminth prevalence, and investigated the effects and interactions of the independent variables age, month and farm, eliminating them stepwise if non significant. Model control was performed by maximum likelihood ratio test, and Pearsons residual plots.

3. Results

3.1. The herds

Short descriptions of the herds are presented in Table 1. All sows and growing pigs were crossbred Landrace, Yorkshire and/or Duroc. In all herds, the sows were kept on pasture, rotating between a farrowing pasture (single sow pastures except on one farm) and a dry sow pasture (most often with groups of 5–15 dry sows). The service of the boars (or the artificial insemination in one herd) took place at the dry sow pastures or in deep litter stables. At weaning, 7–10 weeks of age, both piglets and sows were moved to stables or new pastures, except for one farm, on which the pigs were moved to a deep litter stable only 1 month before slaughter at approximately 6 months of age. All the organic farmers used the pig pastures as an integrated part of their crop rotation and hence the pigs returned to already used pastures with 1–4 years intervals. However, due to the relatively new establishment, about half of the herds had not yet had pigs returning to previously used pastures. On the other hand, six herds also used permanent pastures besides the rotational pastures (Table 1). Curative anthelmintic treatment was not carried out on any of the farms during the study.

3.2. Pastures

The grass height varied from 1 to 60 cm and the pastures had from 0 to 99% grass cover. Usually, the grass cover and grass height was larger on the sow pastures compared with pastures grazed by fatteners: 80–99% grass cover in the sow pastures as opposed to 1–80% in the pig pastures, and usually 2–25 cm grass height in the sow pastures versus 1–10 cm in the pig pastures. All farms but two nose-ringed their sows, but in practice many sows had lost their nose-rings, resulting in about only half the sows being nose-ringed. Nevertheless, it was obvious that the weaners and fatteners on pasture were far more active in foraging the pastures compared with the sows.

3.3. *Faecal samples*

Three helminth species were identified. *Ascaris suum* was found in all nine herds, while *Trichuris suis* and *strongyles* were found in six and five herds, respectively. The identified L3 larvae were all *Oesophagostomum* sp., and all strongylid eggs are therefore considered to belong to this genus. Dry sows and lactating sows were sampled separately, but in the presentation of the results, these two groups have been combined, because their helminth egg excretions were comparable.

A. suum and *T. suis* were primarily found in growing pigs, with 28% of weaners and 33% of fatteners excreting *A. suum* eggs, and 4% of weaners and 13% of fatteners excreting *T. suis* eggs, whereas these two helminths were found sporadically in the sows (Table 2). In contrast, the prevalence of *Oesophagostomum* sp. increased with the age of the pigs, from 5% of the weaners, to 14% of the fatteners, and 20% of the sows (Table 2).

Coccidia were found on all the farms, and were considered to be *Eimeria* sp. according to morphology.

3.3.1. *Ascaris suum*

The repeated faecal samplings revealed considerable variation in *A. suum* egg excretions over time both between herds and within herds (Fig. 1). The statistical analyses of the

Table 2
Prevalence of *A. suum* (Asc), *T. suis* (Tri), and *Oesophagostomum* sp. (Oes) in different age groups of pigs, examined in the present study as well as in a previous study in Danish organic swine herds (Roepstorff et al., 1992) and a study in Swedish outdoor swine herds (Christensson, 1996)

	Asc	Tri	Oes
Present study			
Weaners	28	4	5
Fatteners	33	13	14
Sows	4	<1	20
Organic herds in Denmark 1990–1991			
Weaners	50	11	24
Fatteners	57	7	44
Sows	29	4	50
Outdoor herds in Sweden 1996			
Weaners	67	?	27
Fatteners	55	?	73
Sows	14	?	51

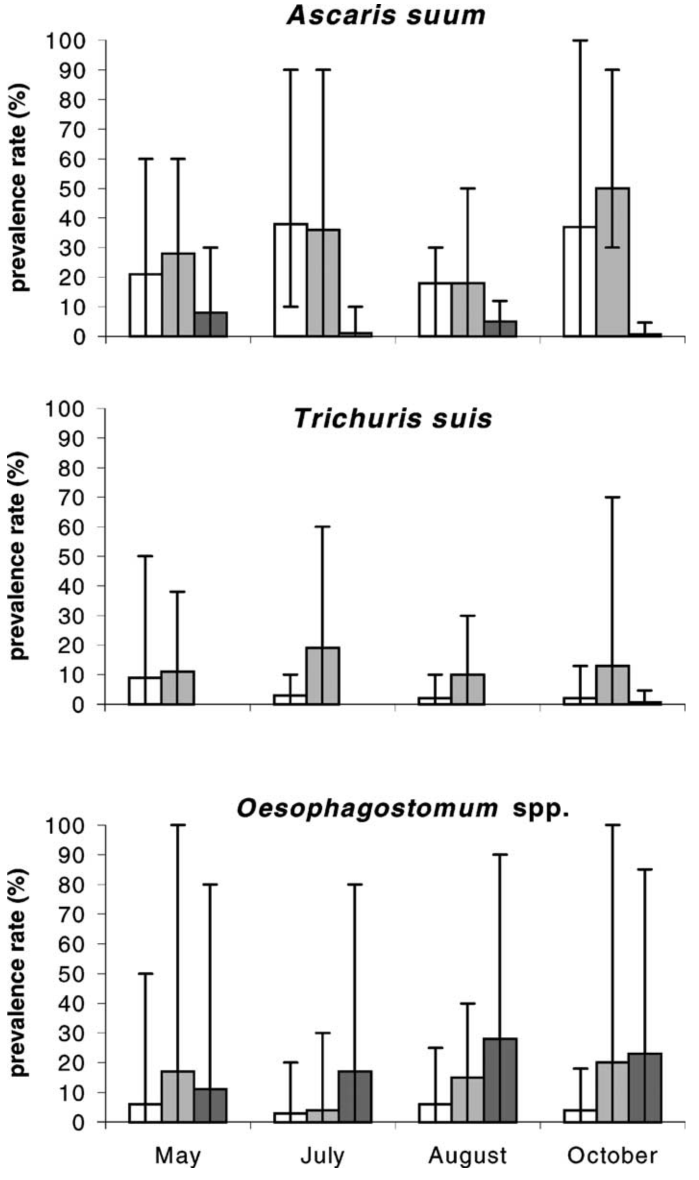

Fig. 1. Prevalence of *A. suum*, *T. suis* and *Oesophagostomum* sp. calculated as mean of the means in the nine herds. Range of herd mean values are indicated in line bars. Empty columns: weaners; grey columns: fatteners; dark columns: sows.

effect of age, month, and farm on the prevalence rates of *A. suum* showed a significant effect of all three variables, as well as their interactions. The *Ascaris* herd prevalences were 18–38% in weaners and 18–50% in fatteners, but great variation was observed between herds. Thus, farm 9 had extremely high infection rates in weaners as well as fatteners (90%

Table 3
FECs of *A. suum*, *T. suis* and *Oesophagostomum* sp. calculated as mean of the mean epg values in the nine herds

	Ascaris mean (min–max)	*Trichuris* mean (min–max)	*Oesophagostomum* mean (min–max)
Weaners	719 (61–3156)	6 (0–35)	23 (0–116)
Fatteners	640 (86–2119)	60 (0–334)	214 (0–1119)
Sows	22 (0–86)	0.06 (0–0.5)	161 (0–934)

Maximum and minimum herd mean values are indicated.

fatteners in August and 100% weaners in October). Significantly higher prevalences of *Ascaris* infections were recorded in October compared with earlier in the season (Fig. 1). The mean *Ascaris* egg excretion values were highest in weaners and fatteners and low in the sows (Table 3).

3.3.2. *Trichuris suis*

T. suis was the second most common helminth when looking at herd prevalences, but the prevalences were generally low within the herds, viz. 2–9% in weaners and 10–19% in fatteners. The mean egg counts were also low (Table 3). Statistical analyses showed significant effect ($P < 0.0001$) of age and farm on the *Trichuris* prevalences but no seasonal effect and confirmed that *Trichuris* was most common in fatteners (see Fig. 1). On farm 5, the *Trichuris* infection pressure was quite high in fatteners (maximum prevalence 70%) as well as weaners (maximum prevalence 50%), and this farm had actually experienced a clinical outbreak of sudden high mortality in weaners, followed by bloody diarrhoea in the surviving piglets just prior to the onset of our study. Bacteriological examination of faecal samples had provided no diagnosis on the aetiology of the clinical outbreak and an endoparasitic infection was suspected by the farm veterinarian, though it was neither verified coprologically nor treated with anthelmintics.

3.3.3. *Oesophagostomum sp.*

The *Oesophagostomum* sp. prevalence (Fig. 1) showed a significant increase with age ($P < 0.0001$) and, additionally, there was a significant effect of farm ($P < 0.0001$) and season ($P < 0.0001$), the prevalence being highest in August. The mean faecal egg excretion was highest in fatteners and sows, and low in weaners (Table 3). Farm 5, which had severe *Trichuris* infections, also had markedly higher prevalence rates of *Oesophagostomum* sp. in weaners (maximum prevalence 50%) and especially in fatteners (maximum prevalence 100%), as well as markedly higher FEC values in weaners (mean: 116 epg) and fatteners (mean: 1119 epg) compared with other herds.

3.4. *Clinical observations*

No animals showed any clinical signs of ectoparasites or endoparasites, during our visits. Farm 8 had experienced severe clinical scabies in 1998, but the whole herd had been treated with Ivomec® pour on, after which no clinical symptoms were seen.

3.5. Soil samples

One-hundred and sixteen pooled soil samples were collected from the sow pastures and 16 of these samples were positive for *Ascaris* eggs (14%), while 17 out of 49 soil samples (35%) collected from the fattener pastures were positive for *Ascaris* eggs. Two samples from the sow pastures were positive for *Trichuris* eggs (2%), whereas one sample from the fattener pastures contained *Trichuris* eggs (2%). The first soil samples were collected in March, before the spring pasture rotation took place. Seven samples from a total of 15 pooled soil samples collected in March were found positive for *Ascaris* eggs and one sample was positive for *Trichuris* eggs. These eggs most likely have survived for 1–4 years. Two of these contaminated pastures had never been grazed by pigs. In May, no helminth eggs were found in any of the 30 soil samples. In July, the first fully developed *Ascaris* eggs were found in the fattener pastures along with developing and undeveloped eggs, and higher numbers of embryonated eggs were found in August and October, the peak being in August (50% embryonated).

3.6. Herbage samples

In May, when grass was sampled in all farms, only one sample was positive for *Oesophagostomum* larvae (5 L3/kg dry matter). One out of four sampled herds was positive in July (mean larval count; 48 L3/kg dry matter), while two herds out of four sampled in August were positive (43 L3/kg and 165 L3/kg, respectively). In the four herds sampled in October, the mean larval counts were 0, 1, 42 and 1300 L3/kg dry matter, respectively.

3.7. Necropsy

The fatteners were slaughtered at the local abattoirs, due to which we only succeeded in obtaining necropsy data from 156 pigs from six herds. Thirty-seven percent of these had 0–4 ws, 33% had 4–14 ws, whereas 30% had more than 14 ws. The liver changes were characterized as chronic fibrous interstitial hepatitis, and the 37% of the livers with no or only very few ws would be accepted for human consumption, whereas the remaining 63% were presumably condemned. Farm 1 had 80% of the livers in the categories that would be condemned for human consumption. Unfortunately, we did not get any necropsy data from farm 9, having the exceptionally high *Ascaris* prevalences and FEC values.

4. Discussion

A. suum, *T. suis* and *Oesophagostomum* sp. were recorded in the organic herds. No animals were found to harbour infections with *H. rubidus*, *Metastrongylus* spp. or *S. ransomi*, and ectoparasitic infestations with scabies and lice were not observed. A comparable study, conducted in 12 organic herds in 1990 and 1991 (Table 2) showed infections with the same three helminth species, as well as infections with *S. ransomi* and ectoparasitic infestations with scabies and lice (Roepstorff et al., 1992). The present study showed lower prevalences as well as FEC values of the helminths, compared with the former investigation (Table 2) in which exactly the same McMaster technique was used. In both investigations the majority of herds were newly established, so differences in age of herds do not explain the different infection levels found in the two studies. Two factors of possible importance for the higher parasite levels in the previous survey are the housing and intensive use of permanent pastures, because the organic pig housing in 1990–1991 was often old stables with a low hygienic standard and the permanent areas were located close to the stable or feeding area, resulting in particularly high stocking densities in these areas. These risk factors had been reduced in the farms of our study, and though six farms still used permanent pastures, these were generally used extensively, except in farm 5, mentioned below. A survey conducted in 10 conventional outdoor pig production units in Sweden (Christensson, 1996) likewise showed remarkably high prevalences of *A. suum* in weaners, as well as fatteners and sows (Table 2). The same picture was seen for *Oesophagostomum* sp. *S. ransomi* was found in two herds, while Christensson did not present any prevalence rates for *T. suis*, but mentioned that this helminth was found in only one of the participating herds. It is difficult to hypothesise on the reasons for the differences in the prevalence of *Ascaris* and *Oesophagostomum* in Danish organic herds versus Swedish outdoor herds, since no information is provided on the management and anthelmintic routines in the Swedish herds. However, the low occurrence of *Trichuris* observed in the Swedish herds, could be due to only a single cross sectional sampling in Christensson's study as opposed to four repeated samplings in the present study.

In intensive indoor herds with a high level of hygiene, slatted floors, and no straw bedding, helminth infections have become less frequent, *T. suis* and *Oesophagostomum* spp. occurring only sporadically (Nansen and Roepstorff, 1999). *A. suum* is found in intensive herds too, but the better the hygiene, the later do the pigs become infected, and in some intensive herds, the infections do not occur until the animals have reached reproductive age (Nansen and Roepstorff, 1999). Piglets, born on contaminated pastures may, on the other hand, become heavily infected much earlier in life than indoor piglets (Roepstorff et al., 1992; Jolie et al., 1998). Seen from a production economic point of view, a late acquisition of the infections is preferred in comparison to infection earlier in life, especially because infection in piglets seems to cause a more substantial growth retardation than infections in older pigs (Mejer et al., 1999). The present study showed moderate infection levels with *A. suum*, but since the majority of the farms in the study had outdoor pigs for only a few years, it is possible that the infection levels in several of the present herds had yet to accumulate. One farm had produced organic pigs for 8 years, and used consecutive pasture rotation, i.e. there were no permanent pastures and pigs returned to the pastures only after 3 years. This herd had remarkably higher *Ascaris* prevalences in weaners and fatteners as well as considerably higher FEC values, probably due to an accumulation of parasite eggs in the soil over time, a hypothesis which is reasonable when looking at the relatively high egg numbers found in the soil samples from this herd (data from individual herds are not presented).

T. suis was the second most common endoparasite found in this study, though the egg excretion levels were generally low, which may well be in accordance with the fast acquisition of resistance against this parasite (Pedersen and Saeed, 2001). One herd (no. 5), however, had a very high prevalence of *Trichuris*, and weaners as well as fatteners had seemingly experienced clinical infection just before the initiation of the present study. The farm had produced organic pigs for approximately 5 years (Table 1), and indoor pens were not always cleaned between groups of pigs. Additionally, a little pasture just outside the stable was used continuously for weaners and fatteners. Soil samples from this farm also showed exceptionally high numbers of *Ascaris* eggs, but only single *Trichuris* egg. Confirmed cases of clinical trichuriosis in pigs exposed to long-term contaminated pastures have been described by Roepstorff et al. (1992) and Jensen and Svensmark (1996), and emphasise the importance of maintaining preventive management routines that impede the accumulation of parasite eggs over time.

Oesophagostomum infections showed the same pattern in age distribution as is commonly seen (Nansen and Roepstorff, 1999), i.e. low infection levels in weaners and increasing infection levels with age. *Oesophagostomum* sp. was found in about half the herds and infection levels were generally low. However, farm 5 that had a high level of *Trichuris* infection, also had remarkably high infection levels of *Oesophagostomum* sp. even in the weaners. The generally low level of *Oesophagostomum* infection in sows is remarkable, as grazing sows in the UK are often heavily infected (Rose and Small, 1980; Thomas and Smith, 1968) unless the helminths are controlled by a move to clean pastures in combination with anthelmintic treatment (Rose and Small, 1983). The main reason for the generally low *Oesophagostomum* level could be that the Danish winter is a little colder than the English, and that *Oesophagostomum* larvae therefore are almost or totally eliminated from contaminated pastures during the winter, as observed by Mejer et al. (2000) and Roepstorff et al. (2001).

Pastures grazed by sows in general had a good grass cover, superior to the pastures grazed by weaners and fatteners, as these age groups had higher stocking rates and foraged far more, thereby turning the soil over, leading to a reduction in the percentage of grass cover, as recently described by Thomsen et al. (2001).

More *Ascaris* eggs were found on the pastures that were grazed by weaners and fatteners, which is in agreement with the higher *Ascaris* egg excretion level in the younger animals. Overwintered *Ascaris* eggs as well as *Trichuris* eggs were found in the soil samples from the pastures in the spring before the pasture rotation, and even two pastures that had never been grazed by pigs, were contaminated with almost fully developed *Ascaris* eggs. According to the farmers, liquid manure had been used as a fertilizer 2 years earlier in one of the farms, whereas the other farm had used the strawmats from the farrowing huts as a fertilizer, which could be the explanation for the parasite egg contamination of the soil.

5. Conclusion and recommendations

This study shows that organic sows and pigs have higher infection rates with helminth parasites compared with sows and pigs housed indoor in intensive systems (Roepstorff et al., 1998). But, the prevalences seen in the present organic farms were generally lower than the prevalences found in Danish organic farms surveyed in 1990 and 1991 (Roepstorff et al., 1992), pointing to a positive effect of pasture rotation as well as the improved hygiene in organic housing of sows and piglets in huts with deep litter or newly established stables with deep litter seen today, as opposed to the housing in old, dirty stables, and high stocking on permanent pastures observed in the previous survey. When exceptionally high infection levels were observed in the present study, this could be explained by particularly inexpedient management routines or alternatively by a long time of recurrent use of the pastures for grazing pigs, both emphasising that consequent preventive management routines are of great importance in outdoor systems and especially on organic farms, on which anthelmintic use is undesired.

Drawing these conclusions together, the advice to organic farmers should be to start off their pig production with helminth-free sows, i.e. animals originating from intensive indoor herds and pre-treated with anthelmintics. This simple precaution is often neglected by organic farmers, many of which prefer to buy organic, or at least outdoor raised, animals. To keep the accumulation and transmission of helminth eggs/larvae at a minimum, the stocking rate should be as low as possible, pasture rotation should be strictly maintained, and permanent pastures as well as stables with low hygiene should be avoided. If clinical infections have been obtained despite these precautions, pigs should be treated with anthelmintics and moved to clean areas to secure a high level of animal welfare.

Acknowledgements

We greatly appreciate the kind welcome and valuable assistance we met from the farmers in the participating organic farms. We also wish to thank Rodrigo Labouriau for statistical advice, as well as Marlene Høg for technical laboratory assistance. Stig Milan Thamsborg, Christian Kapel and Margaret Faedo are warmly thanked for their valuable comments to an earlier version of this manuscript. The Danish Research Centre for Organic Farming provided financial support.

References

Alicata, J.E., 1935. Early developmental stages of nematodes occurring in swine. US Dept. Agric. Tech. Bull. 489, 1–96.

Christensson, 1996. Parasitförekomst. Djurmiljö och parasitförekomst i utegrishållning. Jordbruksinformation, 5, 26–27.

Jensen, T.K., Svensmark, B., 1996. Trichuriasis hos udendørs slagtesvin. VeterinærInformation 2, 3–7.

Jolie, R., Bäckström, L., Pickney, R., Olson, L., 1998. Ascarid infection and respiratory health in feeder pigs raised on pasture or in confinement. Swine Health and Prod. 6, 115–120.

Law no. 479 12/06/1996. Government order no. 560 03/08/1998. Bekendtgørelse om økologisk jordbrugsproduktion.

Mejer, H., Thamsborg, S.M., Roepstorff, A., Eriksen, L., 1999. Økologiske grise får mange indvoldsorm—men hvad betyder det for dyrene? Forskningsnytt 8, 15–17.

Mejer, H., Wendt, S., Thomsen, L.E., Roepstorff, A., Hindsbo, O., 2000. Nose-rings and transmission of helminth parasites in outdoor pigs. Acta vet. Scand. 41, 153–165.

Mwegoha, W.M., Jørgensen, R.J., 1977. Recovery of infectious 3rd stage larvae of *Haemonchus contortus* and *Ostertagia ostertagi* by migration in agar gel. Acta Vet. Scand. 18, 293–299.

Nansen, P., Roepstorff, A., 1999. Parasitic helminths of the pig: factors influencing transmission and infection levels. Int. J. Parasitol. 29, 877–891.

Pedersen, S.K., Saeed, I., 2001. Acquired immunity to *Trichuris suis* infection in pigs. Parasitology 123, 95–101.

Roepstorff, A., Jorsal, S.E., 1989. Prevalence of helminth infections in swine in Denmark. Vet. Parasitol. 33, 231–239.

Roepstorff, A., Jørgensen, R.J., Nansen, P., Henriksen, S.A., Pedersen, J.S., Andreasen, M., 1992. Parasitter hos økologiske svin. Report paper from a project, financed by the Danish Ministry of Agriculture, 36 pp.

Roepstorff, A., Nansen, P., 1998. Epidemiology, diagnosis and control of helminth parasites of swine. FAO Animal Health Manual, Rome.

Roepstorff, A., Nilsson, O., Oksanen, A., Gjerde, B., Richter, S.H., Örtenberg, E., Christensson, D., Martinsson, K.B., Bartlett, P.C., Nansen, P., Eriksen, L., Helle, O., Nikander, S., Larsen, K., 1998. Intestinal parasites in swine in the Nordic countries: prevalence and geographical distribution. Vet. Parasitol. 76, 305–319.

Roepstorff, A., Murrell, K.D., Boes, J., Petkevicius, S., 2001. Ecological influences on transmission rates of *Ascaris suum* to pigs on pastures. Vet. Parasitol. 2151, 1–11.

Rose, J.H., Small, A.J., 1980. Transmission of *Oesophagostomum* spp. among sows at pasture. Vet. Rec. 107, 223–225.

Rose, J.H., Small, A.J., 1983. Observations on the effect of anthelmintic treatment on the transmission of *Hyostrongylus rubidus* and *Oesophagostomum* spp. among sows at pasture. J. Helminthol. 57, 1–8.

SAS/STAT User's guide, Version 6, 4th Edition, SAS Institute Inc., Vol. 2. Cary, NC, 846 pp.

SAS/STAT Software: Changes and Enhancements through Release 6.11, SAS Institute Inc., Cary, NC, 1104 pp.

Thomas, R.J., Smith, W.C., 1968. Anthelmintic treatment of sows with thiabendazole. Vet. Rec. 83, 489–491.

Thomsen, L.E., Mejer, H., Wendt, A., Roepstorff, A., Hindsbo, O., 2001. The influence of stocking rate on transmission of helminth parasites in pigs on permanent pasture during two consecutive summers. Vet. Parasitol. 99, 129–146.