A10. Keywords

Max. 5 keywords to describe the project activity.

Parasites, control, pigs

A11. Short project description/summary on objectives, activities, and expected results, both in Danish and English language (max 1500 characters, incl. spaces for both languages)

Parasites are ubiquitous in livestock in general and organic livestock in particular due to management factors promoting transmission (pastures/outdoor runs, plenty of bedding, restrictive use of parasiticides). The parasites cause poor animal welfare, production losses, disease, and non-uniform products. Pig helminths with hard-shelled eggs are difficult to control, as the eggs are highly resistant and may survive for years. The present project focuses on reducing the transmission of hard-shelled eggs to growing pigs by investigating 1) long-term survival of eggs on pastures (for optimising pasture rotation), 2) inactivation of eggs in bedding material (reducing transmission), and 3) a novel approach in bio-inactivation of eggs (chitin-degrading microfungi). The overall objective is, through close interaction between researchers, advisors and farmers, to develop new strategies to control parasitism in organic livestock. The strategies will ensure high levels of animal welfare (credibility), increased animal productivity (growth), and a minimum reliance on chemical drugs (robustness).

Parasitter findes i alle produktionsdyr, og de er specielt hyppigt forekommende i den økologisk produktion, hvor management faktorer favoriserer smitteoverførslen (ophold på marker, udendørsstier, rigelig strøelse, begrænset brug af parasitmidler). Parasitter forårsager nedsat dyrevelfærd, produktionstab, sygdom og uensartede produkter. Hos svin er indvoldsorm med tykskallede æg særlig vanskelige at kontrollere, da æggene er yderst resistente og kan overleve i årevis i miljøet. Nærværende projekt fokuserer på at reducere smitten med tykskallede æg til smågrise og slagtesvin ved at undersøge 1) langtidsoverlevelsen af æg på mark (for at optimere markrotationen), 2) inaktivering af æg i strøelse (smittereduktion) og 3) en ny metode til biologisk inaktivering af æg (kitinnedbrydende mikrosvampe). Desuden fokuseres på optimering af parasitovervågning i besætningerne.Via intensivt samarbejde mellem forskere, rådgivere og landmænd er det overordnede mål at udvikle nye strategier for praktisk parasitkontrol i økologiske produktionssystemer. Strategierne vil sikre højere dyrevelfærd (troværdighed), øget produktivitet (vækst) og mindre afhængighed af medicin (robusthed).

A12. Project description

(All parts of A12 must be filled out. Use "Garamond" as font, and font size 12, single spaced)

A12.1 The project objectives (2-3 lines).

The aim is, by close interaction between researchers, extensionists and farmers, to develop new strategies for control of parasitism in organic livestock systems. These strategies will ensure high levels of animal welfare (credibility), an increased productivity (growth) and a minimum reliance on chemical drugs (robustness).

A12.2 The background and idea (hypotheses) incl. the national and international "state of art" and incl. references relevant for the section (max. ¾ page).

The parasites in livestock targeted in this proposal (gastrointestinal helminths and coccidia in pigs) are ubiquitous and cause production losses, non-uniform products and disease leading to marked decline in animal welfare, and may also be associated with risks of zoonosis. Organic farming systems are characterized by animals having access to pastures or outdoor runs, roughage in a largely home-grown diet and in-door systems with bedding material. Add to these, increasing sizes of enterprises and associated problems of disease surveillance, and the climate changes, providing an environment more conducive to parasites. All factors will inevitably increase the risks of parasite infections in organic farming (1). Also, there is a justified wish to minimize the use of chemical drugs but despite intentions, treatments are commonly applied (2). The scientific challenge is to design appropriate systems that ensure high standards of animal health and acquisition of natural immunity balanced with acceptable (but unavoidable!) production losses. With 20 years continuous experience in organic farming research, we have a basic understanding of recurrent problems (1) and through own research knowledge of novel approaches that can be relevant to apply (3).

In organic pig farms intestinal helminths (Ascaris, Trichuris and Oesophagostomum) are highly prevalent and important with regards to health, e.g. as a contributory factor to problems around weaning (4). Also coccidia with a reservoir in the bedding may play a role. Deep litter and poor bedding quality are known risk factors but no detailed information is available on oocysts' survival in pens.While Oesophagostomum hardly over-winter on pastures, hard-shelled eggs of Ascaris and Trichuris may survive for prolonged time in bedding material and on pasture. Better knowledge on hygienic management of manure and pasture rotation is needed as the most logical approach. Exploiting interactions of eggs and microfungi in the soil may lead to development of novel control measures (5).

1) Thamsborg & Roepstorff, J Parasitol., 2003,89:S277-S284; 2)Weinreich et al., 2004 WBC, Quebec; 3) Waller & Thamsborg, Trends in Par. 2004, 20:493-497; 4) Nygård et al., 2010 Animal (in press); 5) Basualdo et al., Parasitol. Res. 2000, 86:854-59.

A12.3 The projects contribution to solving important challenges for the organic food, agriculture and aquaculture sectors and the general political goals regarding food, agribusiness and environment as expressed in the governments Green Growth programme. Including an explanation of the projects focus on respectively the entire product/value chain or selected parts here of (e.g. primary production, processing, trade and transport) – max. ½ page.

The project will
- increase the potential for growth of the primary production through improved productivity of livestock, better strategies for disease surveillance and thus use of pasture (i.e. increase the area for organic farming).
- improve the credibility of the livestock sector through better adherence to basic organic farming principles e.g. better animal welfare through enhanced natural immunity and improved rearing practices to evade parasites.
- create more biological robust livestock systems by paving the way for improved pasture rotation strategies, supporting the natural degradation of pathogens in straw bedding and manure, and thereby minimizing external input of, e.g. anti-parasitic drugs.

The project focuses only on the primary production of livestock and expects to provide the farm extension workers with tools for advising the organic farmers. Parasite infections do have implications for product

quality but we consider these to be general and not unique to organic products. By focusing on the solution to the fundamental problem, i.e. limiting infections, we are confident that the product quality will improve.
In the program, our project specifically addresses:
Item 6.1: Further development of pig production, improving animal welfare and natural resistance against infectious diseases.

A12.4 The projects innovative value, relevance and effect including the specific barriers and development potential for the organic sector the project will solve and/or support (max. ½ page).
The scientific, innovative value of the project is high and clear, since to the best of our knowledge, we expect to be first to report:
1) Systematic information on survival of pig helminth eggs on natural pastures that can be utilized in guidelines for pasture rotation. Existing data are largely anecdoctal.
2) Solid data on survival of parasites in bedding material/manure to promote correct management.
3) Potential use of naturally occurring chitin-degrading fungi to control eggs of pig parasites.
4) Development of guidelines for better parasite surveillance and control tailored for and accepted by organic farmers
Parasitic diseases are major challenges to the health and welfare of organic livestock and may limit the growth of the sector due to reduced productivity and suboptimal use of outdoor areas, including natural grasslands. At present, we have far from achieved the long-term goals of control of infectious disease, in this case parasites, through enhanced natural resistance, breeding, feeding and management. In several instances the routine use of drugs is deemed neccesary to sustain animal welfare. Based on 20 years of experience with parasites in organic livestock, we are able to pinpoint and address the critical problems related to parasitic diseases. Through innovative solutions (above) and evidence-based control guidelines, we believe animal health and profitability of the primary animal production can be improved by better and integrated parasite control.

A12.5 Description of activities, methods and expected results divided into work packages with clear denotion of which activity the applicant consider to be either Research, Development or Demonstration. The coherence between work packages must be clearly described and the relation between activities and the tables with milestones and deliverables must be logical and consistent. Moreover, the primary target groups should be clearly identified with a description of how these will be met by the project (max. 1 page per WP and max. 3 pages in total).
The project includes 3 WPs of which the first has strong research components. WP1 will provide information on survival of eggs of pig helminths necessary for designing control measures and examine a novel idea of control. It will thus provide knowledge base and new tools for control of parasites in organic pig production. WP1 feeds into WP2 which will synthesize the outcomes with existing knowledge and develop new strategies to be evaluated on a few selected farms. WP3 is the over-arching management of the project.
Target groups in WP1-2: Farmers, farm advisors (production and veterinarians) and researchers.

WP1: Longevity and inactivation of thick-shelled pig helminth eggs (WP-leader: A Roepstorff)

1.1 Long-term survival of pig helminth eggs on contaminated pastures (R)
Recent data from our laboratory suggest that high numbers of Ascaris and Trichuris eggs survive and remain infective to pigs even after 6 years on pasture, and that the dying-off rate of eggs is slow. To be able to recommend a pasture rotation strategy, there is a strong need for knowing when it is acceptable to reuse contaminated pastures.

Methodology: The long-term (11-13 year) survival of infective Ascaris and Trichuris eggs will be studied on 6 pastures naturally contaminated in year 2001 by means of sentinel tracer pigs (parasite recovery following short term exposure) and soil samples (recovery of eggs) in the autumn of 2011 and 2013.
Expected outcome: Clear guidelines on pasture/outdoor area rotation frequency.

1.2 Inactivation of thick-shelled pig helminth eggs in bedding or faecal material (R,D)
Bedding and faecal material are well-known risk factors of helminth infections in in-door pigs, and the spreading of both on pastures have been shown to heavily contaminate otherwise clean areas. Nevertheless, new data have demonstrated a surprisingly high inactivation of the long-lived resistant eggs within the bedding material in an organic fattening unit. Systematic knowledge on environmental factors (physical, chemical or biological) governing this inactivation is lacking and sorely needed.
Methodology: The inactivating effect of physical/chemical factors (e.g. temperature, ammonia, pH, anaerobic conditions) on eggs is observed over time under controlled laboratory conditions. Physical/ chemical measurements and characterisation of biotic factors in relation to egg developmental stage and egg inactivation are measured in bedding/faecal material under controlled conditions by sampling over time (on-farm). Similar observations will be made with oocysts of coccidia, if possible. When bedding material is removed, it is expected that a high number of thick-shelled eggs is alive but the viability will gradually decline over time. Bedding material or material from latrine areas will be placed in replicated heaps on concrete and either sealed to maintain anaerobic conditions or left un-sealed for composting (on-farm). Samples will be collected over time for parasitological, chemical and physical analyses and the time necessary for egg inactivation will be determined.
Expected outcome: Guidelines for management and handling of contaminated bedding material and manure in animal houses and during storage.

1.3 Antagonistic effect of chitin-degrading microfungi on thick-shelled pig helminth eggs (R)
Helminth eggs contain chitin, and a pilot study in our lab has shown that Ascaris egg numbers may be reduced by stimulating naturally occurring soil microfungi which produce chitinase. Biocontrol measures for phytopararasitic nematodes using crustacean waste products or commercially available chitinase-rich fungus (e.g. Paecilomyces lilacinus or Trichoderma sp.) are presently approved in organic vegetables, and we want to explore this principle for control of parasites in organic livestock. P. lilacinus has been investigated with some success against eggs of Toxocara canis.
Methodology: Pilot studies on the interactions between chitin-degrading microfungi and thick-shelled nematode eggs by adding microfungi (e.g. P. lilacinus) and/or stimulating naturally occurring fungi by adding chitin will be conducted. A three-step protocol is planned: 1) The egg inactivating effect of adding pure chitin (at different levels) and/or microfungi is tested under controlled conditions (laboratory). If the principle works, we will proceed with 2) a pasture plot study, in which the egg inactivation by chitin and/or microfungi is measured under semi-natural conditions. Both pure chitin and crab-shells are tested. At last it is tested 3) whether the principle can "clean-up" a heavily egg-contaminated area on-farm. Small areas, e.g. 1x1m plots are marked and randomly allocated to treatments, e.g. control, chitin-, fungi-dressing. The egg concentration in soil is followed over time.
Expected outcome: A possible novel biocontrol strategy to combat nematodes with thick-shelled eggs.

WP2: Formulation of sustainable strategies and implementation on farms (WP-leader: T. Serup)

2.1 Strategies for parasite control and implementation in organic pig farms (D, Dm)
The purpose of this activity is to secure farmers' input on decisions regarding research design and plans, and on the development of strategies that may be evaluated on a few selected farms.
Methodology: a) Within 2-3 months after the first consortium meeting, 3-6 organic farmers will be invited to VFL and asked to provide a critical view on justifications and research plans for WP1 together with

researchers. Plans will be modified, if necessary. Further, the farmers (or others) will be invited to participate as monitoring farms for the year 2012 (baseline) and 2013 (intervention). b) In 2012, 3-6 farms will be monitored with regards to parasites and productivity in order to provide a baseline for comparison with later interventions c) Based on outcomes of WP1 and existing knowledge, strategies for parasite control, e.g. pasture rotation, manure handling etc., will be formulated at a workshop with participation of farmers, advisors and researchers in early 2013. The strategies should be efficacious with regard to parasite control and practicable in an organic farming context. d) Relevant strategies will be adopted in the mentioned 3-6 farms willing to participate in low-level monitoring (productivity, parasite levels) and to demonstrate outcome to other farmers (1 or 2 only). e) Final recommendations will be formulated at end of 2013 based on research outcome and experiences of participating farmers.
Expected outcome: Practicable strategies for parasite control on pig farms.

WP3: Project management (WP-leader: S. Thamsborg)

Project co-ordination will be ensured through a project management group (PMG) consisting of the leaders of each WP (A. Roepstorff, T. Serup), a rapporteur (H. Mejer) and led by the project leader S. Thamsborg. The PMG representing all partners will meet regularly; prior to planned bi-annual consortium meetings and at the end of each year to review progress before annual reporting to GUDP. The project leader is overall responsible for the fulfilment of the project (see also A12.9)

A12.6 Description of how it will be ensured that the project results can be implemented in practice and perhaps commercialized (max. ½ page). General dissemination: Information on the project will be disseminated to a range of users: to veterinarians by papers in Danish veterinary journals, at meetings and lectures, to veterinary students in their curriculum and to farmers and farm advisors with the support of VFL: articles in farm magazines, information to the advisor team, information to experience groups of farmers, by training courses for farmers and through internet media like "Landbrugsinfo". A project website will be established.

Implementation of strategies: Organic livestock producers will be involved throughout the project. The formulation of guidelines in collaboration with farmers is expected to improve the rate of adoption in the farming community. Organic farmers' organizations will be involved in the dissemination activities, e.g. joint publications. Furthermore, the demonstration part on selected farms (WP2) will ensure immediate transfer of information to other farmers. These strategies are not considered possible to commercialize.

Innovative tools: If successful degradation of eggs with fungi is achieved, possibilities for commercialization of this new indication will be investigated e.g. with the company which is already producing plant nematode destroying fungi on a commercial scale (Borregaard BioPlant, Denmark). Crude chitin/crustacean shells can perhaps be obtained from a shrimp factory in Greenland, through our colleague Dr. L. Nukarak Møller in Nuuk. The consortium has extensive experience with patents, however, we do not consider it realistic to patent this application because some written reports already exist.

A12.7 Description of possibilities for a general utilisation of the results (max. ½ page).
The results will produce knowledge that can improve animal welfare and production economy for the farmers. In general, approaches and strategies developed can be applied in both organic and conventional livestock farms. Of course, the net benefits (e.g. health, product price) anticipated in organic herds may come out differently in conventional production systems due to e.g. different valuation of costs, making some recommendations obsolete. We will explore the possibilities for disseminating the results to conventional pig producers.

Furthermore, strategies will also be discussed in international fora where the consortium has extensive contacts through memberships, board memberships and conferences.

The principle of using of egg-degrading fungi may additionally be applicable to nematodes of other host animals than pigs, e.g. Ascaridia galli in poultry which could be the target for future research. Finally increased knowledge about prevalence and survival of zoonotic parasitic pathogens in the farm environment will be highly useful with regard to protection of recreational and drinking water sources in Denmark.

A12.8 Description of the coherence between the research, development and demonstration activities in the project, including involvement of relevant users of the results (max. ½ page).
All three elements are included in the proposal and are strongly coherent. The research-based knowledge gained in the first years in WP1 will be included in the development of sustainable strategies for parasite control in WP2 in close collaboration with farmers and advisors. Further, in WP2 the development of strategies will be linked to demonstration on selected farms. The research-based novel approach using egg-degrading fungi will probably require further development with other partners before implementation on-farm (A12.6). The coherence will be further supported by other dissemination activities targeting the relevant users (deliverables and presentation at meetings etc.), see A12.6.

Organic livestock producers will be closely involved in the project: in relevant project meetings, in on-farm studies in WP1, in the development of strategies in WP2 and in the demonstration on selected farms in WP2. Furthermore, we also consider livestock extension workers (advisors) as users and they are included as a partner. Organic farmers' organizations will be involved in dissemination activities.

A12.9 Project organisation, management and administration (max. ½ page).
The project is organized in the mentioned 3 WPs, headed by A. Roepstorff (WP1), T. Serup (WP2) and S. Thamsborg (WP3). WP-leaders are responsible for the progress and fulfilment of milestones within the stipulated time schedule of their WPs. Individual partner institutions represented by T. Serup (VFL) and S. Thamsborg (KU-LIFE) are responsible for deliverables and annual reporting (scientific and financial), including a list of dissemination. The whole consortium (all participants) will meet 2 times annually to discuss plans and results, integrate activities, and set goals for forthcoming work. The first meeting will be an Inception Meeting, including farmers' participation to ensure that relevant goals are prioritized. Later meetings will be coordinated with WP2 activities.

The overall project co-ordination will be ensured through a project management group (PMG) that will meet regularly and work as specified under WP3. PMG will also handle problems occurring in relation to intellectual property rights (IPR), including co-authorship. The project leader is overall responsible for the fulfilment of the project, achievement of the milestones, communication within the project and between grant authorities, other stakeholders (organic producers etc.) and the project.

A12.10. The technical competences of the partners and their contribution to the project including how they complement each other (max. 5 lines per partner).
PSU, KU-LIFE: The former Danish Centre for Experimental Parasitology includes veterinarians and biologists and has a strong publication track record on applied and basic parasitology of helminths in pigs, cattle and sheep with emphasis on organic farming and alternative control. PSU, KU-LIFE also haso extensive in vitro and in vivo facilities for studying helminth infections in pigs and solid experience in on-farm field studies. Involved in research in WP1, monitoring in WP2 and management in WP3.

VFL: The Danish Knowledge Centre for Agriculture has extensive experience and expertise in advising farmers, developing advisory tools, and conducting development projects, and it is in close cooperation with local advisory service centres. VFL collects, develops and imparts know-how to Danish farmers and advisers. VFL will, beside assistance in selecting farms for WP1, contribute to the execution of workshops and on-farm demonstration in WP2 and management in WP3.

A12.11. Expected collaboration with other research institutions/companies nationally and internationally (max. ½ page).

• The studies on survival of helminth egg and coccidia oocysts in bedding material and on pasture will be performed in collaboration with Professor Lars Stoumann Jensen (KU-LIFE), expert on the influence of manure and waste products on soil biological fertility.
• (see also A12.6 for other companies)

A12.12. The relation to previous projects within the projects focus areas (if any) including references to these (max. ½ page).

• Manorpig (FØJOII 2000-2005) Organic pig farming: animal health and welfare, including parasite infection
• Prosbio (FØJOII 2000-2005) Steer production and pasture-borne parasites in ruminants
• Hewdaica (FØJOII 2000-2005) Organic dairy production, mastitis and calf diseases etc.
• Wormcops (FP5 2000-2004) Organic small ruminant production: new approaches to control
• Healthy Hay (FP6 MC-RTN 2005-2010) Sainfoin: reinventing an old crop (in vitro effects on cattle nematodes)
• Core Pig (CORE Organic 2007-2010) Organic pig farming: animal health and welfare, including parasite infections
• CAPARA (COST FP7 2009-2012) Goat parasite network

A13. Tables with milestones and deliverables with information as requested in the table in A16.

(deliverables not requested in A16 - only milestones)

WP1			
M1: First tracer-test performed	HM	12/2011	AR
M2: Second tracer-test performed	HM	12/2013	AR
M3: Inactivation studies terminated	AR	08/2012	KK
M4: Fungal egg degradation finalised	AR	12/2012	KK, SMT
WP2			
M5 Farmers' meeting (soon after project meeting 1)	TS	5/2011	all
M6 Workshop (at project meeting 5)	TS	2/2013	all
M7 Evaluation on novel control on-farm finalised	TS	11/2013	all
M8 Final recommenations produced	SMT	11/2013	all
WP3			
M9 Project meeting 1	SMT	2/2011	all
M10 Project meeting 2	SMT	10/2011	all
M11 Project meeting 3	SMT	2/2012	all
M12 Project meeting 4	SMT	10/2012	all
M13 Project meeting 5	SMT	2/2013	all
M14 Project meeting 6	SMT	10/2013	all

A14. List of deliverables from the project (also fill out the table in A17)

D1 Peer reviewed: Long-term survival of pig helminth eggs on organic pastures S1
D2 Popular paper in Danish: Pasture rotation in organic pig productions P1
D3 Peer reviewed: Factor influencing inactivation of thick-shelled pig helminth eggs S1 (C1)
D4 Popular paper in Danish: Parasite-safe management of manure in organic pig production P1
D5 Peer reviewed: Antagonistic effect of chitin-degrading microfungi on thick-shelled pig helminth eggs S1 (C1)
D6 Popular paper (introduction to workshop) Danish: Preliminary guidelines to reduce helminth infections in organic pig farms P2,C4
D7 Report/paper in Danish: On-farm experiences with novel parasite control in organic pigs P1
D8 Popular paper in Danish: Evidence-based strategies of parasite control in organic pigs P1

D3 and D5 will form part of the Ph.D. thesis of KKK (C1)

A15. List of appendices

Appendix 1: CVs (SMT, TS, AR, HM, KKK)

A16. Milestones and time schedule for the entire project

wp no.	Milestone no.	Title/activity	Responsible project participant	Date/year	Other participants
1	1	First tracer-test performed	HM	12/2011	AR
1	2	Second tracer-test performed	HM	12/2013	AR
1	3	Inactivation studies terminated	AR	08/2012	KK,HM, SMT
1	4	Fungal egg degradation finalised	AR	12/2012	KK,HM, SMT
2	5	Farmers' meeting (after project meeting 1)	TS	5/2011	all
2	6	Workshop (at project meeting 5)	TS	2/2013	all
2	7	Evaluation on novel control on-farm finalised	TS	11/2013	all
2	8	Final recommendations produced	SMT	11/2013	all
3	9	Project meeting 1	SMT	2/2011	all
3	10	Project meeting 2	SMT	10/2011	all
3	11	Project meeting 3	SMT	2/2012	all
3	12	Project meeting 4	SMT	10/2012	all
3	13	Project meeting 5	SMT	2/2013	all
3	14	Project meeting 6	SMT	10/2013	all

A17. List over deliverables (D=deliverables) for the entire project, stating whether the deliverable belongs to the research part of the project (R); the development part (D); and/or demonstration (Dm).

D. no.	Deliverable	Responsible project participant	Date/year	R, D, or Dm Effective working time, months [1]	Type of deliverable*
1	Long-term survival of pig helminth eggs on organic pastures	HM	12/2013	R 8.0 MM	S1
2	Pasture rotation in organic pig productions	HM	12/2013	R,D 2.0 MM	P1
3	Factor influencing inactivation of thick-shelled pig helminth eggs	AR	10/2012	R 8.0 MM	S1 (C1)
4	Parasite-safe management of manure in organic pig production	AR	10/2012	R,D 2.0 MM	P1
5	Antagonistic effect of chitin-degrading microfungi on Ascaris suum eggs	AR	12/2012	R 8.0 MM	S1 (C1)
6	Preliminary guidelines to reduce helminth infections in organic pig farms	AR	2/2013	R,D 2.6 MM	P2,C4
7	On-farm experiences, novel parasite control in organic pigs	TS	12/2013	D,DM 7 MM	P1
8	Evidence-based strategies of parasite control in organic pigs	AR/SMT	12/2013	R, D 7 MM	P1

* Fill in the type of deliverable. Use the List of type of deliverables on the last page in Annex 3 “Instructions for filling in the application form”.

[1] The total amount of months must be consistent with the total number of months in the budgets, and will therefore show the relative working effort per work package.