Programme description: **Strategic institute programme**

# Improved welfare in sheep production

## Preventive measures, disease resistance and robustness related to tick-borne fever in sheep

Acronym: **SWATICK**

**Applicant**: Norsk senter for økologisk landbruk (NORSØK)
**Programme leader:** Dr. Håvard Steinshamn

## Contents



## Introduction

The Norwegian consumer perceives all sheep farming in Norway to be 'as good as' organic and a production being close to nature. Surveys show that the consumer believes sheep farming is the most animal welfare friendly production system of all animal production systems in Norway (Berg 2002). However, there are considerable challenges in both organic and conventional sheep production with respect to welfare.

The greatest welfare challenges during the grazing period are tick-borne fever (TBF, "sjodogg"), blow-flies, "alveld" (disease acquired from grazing *Narthecium ossifragum* (L.) Huds) and predators (Norges Forskningsråd 2005, Norsk sau og geitavlslag 2001). Furthermore, the trend towards more extensive production systems with focus on reduced costs and disease treatments due to poor income, increased transport distance and time, and further increase in number of lambs per ewe through breeding are major reasons to welfare worries.

Good animal health and high level of welfare are explicit goals in organic farming (Debio 2003). The possibility to perform natural behaviour is an important principle in organic farming. The objective of natural behaviour implies that animals have the opportunity to behave according to their instincts and social needs. Grazing is therefore an important aspect in organic farming. Organic sheep farming faces similar welfare challenges as conventional farming does. However, according to the basic principles of organic agriculture, the focus on solving these challenges should be on preventive measures. Relying on routine use of synthetic medicines is not desired in organic farming (Debio 2003), and the sustainability of repeated medication can be questioned. Problems with resistance to such remedies are well documented (Wharton 1983). An increase in tick problems increases the use of drugs such as acaricides. Hence, there is a need for alternative strategies of tick control.

Grazing on outlying pastures in mountains and forests is the basis in Norwegian sheep farming. This implies challenges for the production system as well as welfare dilemmas. The production loss in sheep farming is expected to be substantial on such pastures. The lamb loss, from birth in spring to collection from pastures grazing in autumn, lies between 7 – 13 % (Stuen *et al.* 1998). The lamb losses seem to increase in areas with predators (personal comm. Synnøve Vatn and Ragnhild Vikesland) and in coastal areas where ticks are present (personal comm. Michael Angeloff). A mapping of the occurrence of blowfly strike (*myiasis externa*) was conducted by Stuen *et al.* (2005). They found no difference in lamb losses in flocks affected or not affected by blowfly strike. However, lamb losses were significantly higher in flocks grazing on tick infested pastures than in other flocks. Lamb losses in Norway are highest on pastures with ticks (*Ixodes ricinus*) and *Narthecium ossifragum* (L.) Huds. (Norges Forskningsråd 2005).

Ticks can carry a number of diseases, both bacteria and virus diseases. The tick-borne disease of most importance in Norway in sheep farming is TBF, also named "sjodogg" (Øverås 1972, Stuen 1997). Losses on tick infested pastures are substantial, and it is expected that more than 300 000 lambs/sheep are affected by TBF (Stuen and Bergstrøm 2001). Losses up to one third of the lambs are observed on tick infested pastures due to TBF and secondary diseases (Stuen and Kjølleberg 2000). Sheep develop immunity against TBF after infection. Hence, sheep exposed to the infection for the first time are most vulnerable. Bush encroachment and an increase in the deer population are expected to have an effect on the incidence of ticks (Sonenshine 1993). On the other hand, outlying pastures often have a valuable and rich biodiversity that may have positive nutritional and health preventive properties for grazing animals.

Concerning genetics, variation in grazing behaviour is observed between sheep breeds (Steinheim *et al.* 2005). The short-tailed Norwegian breeds were found to browse more on bush vegetation than the long-tailed breed Dala. There is also a report on genetic variation in the ability to handle disease (robustness) and diseases resistance of sheep (Axford *et al.* 2000). This implies possible genetic variance between sheep breeds and / or between sheep individuals within breed in the ability to handle disease, e.g. tick infestation and tick-borne fever, and which will be examined in the proposed project. Turn out time, maternal effects, development of immunity, grazing habits and behaviour and grassland quality are factors of interest when working with prevention of production losses and welfare issues as a consequence of TBF.

## Objectives

***Main objective:***
Improve sheep welfare and productivity through new preventive measures against tick-induced diseases and production losses.
The project will through experiments and analysis of existing data seek to answere:

1. the extent of production losses to TBF in Norwegian sheep farming.
2. the optimal time and conditions for lambs to develop immunity on tick infested pasture.
3. Quantification of between breed variance in resistance to TBF, as well as estimates of genetic variance within breeds in survival on tick infested pastures.

## Background / justification

### 1. Tick-borne fever in Norwegian sheep production

The most common tick-borne disease in domestic animals in Norway is tick-borne fever (TBF), caused by the bacteria *Anaplasma phagocytophilum* (formerly *Ehrlichia phagocytophila*) and transmitted by the tick (*Ixodes ricinus*) (Øverås 1972, Stuen 2003). TBF has for decades been considered as an important disease in lambs along the coast of southern Norway (Stuen 1998). It is common from Vestfold in the south to Brønnøysund in the North, with main area on the southwest coast of Norway (Stuen 1997, Stuen *et al.* 2001, 2005). The occurrence of ticks is however spreading and ticks are observed in inland areas and in Northern Norway outside the normal area (Stuen pers comm.).

Clinical signs of TBF are high fever and reduced immunity. TBF may cause abortion in ewes and temporary infertility in rams (Woldehiwet & Scott 1993), but the main consequence of an *A.phagocytophilum* infection in sheep is the ensuing immunosuppression that leads to secondary infections, such as *Staphylococcus aureau* pyaemia and *Pasteurella hemolytica* (*trehalosi*) septicaemia (Brodie *et al.* 1986, Stuen 1996). A reduced general condition can lead to animals being an easy catch for predators, or dying from other diseases. Sheep flocks on tick pasture may suffer heavy losses due to direct mortality. In one flock that was studied, almost one third of the lambs died on tick pasture, most of them due to TBF and secondary infections (Stuen & Kjølleberg 2000). In addition to direct losses, impaired growth may be important. Stuen *et al.* (1992) found that the mean live weights of TBF infected lambs were reduced several months after the primary infection compared to uninfected lambs. In the UK, more than 300 000 lambs have been found to develop tick pyaemia annually (Brodie *et al.* 1986).

In 1995 more than 11 000 sheep flocks were treated prophylacticaly against TBF with tick repellents / insecticides, i.e. around 40 % of all flocks in Norway (Norwegian Animal Disease Report 1995, Norwegian Agricultural Statistics 1995). Hunt (1986) found that treatment of ewes and lambs with cypermethrin pour-on increased the production with 6 % more lambs at weaning on tick pastures. Furthermore, the mean slaughter weight of treated lambs was 1.5 kg heavier than untreated controls.

### 2. Possible preventive measures against tick-borne fever (TBF)

There are few efficient preventive measures against tick infection and TBF, and their effect is not well documented. General advice given is clearing bush, early infection of lambs and regular use of acaricides (pour-on) (Statens legemiddelverk 2001, Stuen and Kjølleberg 2000).

#### Indirect losses

In a flock of 50 sheep grazing on a pasture, with very low tick burden, only one animal showed clinical symptoms of TBF, but after a three month grazing period 30/50 sheep had been infested by the TBF-bacteria. The slaughter weight of these 30 animals were 3,8 kg lower than animals free from TBF (Stuen *et al.* 2002). It is indicated that about 300 000 lambs are affected by ticks and TBF every year (Stuen and Bergström 2001). There is reason to believe that TBF causes major indirect losses in sheep farming. The hidden numbers of indirect loss caused by TBF is shown through reduced growth in lambs, reduced slaughter weight and quality, economic losses and welfare issues that are important to document. Awareness of tick infestation varies amongst farmers and advisors (Stuen pers comm.).

Knowledge on indirect losses related to tick infested pastures will improve quality, economy and welfare, through implementing preventive measures.

**Turn out time on pasture and immunity**

Lambs get colostrum with immunoglobulines (passive immunity) from mother after birth. This passive immunity from the mother helps the lambs to defeat infection and develop a certain level of immunity against infection (Stuen *et al*. 1992). Eventually the lambs will be able to develop immunity themselves (active immunity). During the development from passive to active immunity, at about 3 – 6 weeks of age, the lambs are especially vulnerable to infection. The two groups of sheep at highest risk are lambs on tick infested pasture and brought in animals arriving on a tick infested pasture for the first time. Very young lambs are, however, relatively resistant to the disease (Stuen *et al.* 1992). Re-infection does occur, but the severity is less than in primary infections. It is therefore interesting to examine whether young lambs exposed to tick infection at a very early stage (within the first week) can handle the disease without becoming seriously ill. During this process, the lambs may develop immunity. Maternal immunity may influence the first infection reaction in lambs, but colostral antibodies are not always enough to protect the lambs completely (Stuen *et al.* 1992, Stuen 1993).

It is shown that it is possible to have moderate levels of both ticks and tick-borne diseases present on a pasture without severe animal losses or clinical disease. This is described for cattle in Australia and the tick-borne disease Babesiosis caused by *Bebesia bovis* and *Bebesia bigemina* (a protozoa) (Queensland government: www.dpi.qld.gov.au, 25.11.2004). The situation is called endemic stability. If cattle are not exposed to *Babesia* as youngsters, the age resistance will gradually wane with time and these animals will become susceptible to infection. If exposed to the disease later in life, they may well develop a severe, life-threatening infection. Although this refers to cattle and another tick-borne disease, the ability of acquiring endemic stability might as well apply to sheep and “sjodogg” and should be subject to further investigation.

Advice on time for pasturing start for development of immunity will have the potential to decrease direct losses and production losses to TBF. Advice on farm management as on time for pasturing and importance of maternal immunity are sustainable preventive measures. Also, these are in line with the aims of organic farming, where natural grazing behaviour is an important principle in sheep production.

**Disease resistance**

There is a worrying increase in resistance to ticks to various acaricides in many parts of the world, especially in tropical areas in cattle production i.e. Australia, Africa and America (Wharton 1983). Host resistance and disease immunity are survival mechanisms for the host. Host resistance is expressed by an animal’s ability to prevent the maturing of large numbers of ticks. It is mainly components in the saliva of the ticks that are important for inducing host resistance. Using the attributes host resistance and disease immunity at the same time as ensuring a high level of production is a challenge. Disease resistance in general is both a genetic and an acquired characteristic and each animal develops a specific level of resistance in response to a challenge. It is found that the level of host resistance to ticks in Zebu cattle (tropical breed) is higher than in European breeds. Various levels of host resistance to ticks are found to occur in different breeds of cattle (Warton, 1983). Warton concluded that host resistance to ticks is heritable in cattle, and that there are possibilities for genetic improvement through selection and breeding.

Genetic differences in resistance to internal parasites in sheep are observed (Bishop and Stear 1999, Stear *et al.*1995). There is indication of individual variance in susceptibility against TBF in sheep in Norway (Stuen 2003). There may, however, be many variables causing variation in resistance to ticks and TBF between individuals:

- Grazing behaviour: Variation between sheep breeds in foraging behaviour and diet selection (Steinheim *et al.* 2005). This may explain a variation in tick infestation, as sheep with different foraging behaviour will be exposed to ticks differently. Bush encroachment and indirect contact with wildlife, e.g. deer, may affect risk of tick infection.
- Maternal effects: Maternal abilities will affect the fitness of lambs and is an important factor for getting fit, strong and robust lambs. It is important to have animals that are in good condition in order to handle a disease infection properly.
- Robustness and genetic resistance against infection: Genetic variation between breeds and/or individuals within breeds in degree of robustness, tolerance or resistance to tick infection and TBF.

Exploiting a possible variation between breeds and/or individuals within breeds in host resistance and disease immunity in appropriate breeding schemes makes a sound basis for effective biological control of tick-borne diseases.

**3. Relevant information**

The report *Forskningsbehov innen dyrevelferd i Norge* (Norges Forskningråd 2005) states that tick-borne fever, along with "alveld", are the two most worrying and unsolved problems that causes production losses and suffering of sheep. The report also focuses on the importance of losses during grazing season in general, because the reasons for the loss of many animals on outlying pastures are unknown and not confirmed. Electronic surveillance of animals can be useful to confirm the cause of death and initiate preventive measures in time (www.telespor.no, Telenor 2004). In the above mentioned report one out of four prioritized research needs within general approaches to welfare is focusing one genetics and disease resistance. The Norwegian Association of Sheep and Goat Farmers have implemented a plan of action to ensure welfare in sheep production (Norsk sau og geitalslag 2001). They focus on TBF as an increased problem causing unacceptable welfare problems. Preventive measures on tick infested pastures are also prioritized issues here.

Organic farming has a main focus on animal welfare. However, knowledge on preventive measures and ensuring of sheep welfare is insufficient. NORSØK has a well developed network and know how in this field as a partner in the EU-funded SAFO-nettwork (www.safonetwork.org) dealing with animal health and food safety in organic farming, and through development of a welfare assessment system on cow welfare. Robust and healthy animals in a sound environment for the animals demand knowledge, follow-up and attention. Such indicators of sheep welfare, clear advice on farm management in light of sheep welfare and knowledge about factors affecting infection and disease resistance on pastures will contribute to a sound sheep production system.

## Hypotheses

Testing of the following main hypotheses will make the basis of this programme:

1. **Ticks and TBF cause substantial indirect losses through reduced weight gain, meat quality, economy and welfare.**
2. **Newborn lambs challenged to tick infested pasture develop active immunity against TBF.**
3. **There is genetic variance (between and/or within sheep breeds) in sheep's tolerance /resistance to ticks and TBF.**

## Methods

**Work package 1: Indirect losses**

Tick infested and non-infested areas will be studied with respect to indirect losses, such as reduced growth, poor slaughter quality, negative economic consequences and reduced welfare. The study will be carried out during the grazing season of 2006 and 2007. Additional data from previous years will also be used.

The Norwegian Sheep Recording System, National Organization of Pasture Management (OBB) and the Norwegian Research Centre for Meat will provide the data on weight, slaughter quality and losses of animals on pasture in order to study these indirect losses. About 30 % of all sheep farmers report data to The National Sheep Recording System, wheras about 80 % of all sheep farmers report data to OBB. All lambs are recorded at slaughter, and data on slaughter weight and quality are transferred to the Norwegian Sheep Recording System. By analyzing available data related to tick infested and tick free pastures, the extent of indirect losses will be revealed.

In collaboration with the OBB contact person working for the County Governor, a questionnaire will be sent to sheep farmers in the areas of interest. Hence, additional relevant information, i.e. birth weight and cause of death, will be obtained. Available data from previous years will be used and supplemented with the newer records. Statistical analyses of these data from tick infested and tick free pastures will be used to estimate the extent of the indirect losses. Blood serum tests will be taken from a sample of sheep during the two grazing seasons of 2006 and 2007 and will be used to define the status of tick infested or tick free pastures. Electronic surveillance (GPS) will be used in selected areas, and makes it possible to track the animal's movements and provides rapid information on occurrence and position of dead animals. Dead animals can easily be found and the causes of death ascertained. The history of the whereabouts of sheep is also useful data for interpreting grazing behaviour and tick infestation.

**Work package 2: Turn out time and immunity**

This will be carried out as on farm research on five sheep farms in tick infected areas, implying that sheep have been exposed to infection the previous year. Two groups of lambs in each flock will be treated as follows:

1) Lambs born on tick infested pasture
2) Lambs born in door and turned out at three weeks of age

Five farms and 30 sheep on each farm will be selected for each treatment. The animals within each flock will be randomly assigned to two treatments, giving 15 sheep and 30 lambs per treatment. The two groups of treatments will be made as equal as possible with respect to age, lambing time and number of lambs (two per ewe). Ewes will be serum tested for antibodies to *A. phagocytophilum* and screened for embryo counting. Lambs will be tested for antibodies to

*A. phagocytophilum* at birth (within the first week) and after 5 to 6 weeks of exposure to tick infested pasture. The lambs will be weighed once a week post partum until they are turned out on outlying fields, approximately 8 weeks post partum, and thereafter at the end of grazing on outlying fields and before slaughter. Slaughter weight and quality will also be collected as well as records of diseases and deaths. In addition, autopsy mortem (stating cause of death) on dead animals will be performed. Electronic surveillance by GPS collars will be used on sheep and lambs when they are on outlying fields. This is done to get rapid information of the position of dead animals in order to find them and ascertain the cause of death. The experiment will be carried out two consecutive years in order to investigate between-year variation in tick infestation.

**Work package 3: Disease resistance**
**3A: Genetic variance**
For the genetic analyses of lamb loss (TBF resistance), data from ram circles in tick infested areas will be used to ensure data of lambs sired by several rams in each flock. This will provide genetic ties between flocks (i.e. rams with offspring in several flocks and lambs of several sires in each flock), and make it possible to correct for environmental flock effects. We expect access to such data from about 5000 ewes on tick infected pastures giving approx. 10 000 lambs sired by a total of approx. 150 rams. This should give a sufficient dataset for estimating heritability for survival on tick-infested pasture. The data on losses and tick infestation of pasture as described in *Work package 1(Indirect losses)* together with breed and pedigree, will be analysed to estimate genetic variance in survival and tolerance to ticks. Survival will be used as indicators of degree of resistance to ticks on tick infested pastures. Electronic surveillance (GPS) will be used to get rapid information on dead lambs and their position, such that cause of death can be recorded by post mortem. The data will be analysed by appropriate mixed models for survival data using available statistical software, e.g. ASREML (Gilmour *et al.* 2002). Experiences and results from a currently running project in AKVAFORSK on methods for analyses of survival data in fish breeding programs will also be useful for choice of models for the genetic analyses of lamb survival (e.g. Ødegård *et al.* 2005). Threshold models, survival models and repeatability linear models are possible choices here also.

**3B: Breed**
An experimental study of differences between four Norwegian sheep breeds: Old Norwegian sheep/Wild sheep (Gammelnorsk sau/Villsau), Norwegian fur sheep, Norwegian short-tailed sheep (spælsau) and Norwegian white long-tailed sheep (NKS) in resistance to TBF will be conducted. The three latter breeds represent the most common breeds in Norway. In addition, 'Wild sheep' should be studied, because they may have passed through a stronger natural selection on tick infested pastures on the west coast. NKS is the breed that has been selected for production traits and may be less resistant to TBF. For each group (breed), 16 lambs will be tested for clinical manifestation and serological response after experimental infection with the bacteria *A. phagocytophilum*. The animals must be bought from tick free areas and tested for specific antibodies tested before the trial starts. Rectal temperature will be measured daily and blood samples will be obtained regularly. The experimental trial will last for two months. During this period the lambs will be stalled indoors to prevent exposure to ticks. Similar experimental trials have been done several times before at the Norwegian School of Veterinary Science (Stuen 2005). Different models for analyses of challenge test data are compared (Dinh, 2005; Ødegård et al, 2005) in the above mentioned project in AKVAFORSK. The results and experiences from this work on fish will also be useful for the analyses of the data from this challenge experiment of different sheep breeds.

## Information

The knowledge that will be developed by this programme is increasingly being demanded, and the results will provide valuable information to sheep farmers, both organic and conventional, especially in areas where ticks are common. The project will provide knowledge that can be used to make farmers aware of the production losses and welfare problems associated with TBF, and knowledge that can be used to advise farmers on pasture turn-out time and breeding strategies as preventative measure against TBF. And if so, the results will contribute to improved animal welfare, meat quality, production and economy in sheep farming.

**Scientific publications**

A minimum of three scientific papers will be published in international journals with referee. The papers will cover the following topics:

- Welfare problems and indirect production losses in sheep grazing tick infested pastures.
- The effect of turn out time on development of resistance to tick-borne fever.
- Genetic variance in resistance to tick-borne fever of sheep.

**Information to farmers and advisors**

The recommendations developed through this programme will be published in various leaflets as well as papers in Norwegian and International agricultural magazines through internet and other relevant media. The results of the programme will be disseminated on national and international conferences and workshops and technical meetings and workshops.

## Resources and professional position

The program will increase the participating institutions' expertise on sheep welfare with focus on preventive measures and disease resistance. Several disciplines are covered, and the combination of veterinary and animal sciences, with focus on immunology, breeding, variation in disease resistance, welfare and farm management creates a unique arena for implementing preventive measures in modern farming systems.

For NORSØK, it is important to increase the scientific competence of its staff by the PhD position included in the program. NORSØK's Strategic Plan (1999 - 2003) puts priority on establishing interdisciplinary expertise focusing on animal welfare, prevention of disease, robust animals and product quality in a sound farming system. Animal welfare is pointed out as a core activity for R&D in Bioforsk Økologisk. NORSØK's long experience in on-farm- and holistic research and animal welfare, together with expertise from the veterinary and genetic disciplines, is here combined to produce new knowledge on sound farming systems.

Dr. Ingrid Olesen at Akvaforsk will be responsible for supervision of the PhD student at NORSØK and provide supervision particularly related statistical analysis of the data and genetic analysis of survival and growth. Associate Professor Snorre Stuen at NVH will be supervisor for the PhD student having expertise on tick-borne fever, immunology and sheep. He will also be actively involved in carrying out Workpackage 2 and 3B.

The Association of Norwegian Sheep and Goat Farmers and The County Governors on the West-coast have stated the importance of carrying out this research programme and their willingness to contribute with knowledge on local conditions and facilitating contact with farmer groups and areas suitable for the project. Positive dialog has been made with Telespor AS, developing electronic surveillance based on GPS for sheep (www.telespor.no, Telenor

2004). Further collaboration will be developed when it comes to access of the technology for this project.

**International contacts:**
NORSØK's participation in the SAFO and NAHWOA networks, dealing with animal health and welfare, has given a wide contact network within Europe. There is established contact with other groups internationally working with TBF, sheep and disease resistance. One imporatant contact is Professor Mike J. Stear, Division of Animal Production and Public Health, Faculty of Veterinary Medicine, Glasgow University. He is professor of Immunogenetics and works with understanding and controlling host-parasite interactions. Glasgow University is welcoming a PhD student for a training period. Roslin Institute with prof Steve Bishop and the Scottish Agricultural College with prof Ilias Kyriazakis are also involved in research dealing with disease resistance and factors influencing tick infection. Contact has been made.

## Ethics

Improvement of animal welfare is a main focus in this programme. However, the ethical problems in carrying out some of the activities must be considered as animals will be involved in an experimental trial where they are infected with *A. phagocytophilum*. In work package 3B, described above, about 64 lambs will be infected with *A. phagocytophilum*. This will cause a fever reaction for about 4-6 days in lambs, with perhaps reduced appetite for 1-2 days. Apart from this there are no other clinical symptoms. The animals will be kept indoors due to pasture being infected by ticks and therefore not possible to use for the experimental animals. Temperature will be measured every day, clinical examination will be done every day and blood sampling will be done about once a week. The lambs are to be infected with infested blood directly into the blood (intravenous). There is no alternative method available to evaluate clinical effect of *A. phagocytophilum*. It will be applied for acceptance from the Norwegian Animal Research Authority to conduct the trial.

## Implications for the environment

Reduced use of drugs to prevent tick infection and to treat tick-borne fever will have positive implication for the environment.

## References

Axford, R.F.E., S.C. Bishop, F.W. Nicholas and J.B. Owen 2000. Breeding for Disease Resistance in Farm Animals. CABI publishing, Oxon.

Berg, L. 2002. Dyr er ikke bare mat. Om synet på dyrevelferd i Norge. Statens institutt for forbruksforskning. pp 62

Bishop, S.C and M.J. Stear 1999. Genetic and epidemiological relationships between productivity and disease resistance: gastro-intestinal parasite infection in growing lambs. *Animal Science* 69: 515-524

Brodie, T.A., P.H. Holmes, G.M. Urquhart 1986. Some aspects of tick-borne diseases of British sheep. Vet. Rec. 1986, 118, 415-18

Debio 2003. Regelverk for økologisk landbruksproduksjon.

Dinh, H. 2005. Genetic analysis of survival to furunculosis and ISA challenge test in Atlantic salmon. M.Sc. thesis, Department of Animal and Aquaculture Sciences, Norwegian University of Life Sciences, Ås. 40 pp.

Gilmour, A. R., B. R. Bullis, S. J. Welham, and R. Thompson 1999. ASREML reference manual. NSW Agric. Biometric Bulletin. No. 3. Orange Agricultural Institute, Orange, Australia.

Hunt, J. 1986. Pour-on licks ticks and swells fell margins. Farmers weekly April 25:24

Mikael Angeloff. NIJOS. Organisert beitebruk. www.nijos.no

Norges Forskningsråd, 2005. Forskningsbehov innen dyrevelferd i Norge. Rapport fra Styringsgruppen for Dyrevelferd – forsknings- og kunnskapsbehov. ISBN trykt utgave 82-12-02156-4 ISBN elektronisk utgave (pdf) 82-12-02157-2

Norsk sau og geitavlslag, 2001. Handlingsplan for dyrevelferd i saueholdet 2001 - 2003. 13 p

Ødegård J., I. Olesen, B. Gjerde and G. Klemetsdal 2005. Genetic analysis of survival data from challenge testing of Atlantic salmon for furunculosis resitance: Model comparisonwith respect to field survival. Submitted

Øverås, J. 1972. Sjukdom hos sau på *Ixodes ricinus* infisert beite. (Diseases of sheep on *Ixodes ricinus* infested pasture). Norsk Vet. Tidsskr. 1972, 83, 561-67.

Queensland Government, 2004. Animal and plant health. Tick fever (bovine babesiosis). Retrieved 09.08.2005 from Queensland Government, Department of Primary Industries and Fisheries. Web site: http://www.dpi.qld.gov.au/tickfever/2353.html

Ragnhild Vikesland. Norsk sau og geitalslag (The Norwegian Association for Sheep and Goat Farmers) www.nsg.no

Sonenshine D.E. 1993. Biology of ticks. Vol. 2, Oxford University Press, New York, 1993, 465 pp.

Statens legemiddelverk, 2001. Terapianbefaling: Antiparasittærbehandling av produksjonsdyr. Statens legemiddelverk, publikasjon 2001:06.

Stear, M.J., K. Bairden, J.L. Duncan, G. Gittinby, Q.A. McKellar, M. Murray and D.S. Wallace 1995. The distribution of faecal egg counts in Scottish Blackface lambs allowing natural, predominantly *Ostetagia circumcinta* infection. Parasitology 110: 573-581.

Steinheim, G., L.A. Nordheim, R.B. Weladji, I.J. Gordon, T. Ådnøy and Ø. Holand 2005. Differences in choices of diet between sheep breeds grazing mountain pastures in Norway. Acta Agriculturae Scandinavice Section A – Animal Science. Accepted 10.3.2005.

Stuen S., K. Bergström, E. Palmér 2002. Reduced weight gain due to subclinical *Anaplasma phagocytophilum* (formerly *Ehrlichia phagocytophila*) infection. *Experimental and Applied Acarology*, 2002, 28, 209-215

Stuen S. and K. Bergström 2001. Serological investigation of granulocytic *Ehrlichia* infection in sheep in Norway. *Acta veterinaria scandinavica*. 2001, 42, 331-338

Stuen S., A.Solli Oppegaard, K. Bergström and T. Moum 2005. *Anaplasma phagocytophilum* infection in North Norway. The first laboratory confirmed case. *Acta veterinaria scandinavica*, 2005, 46, 1-6

Stuen S, Ulvund M.J. and Waldeland H. 1998. Sjukdom hos sau. I: Saueboka, 2.utgave, Landbruksforlaget, 287-352

Stuen S., F. Hardeng, and H.J. Larsen 1992. Resistance to tick-borne fever in young lambs. Research in Veterinary Science 52: 211-216.

Stuen S. 2003. *Anaplasma phagocytophilum* (formerly *Ehrlichia phagocytophila*) infection in sheep and wild ruminants in Norway. A study on clinical manifestation, distribution and persistence, Thesis Dr. Philosophiae, 132pp

Stuen S. 1993. Tick-borne fever in lambs of different ages. *Acta veterinaria scandinavica* 1993, 34, 45-52

Stuen, S. 1996. Tick-born fever (TBF) and secondary infections in sheep. In : Kazár J, Toman R (eds.) Rickettsiae and rickettsial diseases. Veda, Bratislava, 1996, 347-349

Stuen, S. 1997. The distribution of tick-borne fever (TBF) in Norway. Nor. Vet. Tidsskr. 109:83-87. (In Norwegian.)

Stuen, S. 1998. Sjodogg (tick-borne fever) – et historisk tilbakeblikk. (Sjodogg (tick-borne fever) – a historical review). Norsk Vet. Tidsskr. 1998, 110, 703-706

Stuen, S. and K. Kjølleberg 2000. An investigation of lamb deaths on tick pastures in Norway. Proceedings of the 3rd International Conference "Ticks and Tick-borne Pathogenes: Into the 21st Century". Eds M. Kazimirová, M. Labuda and P.A. Nuttall. Institute of Zoology, Slovak Academy of Sciences, Bratislava, Slovakia. Pp 111-115

Stuen, S., F. Hardeng and H.J. Larsen 1992. Resistance to tick-borne fever in young lambs. Research in Veterinary Science 52: 2, 211-216

Stuen, S., M. Nyborg and J. Teigland 2005. Myiasis externa hos sau i Hordaland – data fra en spørreundersøkelse for beitesesongen 2003. Norsk veterinærtidsskrift. Nr 4 2005. pp 245-250

Synnøve Vatn. Helsetjenesten for sau (The National Health Service for Sheep) www.fagkjott.no

Telenor 2004. IT-overvåkning av sau på beite. Pressemelding 29.09.2004.

Telespor AS. www.telespor.no Last access August 2005

Wharton, R.H. 1983. Tick-borne livestock diseases and their vectors. Acaricide resistnace and alternative methods of tick control. In: Ticks and tick-borne diseases. Selected articles from the world animal review. FAO animal production and health paper 36. ISBN 92-5-101289-X

Woldehiwet, Z.and G.R. Scott 1993. Tick-borne (pasture) fever. In: Woldehiwet Z, Ristic M (eds): Rickettsial and chlamydial diseases of domestic animals. Pergamon Press, Oxford, 1993: 233-254