Culling and Mortality among Swedish Crossbred Sows

Linda Engblom
Faculty of Veterinary Medicine and Animal Science
Department of Animal Breeding and Genetics
Uppsala

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Abstract

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The aim of this thesis was to investigate culling and mortality among Swedish crossbred sows. Data collection was prospective (2002–2004) from 21 piglet producing herds in south-central Sweden. Average annual removal rate was 49.5%. Of 14 234 removed sows, 85.2% were slaughtered, 10.5% euthanized on farm and 4.3% found dead. Most sows were removed in low parities and soon after weaning. The most common removal reasons were reproductive disorders (26.9%), old age (18.9%) and udder problems (18.1%). In addition, 96 females euthanized or found dead in one herd during 2006 were post mortem examined. Most sows were euthanized due to lameness and had arthritis as primary finding. Removal hazard was estimated using survival analysis. The factor with highest impact on sow removal was days after farrowing, followed by parity and herd×year combination. Removal hazard was highest shortly after weaning and lowest in medium parity numbers. Moreover old age at first farrowing, small litters and long intervals between weaning and next farrowing resulted in high removal hazard. Genetic parameters were estimated on genetic material supplied by the breeding organisation Quality Genetics. Heritability for sow longevity was estimated from 0.03 to 0.12 with survival analysis and linear model analysis. Correlations between estimated breeding values for longevity traits and traits included in the running Swedish breeding evaluation were estimated. Sow longevity was significantly correlated with low age at first farrowing, high litter weight at three weeks, low growth rate (birth to 100 kg) and inferior conformation (measured at station). Genetic improvement of sow longevity would be possible by including stayability from first to second litter in the breeding evaluation.

Keywords: crossbred, genetic, length of productive life, lifetime production, longevity, mortality, removal reason, sow, stayability, survival analysis

Author's address: Linda Engblom, Department of Animal Breeding and Genetics, Swedish University of Agricultural Sciences, P.O. Box 7023, SE-750 07 Uppsala, Sweden.
E-mail: Linda.Engblom@hgen.slu.se

Till min älskade familj!

Contents

Appendix

Papers I-IV

The present thesis is based on the following papers, which will be referred to by their Roman numerals:

I. Engblom, L., Lundeheim, N., Dalin, A.-M. & Andersson, K. 2007. Sow removal in Swedish commercial herds. *Livestock Science 106*, 76-86.

II. Engblom, L., Eliasson-Selling, L., Lundeheim, N., Belák, K., Andersson, K. & Dalin, A.-M. 2008. Post mortem findings in sows and gilts euthanized or found dead in a large Swedish herd. (Submitted)

III. Engblom, L., Lundeheim, N., Strandberg, E., Schneider, M. D., Dalin, A.-M. & Andersson, K. 2008. Factors affecting length of productive life in Swedish commercial sows. *Journal of Animal Science 86,* 432-441.

IV. Engblom, L., Lundeheim, N., Schneider, M. D., Dalin, A.-M. & Andersson, K. 2008. Genetics of longevity in Swedish crossbred sows. (Submitted)

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Abbreviations

AFF	age at first farrowing
DAF	days after farrowing
$Days_{100kg}$	age at 100 kg live weight on farm (purebred animals)
EBV	estimated breeding value
Ext_N	exterior conformation score in nucleus herds (purebred animals)
Ext_S	exterior conformation score on testing station (purebred animals)
F_MO	farrowing month
Fat_{100kg}	backfat thickness at 100 kg live weight on farm (purebred animals)
HY	herd and year combination
LaPL	lameness-determined length of productive life, days
$LW_{3w}1$	litter weight at 3 weeks, parity 1 (purebred animals)
$LW_{3w}2$	litter weight at 3 weeks, parity 2 (purebred animals)
MPL	mortality-determined length of productive life, days
NPD	non-productive days
PAR	parity number
PAR×DAF	combination of PAR and DAF
PAR×PB	combination of PAR and PB
PB	total number piglets born in the litter
PBA1	piglets born alive, parity 1
$PBA1_c$	piglets born alive, parity 1 of crossbred sows
PBA2	piglets born alive, parity 2 (purebred sows)
PBA3	piglets born alive, parity 3 (purebred sows)
PL	productive life, days
RPL	reproductive disorders-determined length of productive life, days
STAY12	stayability from first to second litter
STAY13	stayability from first to third litter
UPL	udder problems-determined length of productive life, days
WF_INT	number of days between weaning and next farrowing
WSI_1	weaning to first service interval after parity 1 (purebred sows)

Introduction

Sow removal

Sow removal includes culling and mortality. There are two kinds of sow removal. The first kind, removal of old sows is a natural component of piglet production and is called planned removal. Planned removal also includes removal of sows with low productivity. The other kind of removal is called unplanned removal and includes removal of sows due to reasons such as reproductive failure, lameness and mortality. The unplanned removal often occurs in low parity numbers.

During the last decade sow removal has received more attention due to its economic and ethical importance. High removal rate is associated with poor longevity. When the average longevity is low, improvements can be highly profitable (Sehested, 1996). A decreased removal rate of sows reduces the costs for replacement gilts and thereby increases net income. Production systems with low replacement rates are the most profitable, as has been shown in a simulation study by Faust *el al.* (1993). According to Lucia, Dial & Marsh (2000a) and Stalder *et al.* (2003) at least three litters are required from a sow before it gives a positive cash flow for the producer. Other studies have estimated the optimal economic lifespan being at least five parities (Scholman & Dijkhuizen, 1989; Lucia, Dial & Marsh, 2000a; Rasmussen, 2004).

Removal pattern of sows differs depending on level in the breeding pyramid, see Figure 1. Purebred sows in nucleus herds at the top of the pyramid are often removed early in life due to lower breeding value compared with replacement stock, to achieve fast genetic improvement. Crossbred sows in the piglet producing herds at the bottom of the pyramid is under Swedish conditions recommended to be removed after parity eight, to implement the genetic improvements in the herd. A "theoretical" herd following this guideline and without removal of sows before their eight litter needs to replace 27.5% of the sows per year with gilts if the sows produce 2.2 litters every year.

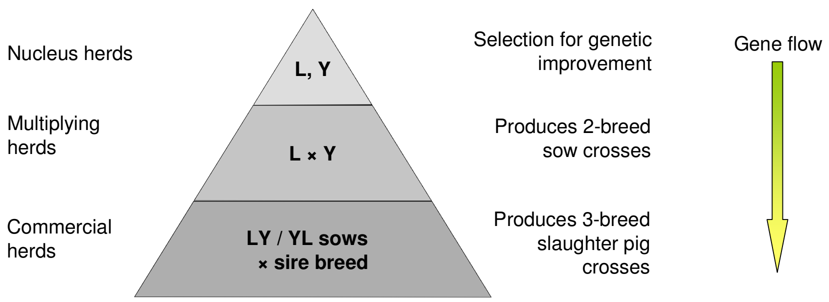

Fig. 1. Breeding structure in pig production.

Knowledge about the removal pattern among Swedish crossbred sows in commercial piglet producing herds is limited. A previous study from the beginning of the 1970s (based on 28,500 sows, mainly purebred Landrace and Yorkshire) showed that 45% of the sows were removed every year, that the average sow produced 4.5 litters before removal and that 20% of the sows were removed after first litter (Andersson, 1997). This study is more than 30 years old and was based on mainly purebred sows housed in individual stalls during gestation, a type of housing which since 1988 has been forbidden according to the Swedish animal welfare legislation. In addition, the Swedish herds are now larger and have batch-wise production. It is therefore of interest to investigate the removal pattern among Swedish crossbred sows of today.

Worldwide, annual removal rate (of sows in production) is reported to be around 50% (Dijkhuizen, Krabbenborg & Huirne, 1989; Boyle *et al.*, 1998; Rodriguez-Zas *et al.*, 2003) and most of the removals were unplanned. The most commonly reported reason for these unplanned removals was reproductive failure accounting for about 30% of all removals, followed by lameness and locomotory problems (11–14%) (Sehested & Schjerve, 1996; Boyle *et al.*, 1998; Lucia, Dial & Marsh, 2000b). The main proportion of removal was in low parity numbers. Approximately 15–20% of the removed sows had only produced one litter (Boyle *et al.*, 1998; López-Serrano *et al.*, 2000; Lucia, Dial & Marsh, 2000b), and the average parity number at removal reported in commercial herds was lower than 5 litters, with a range from 3.1 to 4.6 (Boyle *et al.*, 1998; Jørgensen, 2000; Rodriguez-Zas *et al.*, 2003; Akos & Bilkei, 2004). The highest proportion of young sows were removed due to unplanned removal (Dijkhuizen, Krabbenborg & Huirne, 1989; Boyle *et al.*, 1998; Le Cozler *et al.*, 1999) whereas the proportion of planned removal increased with higher parity numbers (Dijkhuizen, Krabbenborg & Huirne, 1989; Boyle *et al.*, 1998).

Today removal of sows includes a substantial proportion of sows that are not sent to slaughter, but are found dead or euthanized on farm. Sow mortality includes sows found dead. However, also sows euthanized on farm due to trauma or disease are generally also included in studies on mortality. Annual mortality rate (% of sows in production) have been reported to range from 3.4% to 6.9% (Stein *et al.*, 1990; D'Allaire, Drolet & Brodeur, 1996; Lucia, Dial & Marsh, 2000b). A recent Danish study reported that the sows found dead accounted for 11%, and the euthanized sows constituted 10% of the removed sows (Vestergaard, Baekbo & Svensmark, 2006). For sow mortality the reported primary findings at post mortem examinations vary between studies. Heart failure was reported to be the most common finding in two Canadian studies (Chagnon, D'Allaire & Drolet, 1991; D'Allaire, Drolet & Chagnon, 1991) whereas locomotory related findings were reported as most common in other (Christensen, Vraa-Andersen & Mousing, 1995; Irwin *et al.*, 2000; Sanz *et al.*, 2007). The proportion of sows euthanized on farm in Sweden, as well as the reasons for sow mortality are unknown and need be investigated.

Sow longevity

Sow longevity is the sow's ability to stay and produce at an acceptable level in the herd and it is determined by many factors. Not only is the sow's physical status important, but also season, management and housing. In addition, it is the herdsman's subjective decision that determines whether a sow is removed or not. In this decision the herdsman considers the sow's parity number, production, reproductive status, health status and herd structure, as well as access to replacement gilts of relevant reproductive status.

There are several definitions of sow longevity. It can be expressed as age at removal or as number of litters produced before removal. Stayability is a binomial trait measuring the sow's ability to reach a certain parity. Length of productive life is usually defined as the number of days from first farrowing to removal, and lifetime production is the number of piglets produced by the sow during that period. Functional longevity focus on unplanned removal unrelated to production i.e. culling of an animal at a time and for a reason not chosen by the farmer (Ducrocq *et al.*, 1988).

Longevity is not a normally distributed trait, which makes it somewhat difficult to analyse. Today survival analysis and linear model analyses are most commonly used. Survival analysis can handle both completed and uncompleted observations, which enables inclusion of individuals being alive when the study period ends (censored observations) and allows variables to change value (e.g. parity number) during the animal's life (time-dependent variables) as described by Kalbfleish & Prentice (1980). In addition, if removal reason information is available, longevity determined by a specific removal reason can be investigated with survival analysis (competing risk analysis).

Factors influencing sow removal and longevity

Both housing and production system has been reported to influence the removal pattern of sows (Morris *et al.*, 1998; Akos & Bilkei, 2004). It has been shown that herds keeping their sows on partially or totally slatted floor during gestation were likely to have higher annual removal rate (D'Allaire *et al.*, 1989). Olsson (1996) showed that loose-housed sows fed with electronic feeding systems during gestation were removed earlier than loose-housed sows fed in individual feeding stalls. In Sweden, the animal welfare legislation states that sows should be loose-housed and kept in groups during gestation. However, the removal pattern of Swedish sows in this system has not been investigated.

Diverging results have been reported for the effect of rearing intensities of the young gilt on her longevity as a sow. A Danish study reported increased leg weakness problems and reduced longevity due to high feeding intensity during rearing (Jørgensen & Sørensen, 1998), whereas a Swedish study found higher culling up to parity 3 of sows restrictedly fed (80% of ad libitum level) during their rearing period compared with sows fed ad libitum (Le Cozler *et al.*, 1999). Moreover the feed composition, the proportion protein versus energy, has been reported to influence stayability (Long *et al.*, 1998). However, different levels of nutrition during lactation have been reported not to influence sow longevity (Sigfridson, 1996) nor removal rate (Neil, Ogle & Annér, 1996).

The phenotypic association between backfat thickness and sow longevity is not clear. Two studies found unfavourable correlation, i.e. gilts with thicker backfat stayed and produced longer in the herd (Kangasniemi, 1996; Stalder *et al.*, 2005) whereas another study found no association (Rozeboom *et al.*, 1996) and a third study found that a intermediate optimum backfat (16–19 mm) at first farrowing was favourable for sow longevity (Tarrés *et al.*, 2006b). Association between longevity and conformation or exterior traits has been shown in several studies (Grindflek & Sehested, 1996; Ringmar Cederberg, 1999; Jørgensen, 2000). Moreover high age at first farrowing or mating was associated with lower longevity and lifetime production (Le Cozler *et al.*, 1998; Koketsu, Takahashi & Akachi, 1999).

Both the sows' parity number and production level influences the removal risk. The risk of removal increased with higher parity numbers as well as with decreasing litter size (Tarrés *et al.*, 2006a), and a large litter reduced the risk (Friendship *et al.*, 1986; Yazdi *et al.*, 2000a; Yazdi *et al.*, 2000b). Long weaning to service intervals in first parity sows was associated with high removal rate (Tantasuparuk *et al.*, 2001). Furthermore influence of lactation length has been investigated and one study found that sows with shorter lactation length had higher risk of being removed than those that had longer lactation length (Xue *et al.*, 1997) whereas another study found no clear association (Dagorn & Aumaitre, 1979).

Seasonal variation was found for proportion of sows removed due to reproductive failures, showing higher removal rate among sows weaned during summer (Dagorn & Aumaitre, 1979; Koketsu, Dial & King, 1997). Moreover mortality rate varied with season and was higher during summer months (Chagnon, D'Allaire & Drolet, 1991; Deen *et al.*, 2000).

Genetic influence on sow longevity

Several studies have shown that crossbred sows stay longer in the herd than purebred sows (Dagorn & Aumaitre, 1979; Kangasniemi, 1996; Jørgensen, 2000). The sire of the sow also influenced the sow's risk of removal (Yazdi *et al.*, 2000a; Yazdi *et al.*, 2000b). The genetic influence on sow longevity has been evaluated and recent studies have shown that selection can be an efficient way to improve longevity (Heusing, Hamann & Distl, 2005; Serenius, Stalder & Puonti, 2006; Tarrés *et al.*, 2006a). Selection can be performed directly on longevity and stayability, or indirectly through selection for component traits such as improved reproduction and conformation.

Heritability for sow longevity are reported in the range between 0.1 to 0.4 (López-Serrano *et al.*, 2000; Serenius & Stalder, 2004; Heusing, Hamann & Distl, 2005). Genetic correlations between longevity and reproductive traits have been reported to be favourable, i.e. good reproductive capacity was associated with higher longevity (Tholen *et al.*, 1996; Serenius & Stalder, 2004; Heusing, Hamann

& Distl, 2005) as well as between longevity and osteochondrosis/leg score, i.e. less osteochondrosis was associated with high longevity (López-Serrano *et al.*, 2000; Yazdi *et al.*, 2000a; Serenius & Stalder, 2004). The genetic correlation between sow longevity and growth rate recorded at performance testing was found to be significantly unfavourable (i.e. high growth rate was associated with inferior longevity) in one study (López-Serrano *et al.*, 2000) whereas another found no significant association (Serenius & Stalder, 2004). The genetic correlation between sow longevity and backfat thickness recorded at performance testing was found to be unfavourable (i.e. thin backfat depth was associated with inferior longevity) for Large White (López-Serrano *et al.*, 2000; Serenius & Stalder, 2004) but for Landrace only López-Serrano *et al.* (2000) found a significant (unfavourable) correlation.

Aims of the thesis

The overall aim of the present thesis was to investigate the culling and mortality among Swedish crossbred sows in commercial herds.

More specifically it aimed to:

- study the removal rate and pattern (parity, reproductive stage and reason) and their association with reproductive performance
- study the proportions of sows slaughtered, euthanized on farm or found dead
- study the post mortem findings for sows euthanized or found dead and to evaluate the association between clinical observed symptoms and post mortem findings
- study how sow longevity is affected by different factors
- study the genetic background (heritability and genetic correlations) of sow longevity
- study the possibilities to improve longevity of sows by including this trait, direct or indirect in the breeding evaluation.

Summary of the investigations

Materials

Herds

This thesis was based on data from commercial piglet producing herds. The herds were identified and selected with the assistance of the Swedish Animal Health Service as well as the breeding organisations (Quality Genetics and Avelspoolen). In 2001, 25 commercial piglet producing herds with 100 sows or more located in south-central part of Sweden were selected for the study. Criteria for selection were the herdsmen's ability to make reliable registrations in the herd monitoring program PigWin Sugg (Quality Genetics HB, Hörby). Of these 25 herds, 4 were unable to participate in the study, so data from 21 herds were finally included in Paper I and III. Across the 21 herds (2002–2004), mean and median sow numbers were 476 and 318, respectively. For Paper II material was in 2006 collected from 1 of the 21 herds with 2450 sows in production. Paper IV included data from 16 of the 21 herds which used genetic material from the breeding organisation Quality Genetics. Mean and median herd sizes for the 16 herds included in Paper IV were 544 and 329 respectively. During the study, some herds changed (increased or decreased) in size, but not by more than 15% of the initial herd size.

Housing system and management

In all the 21 herds production was batch-wise, i.e. a group of sows were weaned at the same time, bred within a short period of time, and kept together during pregnancy, resulting in farrowing within one week. Of the 21 herds, 4 were 'sow pools', i.e. systems in which a central unit supplies satellite units with pregnant sows in a leasing system. The pregnant sows are transported to the satellite units approximately 3 weeks before expected farrowing. After weaning, the sows are returned to the central unit to be mated for the next reproductive cycle or sent to slaughter. The number of satellite units for each sow pool varied between 5 and 13.

The number of sows in a batch varied between the 21 herds. So did the number of weeks between two batches, from 1 to 8 weeks. Sows were moved from gestation units to farrowing units between 1 and 5 days before expected parturition. Cross-fostering was practiced in all herds and the average lactation period was between 4 and 5 weeks (Swedish animal welfare legislation requires at least 4 weeks of lactation). After weaning, the sows were group-housed in a mating unit where they stayed, depending on the herd, for 1–7 weeks and were thereafter moved, still group-housed, to a gestation unit.

The housing of sows during mating and gestation:

- In 14 herds, sows were in the mating and gestation units kept in large groups (30–50 sows per large pen) on deep litter bedding (in most cases straw), mainly in uninsulated buildings (Figure 2). Of these 14 herds, 10 had individual feeding stalls in both mating and gestation units.

- In 5 herds, sows were kept on deep litter bedding in the mating unit in groups of 30–50 (Figure 2) but during at least a part of the gestation, these sows were kept in smaller groups (5–9 sows per pen) on concrete/partially slatted floor with access to straw (Figure 3 and 4).
- In 2 herds, the sows were kept in pens (5–9 sows per pen) with concrete/partially slatted floor during both mating and gestation (Figure 3 and 4).

Fig. 2. Loose-housing of sows in pens with deep straw bedding and individual feeding stalls.

Fig. 3. Sow pen with concrete/partially slatted floor with access to straw and individual feeding stalls.

Fig. 4. Sow pen with concrete/partially slatted floor with access to straw.

In all herds sows were housed in individual farrowing pens during farrowing and lactation (Figure 5). However, in one herd, lactating sows were grouped together with their litters on deep straw bedding (5–10 sows with the litters in one large pen) after approximately 2 weeks of lactation.

Fig. 5. Individual farrowing pen with a heating lamp in the piglet area (left corner).

After weaning, oestrus was checked twice (18 herds) or once (3 herds) a day. Artificial insemination was used extensively in all herds. Pregnancy was monitored with ultrasound equipment in all but one of the herds. Sows were removed if they returned to oestrus after first mating (4 herds), after second mating (13 herds) or after three or more returns to oestrus (4 herds)

The main component of the feed (grain, mainly barley) was produced on the farm (18 herds) or purchased (3 herds). This grain was supplemented with commercial concentrate or premix of vitamins and minerals. Sows were fed dry feed (7 herds) or liquid feed (14 herds). During lactation the sows were either fed ad libitum or given a ration based on litter size. A sow with 10 piglets was, according this standard ratio given at least 101 MJ/day (Simonsson, 1994). From weaning until service approximately half of the amount fed during lactation was given. During the gestation period the sows were fed 25–40 MJ per day. Extra feed was given during the cold period of the year to sows kept in uninsulated buildings as well as to thin sows.

Animals

The sows included in this thesis were (except for 7 purebred Landrace in Paper II) crossbred Landrace×Yorkshire in various combinations. The genetic material in Paper I and III was supplied by 'Quality Genetics' (16 herds) or 'Norsvin' (5 herds), while Paper IV only included genetic material from Quality Genetics. For replacement, one herd had its own multiplying unit and seven herds used two-breed rotational crossing. In the remaining 13 herds, gilts were purchased from multiplying herds, either as young, prepubertal gilts (about 30 kg, 8 herds) or as pregnant gilts (7 herds). The purchased animals were isolated in separate buildings (in quarantine) for at least 3 weeks before entering the herd. All the herds followed the vaccination recommendations given by the Swedish Animal Health Service; vaccinations against porcine parvovirus, erysipelas and E. coli enteritis (both gilts and sows). Four herds also vaccinated against mycoplasma pneumonia. All 21 herds were free from sarcoptic mange.

Methods

Data collection I (Paper I, III and IV)

Data collection started in January 2002 and continued for 3 years. After an initial visit, the herds were revisited approximately 3, 6, 12, 20, and 30 months later. At each visit, data were collected electronically from the herd monitoring program PigWin Sugg and additional information was recorded on paper. Data were checked for obvious errors and if possible, corrected or otherwise excluded. Information about herd characteristics was also collected at these visits.

From the herd monitoring program, the following parameters were extracted for each sow: birth information (date and birth herd), breed composition, reproductive data (dates for mating, farrowing and weaning, total number of piglets born, born alive and weaned), and information about removal (date and reason). The removal reasons were grouped into removal categories (Paper I), see Table 1. Herd staff also recorded whether the sow was sent to slaughter, euthanized or found dead, but no information on cause of death was included.

Table 1. *Removal categories and removal reasons*

Removal category	Removal reasons
Reproductive disorders	Weak or no oestrus, return to oestrus, not pregnant, long intervals between farrowings, abortions, mummification, endometritis, discharge, dystocia, vaginal and rectum prolapse
Low productivity	Inadequate performance: small litters, uneven litters and low number of weaned piglets, including sows that crushed many piglets
Udder problems	Low or no milk production, mastitis, udder abscess
Lameness	Lameness, arthritis, hoof injuries, hoof abscess
Traumatic injuries	Acute injuries, wounds, leg fractures, paralysis
Inferior body condition	Inappetence, abscess, sore on the shoulders, general bad condition
Found dead	Animals found dead
Old age	Old age
Miscellaneous	Behavioural disturbances, no specified reason

Data collection II (Paper II)

To obtain more information about sows euthanized or found dead, a second data collection was performed during 2006 from one of the herds, a sow pool. The sow pool with 2200 crossbred Landrace×Yorkshire sows had a central unit supplying 13 satellite units with pregnant sows within a leasing system. At the site of the central unit there was also a multiplying unit with 250 purebred Yorkshire and Landrace sows producing crossbred gilts for the sow pool. From January 22 to September 4 2006, altogether 130 sows and gilts (old enough to be mated, parity 0) were euthanized or found dead in the central unit, satellites units or in the multiplying unit. Of these 130 animals, 96 carcasses after 70 sows and 26 gilts were transported to the National Veterinary Institute (SVA) in Uppsala for post mortem examination. Of 32 sows/gilts found dead 17 (53%) were post mortem examined, and of 98 sows euthanized 79 (81%) were examined. Post mortem examination was performed according to standard procedure. The carcasses were cut open and all inner organs were taken out and examined. When necessary, bacteriological and histological samples were taken for further analyses. Moreover production data for each individual sow/gilt were collected from PigWin Sugg.

Data preparation

Paper I, III and IV included data on crossbred Landrace×Yorkshire sows with at least one farrowing. A general restriction was imposed to avoid sows with erroneously reported dates of birth or farrowing. Sows whose first litter was recorded to be born before 290, or later than 480 days of age were excluded from the analyses. Further restrictions were placed on the data: sows that produced their first litter in “another herd” were excluded from the analyses, as were sows sold to “another herd” (these restrictions affected only few sows in few herds).

Paper I included data on 14 234 sows removed from January 1, 2002 to December 31, 2004. Paper II included 96 sows and gilts post mortem examined. Paper III and IV included sows with at least one farrowing from January 1, 2001 to

December 31, 2004. The data in both these papers were left truncated at January 1, 2001. Left truncation of the data allowed inclusion of all sow present in the herds, irrespective of parity number. In addition, records were treated as censored if the sow was still alive at the end of the studied period on December 31, 2004. The data set was prepared with time dependent variables changing value during the sow's life. Paper III included data on 20 310 sows, whereas Paper IV only included sows with pedigree information (identity of the sire of the sow) where the sire of the crossbred sow was supplied by Quality Genetics, resulting in records of 10 373 sows. For more detailed information about the number of observations in each of the traits observed, see Paper III and IV.

To be able to perform genetic analyses (Paper IV), the data set was split into two sets according to the breed of the sire of the sows, i.e. Landrace sires (LS) and Yorkshire sires (YS). The final two data sets used in the analyses consisted of 3626 sows offspring of 319 LS (LS_sow) and 6747 sows offspring of 315 YS (YS_sow). The pedigrees used in the analyses included only information on the pedigree of the sire of the crossbred sow. The dam of the sows were in most cases of the other breed, or breed combination and often with for us unknown pedigree.

Breeding evaluation (Paper IV)

For Paper IV estimated breeding values, EBVs (June 2007) for the sires of the crossbred sows were obtained from the breeding organization Quality Genetics. The traits evaluated in the running Swedish breeding evaluation are:

- piglets born alive in parity 1 (PBA1), parity 2 (PBA2) and parity 3 (PBA3)
- weaning to first service interval after parity 1 (WSI_1)
- age at first farrowing (AFF)
- litter weight at 3 weeks in parity 1 ($LW_{3w}1$) and parity 2 ($LW_{3w}2$), both adjusted for differences in litter size
- age at 100 kg live weight at farm test (Age_{100kg})
- backfat thickness at 100 kg live weight at farm test (Fat_{100kg})
- exterior conformation score (legs and gait) in nucleus herds (Ext_N) and at boar testing station (Ext_S). A high EBV is desirable for Ext_N whereas a low EBV is desirable for Ext_S.

Statistical methods

For Papers I and II descriptive statistics (means and frequencies) were performed with the SAS program, version 9 (SAS Institute, Inc, Cary, NC, USA).

For Papers III and IV survival analysis (Paper III and IV) and linear models (Paper IV) were applied for the data analyses. The software packages used were Survival Kit V3.12 (Ducrocq & Sölkner, 1998) and DMU (Madsen & Jensen, 2000), respectively.

Survival analysis

Removal hazard during productive life (PL_{SA}) was analysed. The definition of PL_{SA} was the number of days between first farrowing and removal or the termination of data collection (December 31, 2004). In Paper III competing risk analyses were performed for reproductive disorders-determined length of productive life (RPL), udder problems-determined length of productive life (UPL), lameness-determined length of productive life (LaPL), and mortality-determined length of productive life (MPL). Table 1 lists the removal reasons regarded in these four longevity traits. In the competing risk analyses, in addition to the censoring rules for PL_{SA}, records were treated as censored where the removal code did not correspond with the specific cause of removal being analyzed.

Removal hazard during productive life was analyzed in survival analysis using the following Weibull model:

$$h(t) = h_0(t) \exp [x(t)'\beta + z(t)'u]$$

where $h_0(t)$ is the baseline hazard function $\lambda\rho (\lambda t)^{\rho - 1}$, assumed to follow a Weibull distribution with scale parameter λ and shape parameter ρ; t is time in days from first farrowing; β contains the fixed (possibly time-dependent) covariates affecting the hazard, with the corresponding design vectors x(t)' and u is a vector of random (possibly time-dependent) variables with associated incidence vector z(t)'.

In Paper III, three models (1 to 3) were applied to determine the overall risk for removal (PL). In the competing risk analyses of RPL, UPL, LPL, and MPL only Model 1 was used. The models were as follows:

Model 1: DAF + PAR + HY + PB + WF_INT + F_MO + AFF
Model 2: DAF + PAR×PB + HY + WF_INT + F_MO + AFF
Model 3: PAR×DAF + HY + PB + WF_INT + F_MO + AFF

The covariates in these statistical models were:

- number of days after farrowing (DAF), fixed time-dependent with 15 classes, changed at 0 d, 10 d, 20 d … 140 d after each farrowing
- parity number (PAR), fixed time-dependent with 9 classes, changed at each farrowing date up to parity 9 (higher parities were grouped with parity 9)
- combination of herd and year (HY), fixed time-dependent with 63 classes, changed at January 1 each year
- total number piglets born in the litter (PB), fixed time-dependent with 7 classes (≤ 7, 8–9, 10–11, 12–13, 14–15, 16–17, ≥ 18), changed at each farrowing date
- number of days between weaning and next farrowing (WF_INT), fixed time-dependent (weaning to service interval + gestation length + non-productive days) with 5 classes (≤ 119, 120–122, 123–136, 137–157, ≥ 158; parity 1 sows were included in class 120–122 d), changed at each farrowing date
- farrowing month (F_MO), fixed time-dependent with 12 classes, changed the first day of every calendar month
- age at first farrowing (AFF), fixed time-independent with 5 classes (≤ 10 mo, 11 mo, 12 mo, 13 mo, ≥ 14 mo)
- combination of PAR and PB (PAR×PB), fixed time-dependent with 63 classes

- combination of PAR and DAF (PAR×DAF), fixed time-dependent with 135 classes.

The model applied in Paper IV in the survival analysis of PL_{SA} included:
- herd-year combination (HY), random time-dependent, assumed to follow a log-gamma (γ) distribution and was integrated out in the analyses.
- farrowing month (F_MO), fixed time-dependent
- sire, random time-independent assumed to follow normal distribution

At survival analysis of longevity traits, a low value is desirable and means low removal hazard. The order of the factor's influence on the removal risk for the five traits (Paper III) was measured by their contribution to the likelihood function (R^2 of Maddala) of the full model. The solution for a fixed factor is expressed as a hazard ratio. Hazard ratio is defined as the ratio between the estimated hazard for being removed under the influence of certain environmental or genetic factors and the estimated hazard for a single reference class. Thus, hazard ratio is a ratio describing the relative risk of removal. For PL_{SA} heritability (Paper IV) was calculated as suggested by Yazdi *et al*. (2002):

$$h^2 = [4\sigma_s^2] / [\sigma_s^2 + (1 / p)]$$

where σ_s^2 is the sire variance and p is the proportion uncensored records.

Linear model analysis

For the linear models analyses in Paper IV five traits were constructed. Two stayability traits, stayability from first to second litter (STAY12) and from first to third litter (STAY13), were assigned a value of 0 for a sow removed before 2nd or 3rd parity respectively, and 1 for a sow surviving up to 2nd or to 3rd litter, respectively following López-Serrano *et al.* (2000). The third linear trait, length of productive life (PL_{LM}) was defined as the number of days from the first farrowing to culling. The difference compared with PL_{SA} (survival analysis) is that only complete records, i.e. only sows which had been removed before December 31, 2004, were included in PL_{LM} (linear models). The fourth linear trait, lifetime production was determined as the number of piglets born alive during the PL_{LM} of the sow. In addition to these four longevity traits, the number of piglets born alive in parity 1 for crossbred sows ($PBA1_C$) was also included in the analyses as a reference trait.

In the linear analyses co(variance) components were estimated using the average information (DMU AI) residual maximum likelihood (REML) algorithm based on mixed linear models (Madsen & Jensen, 2000). Linear model analysis was performed using the following animal model:

$$y = Xb + Zu + e$$

where y is the vector of observations of the traits considered one trait (univariate) or two traits (bivariate) at a time, X and Z are the incidence matrices for fixed (b) and random (u) effects, and e is the vector of residuals.

The model fitted for the five linear traits included the random effect of animal, the fixed effect of herd, the fixed effect of year and the random effect of herd×year×period (hyp) combination. Period (last farrowing) was here set as two-month periods. The random effect of animal was assumed to be normally distributed with zero means and variances of $\mathbf{A}\sigma_a^2$, where **A** is the additive relationship matrix. The pedigrees used in the analyses included information on dam and sire of the sow and information on the pedigree of the sire. The heritability was calculated as:

$$h^2 = \sigma_a^2 / (\sigma_a^2 + \sigma_{hyp}^2 + \sigma_e^2)$$

Correlations

In Paper IV genetic (r_g) and phenotypic (r_p) correlations were estimated in the bivariate linear analyses. In addition, correlations between sires EBVs (r_EBV) for longevity traits as well as between longevity traits and traits included in the running Swedish breeding evaluation (Quality Genetics) were estimated using Spearman rank correlations. In these calculations only sires with at least 10 female offspring in the data were included.

Main results

Removal rate (Paper I)

The removal pattern differed between the 21 herds, both in age structure and removal reasons. The annual removal rate was on average 50%, and ranged from 34% to 66% between herds. The percentage of sows that were sent to slaughter was high, on average 85.2%. The remaining proportion was euthanized at farm (10.5%) or found dead (4.3%). The proportion of sows sent to slaughter increased with higher parity number, while the proportion of euthanized sows decreased. The proportion slaughtered was higher than the proportion euthanized for all removal reasons but traumatic injuries including fractures, of which 81.6% were euthanized.

Non-genetic factors influencing sow longevity (Paper I and III)

All factors investigated in Paper III significantly influenced the removal hazard (PL). The order of impact was:

1. days after farrowing (DAF)
2. parity number (PAR)
3. herd and year combination (HY)
4. total number piglets born in the litter (PB)
5. days between weaning and next farrowing (WF_INT)
6. farrowing month (F_MO)
7. age at first farrowing (AFF)

The six first factors were significant at $p<0.001$ and AFF was significant at $p=0.005$.

Reproductive stage

Most sows were removed during a short period after weaning (Paper I), see Figure 6a. The removal hazard was higher ($p<0.001$) 30 to 40 days after farrowing compared with other periods. The same hazard pattern was found in all parity numbers, but more accentuated in higher parities (Paper III), see Figure 6b.

Parity number

On average the sows produced 4.4 litters before they were removed. Among the removed sows the proportion low parity number sows was highest, see Figure 7, but the variation between herds was large. The average proportion of sows removed after first parity was 17%, ranging from 6% to 30% between herds (Paper I). The removal hazard was high in parity 1 but even higher from parity eight (Paper III), see Figure 7.

Herd and year

There was a large variation between the 21 herds regarding removal pattern. The average removal parity number ranged from 3.4 to 4.7 between herds (Paper I).

Production level

On average the removed sows had produced 11.6 PBA per litter and 24.9 PBA per herd year. Both PBA per parity and piglets weaned per parity increased with higher removal parity number. Over their lifetime removed sows on average accumulated 55.9 PB, 52.7 PBA and 44.1 piglets weaned (Paper I). The production level of the sow influenced the removal risk. Sows with small litters (≤ 9 piglets born) had 24% to 60% higher ($p<0.001$) hazard for removal than those with litters of 12 to 13 piglets born and this pattern was seen in all parities. This higher hazard for small litters was accentuated in higher parity numbers (Paper III).

Non-productive days

On average, removed sows had 25 non-productive days per parity and 67 days between last farrowing and removal. Both number of NPD per parity and the interval between last farrowing to removal decreased with higher removal parity number (Paper I). Intervals between weaning to next farrowing of 120 to 122 days resulted in lower ($p<0.001$) hazard than shorter or longer intervals. Sows with 120 to 122 days interval showed oestrus, were inseminated 5 to 7 days after weaning, and became pregnant at this first mating. Intervals longer than 137 days, indicating at least one return to oestrus resulted in at least 50% higher ($p<0.001$) hazard for removal compared with 120 to 122 days intervals (Paper III).

Farrowing month

Farrowing month was a significant factor influencing sow removal but the overall pattern was not clear (Paper III).

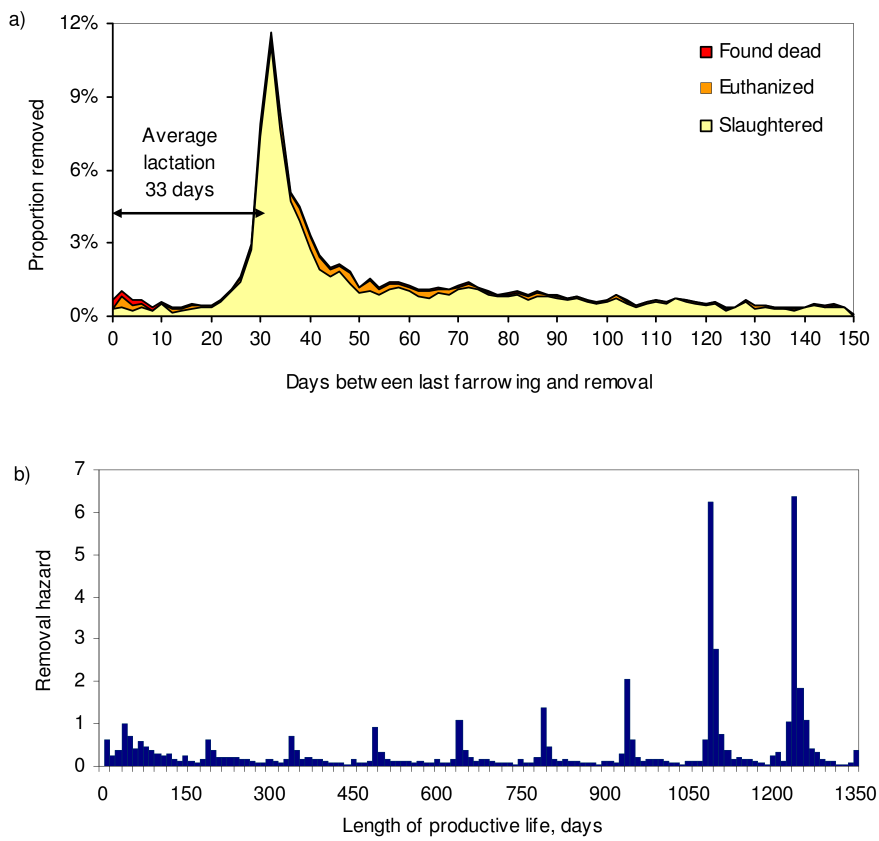

Fig. 6. a) Proportion removed during the reproductive cycle (Paper I); b) removal hazard during the productive life (Paper III).

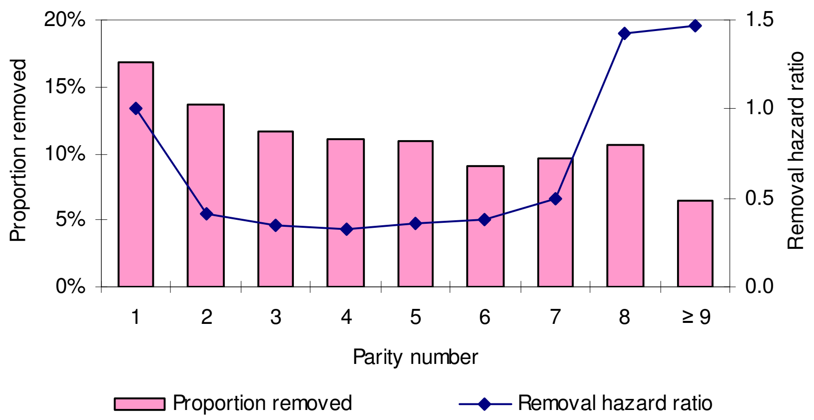

Fig. 7. Proportion of sows removed within parity numbers (Paper I) and removal hazard ratio with parity 1 as reference class (Paper III).

Age at first farrowing

Average age at first farrowing was 365 days (Paper I). Sows being 14 months or older at the first farrowing had 16% higher (p<0.001) removal risk than sows that were 12 months at their first farrowing (Paper III).

Removal reasons (Paper I and III)

The proportion of sows removed due to different removal reasons varied considerably between herds. Overall, main removal reasons were reproductive disorders (26.9%), old age (18.7%) and udder problems (18.1%). Low productivity accounted for 9.5% and lameness including claw lesions for 8.6% of the removals (Paper I).

The distribution of the removal reasons differed between parity numbers (Paper I), see Figure 8. In the lower parities (1–3) most sows were removed due to reproductive problems. Traumatic injuries and lameness including foot lesions were also most frequent in first parity and decreased with higher parity numbers. Removal due to udder problems was most common in medium parity numbers (3–6), whereas most sows in parity 7 and higher were removed due to old age.

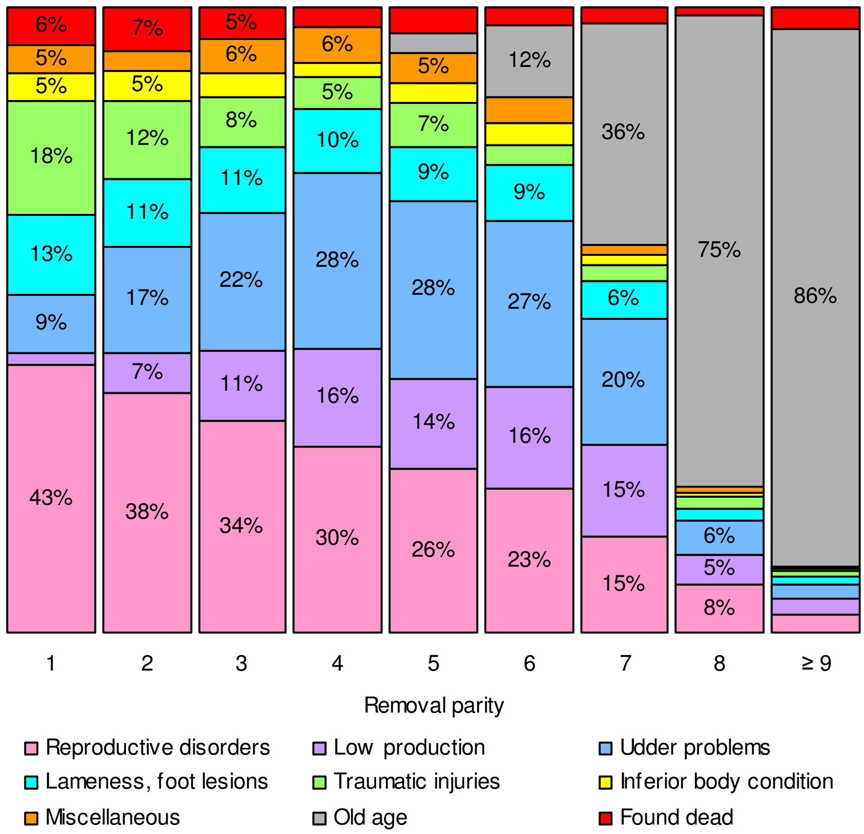

Fig. 8. Average proportion (%) of sows per removal category within removal parity. Only categories within parity with a proportion of at least 5% are presented with figures.

Planned removal was due to low production or old age. Sows removed due to low production had low numbers of PBA (10.3) and weaned piglets (8.8) per parity and the shortest interval from last farrowing to removal (40.1). Sows removed due to old age had the highest production level (PBA), both per parity (12.2) and per herd year (27.9). These sows also had the lowest number of non-productive days per parity (9.0) and short interval between last farrowing and removal (43.5, Paper I). The remaining removal reasons were unplanned removal reasons and four of them were investigated further in Paper III to determine and assess the factors influencing the specific removal hazard.

Reproductive disorders, RPL

Reproductive disorders were mainly due to return to oestrus (Paper I). The significant factors (Paper III) influencing the length of reproductive disorders-determined length of productive life (RPL) were in descending order of impact:

1. Parity. The hazard for removal was higher ($p<0.001$) in parity 1 than in higher parity numbers (Paper III).
2. HY. The proportion of sows removed due to reproductive disorders ranged from 11% to 51% between herds (Paper I).
3. F_MO. The hazard for removal was higher ($p<0.05$) in January, February, September and October than in July (Paper III).
4. AFF. Sows being 14 months or older at their first farrowing had 21% higher ($p<0.01$) hazard for removal than those being 12 months at their first farrowing (Paper III).
5. DAF. Of the sows removed due to reproductive disorders, 87% were removed 60–150 days after last farrowing (Paper I) and the removal hazard was highest 70–100 days after farrowing (Paper III).
6. PB. Sows with litters of 7 piglets born or less had 21% higher ($p<0.001$) hazard for removal than those with litters of 12 to 13 piglets (Paper III).
7. WF_INT. Sows with intervals longer than 137 days between weaning and next farrowing had 60 to 100% higher ($p<0.001$) hazard for removal than those with 120–122 days interval (Paper III).

Sows removed due to reproductive disorder had just below average PBA per parity (11.4) but the high number of non-productive days per parity (50.6) resulted in low annual production, 21.9 PBA per year (Paper I).

Udder problems, UPL

Udder problems were mainly due to mastitis including udder abscesses (Paper I). The significant factors (Paper III) influencing the length of udder problems-determined length of productive life (UPL) were in descending order of impact:

1. DAF. Sows removed due to udder problems were mainly removed soon after weaning (Paper I). The hazard for removal was highest ($p<0.001$) 30 to 40 days after farrowing (Paper III).
2. HY. The proportion of sows removed due to udder problems ranged from 2% to 36% between herds (Paper I).
3. Parity. The removal hazard was higher ($p<0.001$) in parity 1 than in higher parity numbers (Paper III).

4. F_MO. The hazard was higher ($p<0.01$) in December than in July.
5. WF_INT. The removal hazard was higher ($p<0.001$) for intervals ≤ 119 days and 123 to 136 days between weaning and next farrowing than for the 120 to 122 days interval (Paper III).
6. PB. Sows with litters of 9 piglets or less had more than 20% higher ($p<0.01$) hazard for removal than those with litters of 12 to 13 piglets (Paper III).

Sows removed due to udder problems had high annual production (26.7 PBA), few NPD per parity (14.1) and short interval between last farrowing and removal (44.9, Paper I).

Lameness, LaPL

Lameness also included foot lesions and 32% of these sows were euthanized at farm (Paper I). The significant factors (Paper III) influencing the length of lameness determined length of productive life (LaPL) were in descending order of impact:

1. DAF. The hazard for removal was highest ($p<0.001$) 30 to 40 days after farrowing (Paper III).
2. HY. The proportion of sows removed due to lameness including foot lesions ranged from 1% to 20% between herds (Paper I).
3. Parity. The hazard for removal was higher ($p<0.001$) in first parity than in higher parity numbers (Paper III).
4. WF_INT. The removal hazard was higher ($p<0.001$) for intervals 137 to 157 days between weaning and next farrowing than for the 120 to 122 days interval (Paper III).

Sows removed due to lameness had average production level, 24.6 PBA per year and average non-productive days (22.6, Paper I).

Found dead, MPL

The significant factors (Paper III) influencing the length of mortality determined length of productive life (MPL) were in descending order of impact:

1. HY. The proportion found dead varied from 2% to 8% between the herds (Paper I).
2. DAF. Most of these sows were found dead soon after farrowing (Paper I). The hazard was highest 0–10 days after farrowing (Paper III).
3. Parity. The proportion found dead was highest in low parity numbers (Paper I) whereas mortality hazard was highest ($p<0.001$) in parity numbers from 8 (Paper III).
4. F_MO. The mortality hazard was higher ($p<0.05$) during July and August (Paper III).
5. PB. Sows with litters of 7 piglets or less had 82% higher mortality hazard ($p<0.001$) than those with litters of 12 to 13 piglets (Paper III).

The production level of sows found dead was at average level with 24.6 PBA per year whereas the non-productive days per parity, 23.4 was somewhat lower than average (Paper I).

Post mortem findings in sows/gilts found dead or euthanized on farm (Paper II)

Of the 96 post mortem examined carcasses, 70 were from sows and 26 from gilts. Common findings at post mortem examination of sows/gilts found dead (n=17) were circulatory failure (n=4) and trauma related injuries (n=4). Most of the sows/gilts found dead (n=12) did not show any previous clinical symptoms. The most common finding at examination of euthanized sows/gilts (n=79) was arthritis (n=35), followed by osteochondrosis (including epifysiolysis, n=13) and fractures (n=10). Arthritis was in all cases but one of chronic, purulent type and commonly found in elbow, stifle and/or shoulder. Lameness was the most common observed symptom for animals with the primary finding arthritis, osteochondrosis and fracture. Notably, in 43% of the cases with primary post mortem finding arthritis, the clinical symptoms suggested it being a fracture. Of all findings (including the incidental findings) the most common were arthritis (45%), one or more abscesses (39%) and teeth injuries (31%).

Genetic impact on sow longevity (Paper IV)

The genetic analyses of sow longevity (PL_{SA}) showed that the sire of the crossbred sows influenced their longevity. The sows after the worst sire had 1.7 times higher (LS_sow) and 2.4 times higher (YS_sow) risk of removal than sows after the best sire. Heritability of longevity was estimated at 0.06 (LS_sow) and 0.12 (YS_sow) with survival analysis (PL_{SA}) and at 0.03 to 0.08 with linear model analyses (STAY12, STAY13, PL_{LM}, LTP), see Table 2.

Table 2. *Heritability estimates (diagonal), genetic / [estimated breeding value]* * *(above the diagonal) and phenotypic (below the diagonal) correlations between longevity traits and piglets born alive ($PBA1_C$). Standard errors are given as subscripts for the linear traits*

Trait	Data set	PL_{SA}	STAY12	STAY13	PL_{LM}	LTP	$PBA1_C$
PL_{SA}*	LS_sow	**0.06**	[-0.56]	[-0.53]	[-0.58]	[-0.60]	[-0.03]
	YS_sow	**0.12**	[-0.52]	[-0.43]	[-0.36]	[-0.29]	[0.04]
STAY12	LS_sow	-	**$0.04_{.02}$**	$1.00_{.17}$	$0.81_{.29}$	$0.93_{.42}$	$-0.29_{.28}$
	YS_sow	-	**$0.03_{.01}$**	$0.98_{.07}$	$0.72_{.18}$	$0.61_{.19}$	$0.03_{.26}$
STAY13	LS_sow	-	0.66	**$0.05_{.03}$**	$0.62_{.23}$	$0.68_{.23}$	$-0.21_{.32}$
	YS_sow	-	0.67	**$0.06_{.02}$**	$0.97_{.08}$	$0.78_{.11}$	$0.14_{.22}$
PL_{LM}	LS_sow	-	0.56	0.77	**$0.04_{.03}$**	$1.00_{.01}$	$-0.62_{.40}$
	YS_sow	-	0.50	0.68	**$0.05_{.02}$**	$1.00_{.00}$	$-0.13_{.27}$
LTP	LS_sow	-	0.51	0.70	0.84	**$0.03_{.03}$**	$-0.34_{.49}$
	YS_sow	-	0.44	0.63	0.80	**$0.08_{.03}$**	$0.47_{.20}$
$PBA1_C$	LS_sow	-	0.07	0.06	0.08	0.20	**$0.12_{.03}$**
	YS_sow	-	0.03	0.05	0.04	0.21	**$0.06_{.02}$**

PL_{SA}= PL analysed with survival analysis, PL_{LM}= PL analysed with linear model

* correlations between PL_{SA} and the other traits studied were calculated from estimated breeding values using Spearman rank correlations and are presented within square brackets.

Genetic correlations between the four linear longevity traits analysed were all high and positive (0.6 to 1.0), as well as the phenotypic correlations (0.5 to 0.8), see Table 2. The correlations between sires EBVs for all the five longevity traits were all significant (p<0.001) and moderate to strong. The r_EBV for the linear traits were all in the same direction as the genetic correlations shown in Table 2.

However, the level of the correlations was lower for all traits, except between STAY13 and PL_{LM} in LS_sire which was at the same level.

The EBV correlations between the longevity traits and the traits included in the present Swedish breeding evaluation (Quality Genetics) were in few cases significant:

- Age at first farrowing (AFF) was significantly ($p<0.001$) favourable correlated with STAY12 (-0.31) and significantly ($p<0.05$) favourable to STAY13 (-0.20). This means that lower age at first farrowing was associated with high stayability for crossbred sows.
- Mothering ability expressed by litter weight at three weeks (only available for Yorkshire sires) was significantly ($p<0.05$) favourable correlated to LTP (0.19 and 0.20) and to LPL (0.13). This means that purebred sows having heavy litters were associated with longer life and higher lifetime production for crossbred sows.
- Growth rate (Age_{100kg}) was significantly ($p<0.01$) unfavourable correlated with STAY12 (0.32) in the data set with Landrace sires. This means that high growth rate was associated with low stayability for crossbred sows.
- The exterior conformation trait recorded at testing station (Ext_S, only available for Yorkshire sires) was significantly ($p<0.05$) unfavourable correlated with PL_{SA} analysed with survival analysis (-0.20). This means that a desirable conformation at testing station was associated with shorter productive life for crossbreed sows.

The EBV correlation between “the same trait” (PBA1) recorded on crossbred sows in commercial herds and on purebred sows in nucleus and multiplying herds were significant ($p<0.01$) and estimated at 0.32 (LS) and 0.36 (YS).

General discussion

This thesis was performed to investigate culling and mortality among Swedish crossbred sows in commercial piglet producing herds. High removal rates and early unplanned removal is likely to reduce production and influence herd economics negative. It is therefore important to have knowledge about factors influencing the removal of sows and sow longevity with the aim to make improvements.

Field data

To study removal and longevity of Swedish crossbred sows data had to be collected directly from commercial herds since the breeding data base (on which breeding evaluation is based) only include data from nucleus and multiplying herds. Average Swedish piglet producing herds had (including replacement gilts and boars) 106 sows in 2005 and 116 sows in 2006 (Anon., 2007). The studied herds represented medium sized and larger Swedish piglet producing herds (Paper I and III). The genetic analyses were restricted to genetic material from the Swedish breeding organisation Quality Genetics (Paper IV). The herd in Paper II is to be considered as a sample of a Swedish sow pool.

Field data have the advantage being based on "real" production. However the disadvantage with field data is that they are less controlled compared with research station data and thereby might be less accurate. To overcome this problem, this study was performed mainly prospective and at first herd visit detailed instructions were given to improve quality of registrations performed by the herd staff. In addition, the herds were visited several times during the recording period to check the quality of the data. When needed the data were also complemented and if possible corrected or otherwise excluded. It should also be mentioned that the most important factor on which herds were selected for the study was their herdsmen's ability to make reliable registrations.

In the large data collection (Paper I, III and IV), removal reasons registered in the herd monitoring program were based on the herdsmen's observation and judgement. To obtain an indication on how correct the clinical observations on farm were, a smaller study (Paper II) based on post mortem examination of sows found dead or euthanized on one farm. However, most of the removed sows were sent to slaughter. To evaluate the quality of the removal reasons recorded, data on findings from veterinary inspection at slaughter for sows from the 21 herds were also collected (not published). Slaughter records including veterinary remarks were retrieved from the slaughter organisations and the Swedish Board of Agriculture (SJV) for all 21 herds for the period 2001 to 2004. This data were however not possible to link to the individual sows. Therefore, for each herd and 6-months period, averages of this slaughter information were calculated. Corresponding herd averages for these periods were calculated for the clinical removal recordings. In total 124 herd-6-months averages were included in the estimation of correlations (Spearman rank) between: average slaughter weight and average parity number at removal, as well as between: proportion remarks on udder abscesses and proportion removed due to udder abscesses). Both were significant ($p<0.01$) and moderate, 0.27 and 0.23, respectively. This indicates that the removal reason recordings based on herdsmen's observation and judgement agrees reasonably well with findings at slaughter for at least these two parameters.

Removal of sows is obviously based on several contributing causes. In the herd monitoring program there are possibilities of recording two removal reasons for each sow. However due to technical limitations of the software PigWin Sugg, most herds only recorded one removal reason. Consequently, the proportion of sows with several removal reasons recorded was very low in the data and the analyses were based on one removal reason per sow. However, the influence of several contributing reasons was evident for some of the results found. For example, the lameness and udder problems removal hazard was higher for long farrowing intervals compared to normal farrowing intervals. This implies that also reproductive disturbances could have contributed to the removal of some of these sows.

Removal pattern

In agreement with studies in other countries (Stein *et al.*, 1990; Boyle *et al.*, 1998; Rodriguez-Zas *et al.*, 2003) and with a Swedish study from the 1970s (Andersson, 1997) the annual removal rate in the Swedish commercial herds studied in present study was approximately 50%. This was almost twice as high as it should be if all sows produced eight litters. The main proportion of the removal was unplanned and took place in low parity numbers. A conclusion that can be drawn is that sows that manage to pass the first parities and are not removed due to udder problems in medium parity numbers are the ones that fit in the system and produce well. In present study these sows, the ones finally removed due to old age, accounted for only 19% of the removal (Paper I).

Almost 30% of the removed sows were removed due to reproductive failures. This was about the same proportion as reported from other countries (D'Allaire, Stein & Leman, 1987; Dijkhuizen, Krabbenborg & Huirne, 1989; Lucia, Dial & Marsh, 2000b) and showed that the Swedish loose-housing system in combination with batch-wise production does not change the proportion of sows removed due to reproductive disturbances. An early study in Sweden (Einarsson & Settergren, 1974) showed about the same proportion of sows removed due to reproductive disorders. However, in that study where mainly natural mating was used, the most frequent removal reason was anoestrus, whereas in Paper I the main subgroup was 'return to oestrus'. Compared with the old system, in which weaned sows were individually housed in stalls, the housing system used today in Swedish piglet production (i.e. group housing after weaning and boar stimulation) has a stimulatory effect on induction of oestrus after weaning (Langendijk, Soede & Kemp, 2000; Kemp, Soede & Langendijk, 2005). Today's batch-wise production system, with groups of sows weaned at the same time, also requires use of artificial insemination. The high frequency of removal due to 'return to oestrus' found in

Paper I may partly be due to insufficient oestrus control or inferior insemination techniques and routines. This is supported by another study that investigated the reproductive organs of female sows from a herd with reproductive failure, mainly due to returns to oestrus (Dalin, Gidlund & Eliasson-Selling, 1997). Of the examined sows in that study, 50% had no pathological finding and most of the sows (69%) cycled normally. However negative effects of stress on reproduction (early pregnancy) due to group-housing (e.g. rank order fighting) in the examined herds can not be ruled out (Pedersen *et al.*, 1993; Razdan *et al.*, 2004).

In Paper I udder problems accounted for a higher proportion of sows removed, compared with previous studies (Einarsson & Settergren, 1974; Friendship *et al.*, 1986; Stein *et al.*, 1990). The removal for udder problems in Paper I was mainly caused by chronic mastitis including udder abscesses. Hultén et al. (2003) showed that granulomatous mastitis was common among group-housed sows kept on deep straw bedding. The few reports on udder problems as a removal reason in countries using housing systems other than those used in Sweden, i.e. individual stalls during gestation, suggests that group-housing on straw bedding might be a factor contributing to the development of granulomatous mastitis. The factors behind this would be interesting to investigate further.

A significant number of animals were euthanized on farm or found dead in the herds studied. The proportion of sows found dead was lower compared to other studies (Stein *et al.*, 1990; Koketsu, 2000; Lucia, Dial & Marsh, 2000b) whereas the proportion euthanized was at the same level (Vestergaard, Baekbo & Svensmark, 2006). In Paper I and II most euthanized sows were put down due to lameness or traumatic injuries (including fractures) and this removal was most common in low parity number sows. These injuries may have occurred when sows mounted each others during oestrus or fought to establish rank order in the loose-housing mating pens. It is therefore advisable to group sows according to body size during service and gestation to avoid injuries.

Of 14 234 removed sows, 3.3% were recorded to be removed due to fractures. However, among the 96 animals post mortem examined, 43% of the sows with arthritis as pathological anatomical diagnosis the clinical observation classified it as a fracture. This is interesting since it shows that a significant proportion of the sows with arthritis may incorrectly, in the recording of removal reasons, be reported as having fractures. This shows the importance of post mortem examinations to obtain proper diagnoses. Moreover, this is important knowledge to make improvements on herd level. The high incidence of arthritis in the post mortem examined animals shows that further investigations are required to obtain more knowledge about the etiology for this health problem and to design prophylactic measures.

Herds varied considerably with respect to removal rate, removal parity and removal reasons in Paper I. This variation between herds is probably due to different herd factors such as housing, management and removal strategy. With the data available it was not possible to analyse which herd factors that influenced longevity and removal due to the low number of herds included in the study. A new study (based on a large number of herds) is necessary to investigate the impact of housing, management and production system (sow pool or not) factors influence on removal of sows.

Breeding for sow longevity

Improvements in housing and management routines can probably not solely reduce the unplanned removal of young sows. Therefore, improvements have to be accomplished with selection for improved longevity making the sows more robust (Knap & Wang, 2006). However, the running Swedish breeding evaluation (Quality Genetics) did not have any obvious influence on sow longevity, neither positive nor negative. Since removal rate is high (but on the same level as in other countries) and a large proportion of the removed sows are young, the longevity of the average sow has the potential to be improved.

Improvement of sow longevity could be achieved by including additional traits in the breeding evaluation, indirect via correlated response or direct traits. The finding that osteochondrosis was common among the post mortem examined sows/gilts, i.e. is still a significant problem, and the knowledge that heredity plays a significant role for development of osteochondrosis (Reiland *et al.*, 1978; Lundeheim, 1987) indicate the importance of increasing the selection pressure on constitution and osteochondrois. Moreover the unfavourable correlation between the exterior conformation trait measured at boar station and sow longevity indicates that this trait does not give the expected progress. Conformation is a trait aimed to improve longevity and it should therefore be favourably genetical correlated to longevity. This discrepancy should be examined further and if necessary the conformation evaluation at station modified. Properly designed exterior conformation evaluations (made in nucleus herds and on station) have a high potential to improve the legs strength of the sows and thereby reduce removal due to lameness.

In addition to traits included in the breeding evaluation that improve sow longevity indirectly, a direct longevity trait may be included in the breeding evaluation to improve selection for longevity. Traits included in breeding programmes should have large genetic variation, be displayed early in life, be easily, not expensive to record and result in high accuracy in the breeding evaluation. Survival analysis has been considered to be superior over linear model analysis for longevity traits, with higher heritability estimates for longevity (Serenius & Stalder, 2004; Schneider *et al.*, 2005). However, also with survival analysis, the reliability of the breeding values for PL may be unsatisfactorily low at selection due to high proportions of uncompleted records (i.e. censored) among the animals contributing with information. Moreover the genetic parameters for RPL was estimated (not published) with competing risk analysis. However this approach resulted in low heritability estimates due to the high proportion censoring and is therefore not usable.

Thus a predictive trait for longevity, expressed early in life is preferred to obtain high reliability in combination with short generation intervals. In Paper IV stayability from first to second parity and from first to third parity was evaluated. An advantage with stayability from first to second parity is that it is likely to be the same trait in the multiplying herds as in the commercial herds. None of the longevity traits evaluated are likely to be the same trait at nucleus level since a high proportion of those sows are removed already after the first litter due to comparatively low breeding values compared with the next generation animals. Stayability is easy and not expensive to measure and would reduce the “worst” removal, i.e. the removal before second parity.

Stayability from first to second parity seems therefore to be the most appropriate trait to include in the Swedish breeding evaluation. A trait measuring the probability for the sow being served for her second litter, in the multiplying herds, has recently been included in the Danish breeding evaluation by Danavel (Danish pig production, 2006). Before including a STAY12 in the Swedish breeding evaluation, it is necessary to evaluate the possible economic gain. It has also to be decided between which two events in the sows reproductive life STAY12 should be defined, as well as to estimate the heritability of this trait for Swedish purebred sows with data from multiplying herds. In addition, the genetic correlation between this STAY12 in the multiplying herds and in commercial herds has to be estimated to ensure that it is the same trait at both levels in the breeding pyramid. If the correlation is low it is necessary to include information also from the commercial herds on this trait in the breeding evaluation. At present, this information is not collected.

Implications of sow removal at herd level

The variation between herds in Paper I illustrated that all herds were unique, all having unique environment, management and removal policy resulting in different removal patterns. It is the unplanned removal that is most important to focus on since the planned removal mainly reflects the age structure in the herd. To describe the unplanned removal in a herd and to avoid dependences it is suggested that sow removal be should be defined as follows:

$$\text{Unplanned removal rate} = \frac{\text{number of sows removed due to unplanned removal}}{\text{number of sows possible to remove (sows in production)}}$$

Unplanned removal rate gives an estimate of the removal in the herd with less influence of the age structure in the herd. However, the unplanned removal rate is not representative when the herd size is drastically changed.

$$\text{Removal rate for a specific reason} = \frac{\text{number of removed sows for a specific removal reason}}{\text{number of sows possible to remove (sows in production)}}$$

Removal for a specific reason can be estimated in the same way as unplanned removal rate presented above. This gives a measurement independent of other removal reasons, unlike the today commonly presented proportion of all removed sows. Removal due to mortality is a specific removal reason which often is presented as a proportion of sows in production.

In all herds it is necessary to keep track of the removal rate and removal pattern to identify problems in the production which can be improved. Paper I showed that the main removal reason was reproductive failure, mainly due to returns to oestrus. Herds with high removal due to this reason have sows accumulating high number of non-productive days as shown in Paper I. This is costly. Every non-productive day of the sow is estimated to reduce the income with 3 Euro and also make herd planning difficult. Animal flow needs more attention in herds practicing batch-wise production, especially in herds with more than three weeks between the batches since sows that returns to oestrus may not fit into another batch. Therefore in herds with long intervals between batches it is especially important to have good AI routines and high farrowing rates and avoid high removal rates due to return to oestrus. Replacing many sows with gilts may worsen the situation in such herds since parity 1 sows is reported to have lowest farrowing rate and highest remating rate (Tummaruk *et al.*, 2000) as well as the highest proportion of removal due to reproductive disorders (Paper I).

Replacing sows with gilts

Removed sows are to be replaced by gilts. High replacement rate requires access to a large pool of gilts and this is costly. In addition, high removal rates lead to high proportion of low parity sows in the herd. This will decrease the number of piglets produced in the herd since first parity sows have smaller litters compared to older sows. Furthermore, high proportion of unplanned removal results in limited possibilities for planned removal especially in cases of limited access to gilts. It is therefore highly profitable to increase sow longevity in herds with low longevity and high removal rates.

This thesis investigated the removal of Swedish crossbred sows. However, since removed sows are replaced by gilts the status of the replacement gilts that are available also influences the replacement decision. The herdsman has to consider whether it is more profitable to remove a sow which for example has returned to oestrus once and replace it with a gilt, or if it would be more profitable to give the sow a second chance. A simple calculation has been performed to evaluate the optimum removal parity for Swedish crossbred sows. The value for the additional litter was evaluated taking the cost for replacement gilt, payment for the sow at slaughter and genetic improvement into account. The results showed that the net income for a sow increased up to parity six, which agrees with a Danish study (Rasmussen, 2004). Other studies have reported it to be at least five parities (Scholman & Dijkhuizen, 1989; Lucia, Dial & Marsh, 2000a). It is also profitable to keep sows with high production after six parities, since for this sow the recruitment cost is already paid.

The decision to replace a sow with a gilt not only depends on the sow's history and age, but also on whether the new gilt can be considered superior to the sow. The results from this thesis shows that the crossbred sows need to become more robust. This can, in addition to improvements in breeding programmes, be accomplished by higher quality demands on the crossbred gilts recruited. Higher rate of removal of gilts with bad legs/constitution and gilts with impaired reproductive capacity (late puberty or return to oestrus or both) could be one way to improve sow longevity. Gilts with bad reproductive capacity as gilts will also have impaired reproductive capacity as sows (Sterning, Rydhmer & Eliasson Selling, 1998). However, in cases when replacement stock is bought it is difficult for a herd to set quality demands. In contrast, piglet producing herds with their own production of replacement stock can decide which gilts that should be kept. A multiplying herd of its own might be a possibility for larger herds, but two breed rotational crossing can be a good option for smaller herds.

Two breed rotational crossing has become more beneficial since the introduction of the program PigSelect (Quality Genetics HB, Hörby) which enables commercial herds to obtain breeding values for their crossbred sows. However it should be kept in mind that production of replacement stock requires interest, knowledge, space and time. Correct identity and recording is important. Buying replacement stock has the advantage that it comes from a multiplying herd specialized in producing gilts. Besides less risk of introducing new infections, production of gilts within the piglet producing herd makes it possible that the gilts are raised in the same environment as they later will produce in. Selection can therefore be based on both the performance of their own and their dams in their specific environment. This reduces the risk of genotype-environment interactions. It would be interesting to compare sow longevity in herds where replacement gilts are purchased with herds raising their own replacement stock.

Conclusions

- The annual removal rate of sows was about 50% in the Swedish commercial herds studied. Most removal occurred soon after weaning, was unplanned and occurred in low parity numbers. Most common removal reason was reproductive disorders (27%), followed by old age (19%) and udder problems (18%).

- Of the removed sows 85.2% were sent to slaughter, 10.5% were euthanized on farm and 4.3% were found dead. The proportion sent to slaughter increased and the proportion euthanized decreased with higher parity numbers.

- Among post mortem examined sows and gilts, most were euthanized due to lameness. The most common finding in euthanized sows/gilts was arthritis followed by osteochondrosis and fractures. Most sows/gilts found dead had no prior clinical symptom. Common causes of death were circulatory failure or trauma related injuries. Post mortem examination was necessary to obtain the correct diagnosis.

- Days after farrowing was the main risk factor for sow removal among the factors tested, followed by parity number and herd × year combination. Overall, the hazard for removal was highest shortly after weaning. Hazard for removal was low in medium parity numbers. Furthermore old age at first farrowing, small litters, and long intervals between weaning and next farrowing resulted in high removal hazard.

- Estimates of heritability of sow longevity were in the range between 0.03 and 0.12 using survival analysis and linear model analyses. The estimated breeding value correlations between the longevity traits and the traits included in the present Swedish breeding evaluation (Quality Genetics) were in few cases significant. Increased longevity of the crossbred sow was correlated with low age at first farrowing, high litter weight at three weeks, and low growth rate and inferior conformation at boar testing station.

- To genetically improve longevity of the sow, the selection intensity on indirect measurements of longevity, such as exterior constitution (at 100 kg live weight) and incidence and severity of osteochondrosis (at 100 kg live weight) should be increased. In addition, a direct sow longevity trait, preferably stayability from first to second litter should be included to improve selection for sow longevity and decrease the high proportion of removal in low parity numbers. This stayability trait should be recorded in multiplier herds, and if necessary also in commercial piglet producing herds.

Future research

- More research is necessary to evaluate the impact of different housing systems and management on sow longevity and removal pattern. Such an investigation would require data from a large number of herds.

- The finding that most of the post mortem examined sows had arthritis as main finding, needs to be confirmed on a larger number of animals and herds. If this is a general problem, further investigation is needed to find out more about the etiology so prophylactic measures can be implemented.

- This thesis did not investigate the impact of the sows own birth parity number. This, as well as the sow's own birth litter size and the impact of these two parameters on sow longevity, would be interesting to evaluate.

- Further investigations are needed to evaluate between which two events in the sows reproductive life, stayability from first to second parity should be defined. Moreover the genetic correlation between this stayability trait in multiplying herds and in commercial herds needs to be established to ensure that the genetic improvements will be implemented at commercial level of the breeding pyramid.

- Improvement of exterior conformation score on boar testing station included in the breeding evaluation is necessary.

- In present study most of the commercial piglet producers either bought the replacement gilts from nucleus and multiplier herds (F1-gilts), or produced their replacement stock in their own herd, using two breed rotational crossing. The possible difference in sow longevity between these two types of recruitment should be investigated.

- Estimation and publication of "average sow longevity" from multiplying herds would make it easier for piglet producing herds to select the best gilt producer.

- Some numeric differences in longevity/stayability were found between F1-sows, depending on the sire breed. This difference should be investigated further, particularly since the new breeding cooperation between the Nordic countries, has resulted in that Swedish multiplying herds now will only have Yorkshire sows. With this new breeding structure it is important to monitor the removal pattern and longevity at commercial herd level.

Populärvetenskaplig sammanfattning

Utslagning och dödlighet hos svenska korsningssuggor

Det finns två typer av utslagning av suggor. Den första typen, utslagning av gamla suggor är en naturlig del i smågrisproduktionen och kallas planerad utslagning. Planerad utslagning inkluderar även utslagning för att suggan ger små kullar eller avvänjer få smågrisar (låg produktion). Den andra typen av utslagning kallas oplanerad och inkluderar utslagning för bland annat reproduktionsproblem, benproblem och dödlighet. Den oplanerade utslagningen sker ofta i låga kullnummer. Hög utslagning innebär många unga suggor i besättningen och låg medelålder.

Under det senaste decenniet har utslagningen av suggor fått ökad uppmärksamhet. En minskad utslagning sänker årliga kostnaderna för rekryteringsgyltor och ökar därmed besättningens nettoinkomst. Målet med denna avhandling var att kartlägga utslagningen av svenska korsningssuggor, vilka faktorer som påverkade denna utslagning och komma med förslag som kan leda till ökad livslängd.

Studien baserades på data från 21 besättningar (varav 4 suggpooler), med totalt ca 10 000 suggor i produktion. De besättningar som valdes ut till studien använde datorprogrammet PigWin Sugg och hade god kvalitet på registrerade data. Materialinsamlingen startade våren 2002, och avslutades våren 2005. Vid det första besöket i besättningarna poängterades betydelsen av noggranna registreringar. Därefter besöktes besättningarna en till två gånger per år tills datainsamlingen var avslutad. Vid varje besättningsbesök kopierades besättningens PigWin-databas elektroniskt. Som komplement till den första studien obducerades under 2006 96 självdöda eller avlivade suggor (inklusive 26 gyltor gamla nog att betäckas) från en av de 21 besättningarna .

Informationen från PigWin har kontrollerats och därefter statistiskt analyserats. I materialet finns sånär som på de 26 gyltorna som obducerades bara suggor med minst en kull. Suggornas livslängd och utslagning har analyserats med flera typer av statistiska metoder.

Resultat

I genomsnitt byttes årligen 50 % av suggorna ut, men denna andel varierade mycket mellan besättningar (från 34 % till 66 %). Av de utslagna suggorna skickades 85,2 % till slakt. Motsvarande siffror för avlivade och självdöda suggor var 10,5 % och 4,3 %. Andelen avlivade och självdöda suggor var högst i låga kullnummer och andelen som skickades till slakt ökade med stigande kullnummer. Andelen suggor som skickades till slakt var högst fyra veckor efter grisningen (d.v.s. snart efter avvänjning) och var hög under de följande tre veckorna. Andelen avlivade suggor var jämförbar med vad man funnit i andra länder, medan andelen självdöda var lägre än vad som redovisas i studier från bland annat Danmark och USA.

Av de utslagna suggorna fick 17 % bara en kull. Genomsnittligt kullnummer vid utslagning var 4,4 (varierade från 3,4 till 5,7 mellan besättningarna). I genomsnitt lämnade suggorna besättningen 67 dagar efter sista grisningen och i genomsnitt producerade en sugga under sin livstid 56 födda, 53 levande födda och 44 avvanda smågrisar.

Den vanligaste utslagsorsaken var reproduktionsproblem (27 %), följt av hög ålder (19 %) och juverproblem (18 %). Utslagningen för låg produktion utgjorde 10 % och ben eller klövproblem 9 %. Andelen suggor som skickades till slakt var högre än andelen avlivade för alla utslagningsorsaker utom för fysiska skador (bl.a. orsakade av slagsmål) där 80 % av suggorna avlivades. Även en stor andel av suggorna som slogs ut för ben eller klövproblem avlivades (32 %). Reproduktionsproblem är den vanligaste utslagsorsaken även i rapporter från andra länder och utgör ca 30 %. Dock har den höga andelen utslagning för juverproblem inte observerats utomlands. Vad är orsaken till denna skillnad?

Rapporterad utslagsorsak varierade mellan olika kullnummer. I lägre kullnummer (1–3) slogs flest suggor ut för reproduktionsproblem. Den andelen sjönk med stigande kullnummer. Fysiska skador (inklusive benbrott) var också vanligast hos suggor med låga kullnummer och minskade med stigande kullnummer. Utslagning för juverproblem var vanligast i kullnummer 3–6 medan de flesta suggor med kullnummer 7 och högre slogs ut för hög ålder.

Obduktion av de 96 suggor/gyltor som avlivats eller självdött visade att de flesta hade en sjukdomsrelaterad diagnos. Av de 17 obducerade självdöda suggorna/gyltorna var vanliga dödsorsaker cirkulationssvikt och fysiska skador. Det vanligaste fyndet bland de 79 avlivade suggorna/gyltorna var artrit (ledinflammation), följt av ledskador (osteochondros) och benbrott. För 43 % av suggorna/gyltorna med artrit som huvudfynd vid obduktion misstänkte besättningspersonalen benbrott. Detta är värt att notera, eftersom det visar att en stor del av suggorna med artrit kan klassas felaktigt som benbrott. Vid obduktionen observerades även skador på tänderna (avslagna, spruckna, saknade) och 31 % av suggorna/gyltorna hade mer eller mindre allvarliga tandskador. Andra vanliga anmärkningar var förekomst av bölder som hittades hos 39 % av de obducerade suggorna/gyltorna.

Så kallad överlevnadsanalys visade att antal dagar efter avvänjning hade störst inverkan på risken att suggan skulle slås ut, följt av kullnummer samt miljön (en kombination av besättning och år). Störst risk för utslagning var det 30–40 dagar efter grisning, det vill säga i samband med avvänjningen (i detta intervall oftast planerad utslagning). Risken för utslagning var lägst i kullnummer 2 till 7. Risken för utslagning efter avvänjning ökade med suggans kullnummer, vilket visade att den planerade utslagningen ökade med stigande kullnummer. Suggor som var 14 månader eller äldre vid sin första grisning hade högst risk för utslagning. Detta visar att gyltor som blir sent dräktiga även senare i livet i högre utsträckning har problem. Små kullar (< 9 smågrisar födda) innebar en högre risk för utslagning jämfört med medelstora kullar (12–13 smågrisar) och denna risk ökade med stigande kullnummer. Långa grisningsintervall, motsvarande minst ett omlöp innebar högre risk för utslagning. Risken att suggor skulle slås ut var ganska jämn under året, men risken för att suggor självdog var högre i juli och augusti.

Arvet hade viss inverkan på suggors livslängd. Val av galt (fader) hade betydelse och suggor efter den sämsta galten hade 2,4 gånger högre risk att slås ut jämfört med suggor efter den bästa galten. Arvbarheten för livslängd skattades till 0,03–0,12 för flera olika mått på överlevnad, samma nivå som till exempel kullstorlek. Vidare undersöktes samband mellan mått på livslängd och avelsvärden från dagens svenska avelsvärdering (Quality Genetics). Resultaten visar att det idag inte finns någon stark indirekt selektion varken för eller emot suggors livslängd.

Vad kan vi göra för att minska utslagningen?

Det är viktigt att besättningar vet hur många suggor som slås ut, varför de slås ut och när denna utslagning sker för att kunna identifiera och åtgärda problem. Det är den oplanerade utslagningen som är viktigast att minska, då den planerade utslagningen främst beskriver åldersstrukturen i besättningen (alla suggor måste ju förr eller senare lämna besättningen). För att beräkna utslagningen i en besättning bör man därför beräkna och värdera följande två andelar:

$$\text{Oplanerad utslagning} = \frac{\text{Antal suggor utslagna p.g.a. oplanerade orsaker}}{\text{Antalet suggor som kan slås ut (suggor i produktionen)}}$$

$$\text{Utslagning för en viss orsak} = \frac{\text{Antal suggor utslagna för en viss orsak}}{\text{Antalet suggor som kan slås ut (suggor i produktionen)}}$$

För att genetiskt förbättra suggornas hållbarhet bör mer vikt läggas på ledskador och exteriör i Quality Genetics avelsvärdering. Vidare bör ett direkt mått på livslängd införas, förslagsvis ett mått som beskriver om suggorna fått en andra kull eller slagits ut efter första kullen.

Den höga andelen suggor utslagna för reproduktionsproblem utgjordes främst av suggor som löpt om. Dessa suggor hade många improduktiva dagar per kull och trots normalstora kullar en låg årsproduktion. För att minska andelen omlöp är det viktigt med bra rutiner för brunstkontroll och inseminering i en besättning.

Denna undersökning hade inte tillräckligt med data för att kunna fastställa vilka besättningsfaktorer, t.ex. inhysningssystem och skötselrutiner som påverkar utslagningen. Till detta behövs data från många fler besättningar. Andra resultat som kan vara intressanta att studera vidare är:

- om artrit är ett stort problem bland svenska suggor och om så är fallet, vad kan man göra för att minska förekomsten?
- skiljer livslängden mellan gyltor som köpts från hybridproducenter och gyltor som produceras i besättningen (via alternerande återkorsning)?
- hur påverkar det nordiska avelssamarbetet suggornas livslängd, när svenska hybridproducenter bara har tillgång till Yorkshiresuggor?

References

Akos, K. & Bilkei, G. 2004. Comparison of the reproductive performance of sows kept outdoors in Croatia with that of sows kept indoors. *Livestock Production Science 85*, 293-298.

Andersson, K. 1997. *Svinboken*. LTs förlag. Falköping. p. 153.

Anon., 2007. Yearbook of agricultural statistics including food statistics. Statistics Sweden, SCB. ISBN 978-91-618-1387-2.

Boyle, L., Leonard, F.C., Lynch, B. & Brophy, P. 1998. Sow culling patterns and sow welfare. *Irish Veterinary Journal 51*, 354-357.

Chagnon, M., D'Allaire, S. & Drolet, R. 1991. A prospective study of sow mortality in breeding herds. *Canadian Journal of Veterinary Research 55*, 180-184.

Christensen, G., Vraa-Andersen, L. & Mousing, J. 1995. Causes of mortality among sows in Danish pig herds. *Veterinary Record 137*, 395-399.

D'Allaire, S., Drolet, R. & Brodeur, D. 1996. Sow mortality associated with high ambient temperatures. *Canadian Veterinary Journal 37*, 237-239.

D'Allaire, S., Drolet, R. & Chagnon, M. 1991. The causes of sow mortality - a retrospective study. *Canadian Veterinary Journal 32*, 241-243.

D'Allaire, S., Morris, R.S., Martin, F.B., Robinson, R.A. & Leman, A.D. 1989. Management and environmental factors associated with annual sow culling rate: a path-analysis. *Preventive Veterinary Medicine 7*, 255-265.

D'Allaire, S., Stein, T.E. & Leman, A.D. 1987. Culling patterns in selected Minnesota swine breeding herds. *Canadian Journal of Veterinary Research 51*, 506-512.

Dagorn, J. & Aumaitre, A. 1979. Sow culling: Reasons for and effect on productivity. *Livestock Production Science 6*, 167-177.

Dalin, A.M., Gidlund, K. & Eliasson-Selling, L. 1997. Post-mortem examination of genital organs from sows with reproductive disturbances in a sow-pool. *Acta Veterinaria Scandinavica 38*, 253-262.

Deen, J., Xue, J.L., Irwin, C. & Geiger, J. 2000. *A study of the epidemiology of sow mortality*. In: Proceedings of the 16th International Pig Veterinary Society Congress, Melbourne, Australia, p. 289.

Dijkhuizen, A.A., Krabbenborg, R.M.M. & Huirne, R.B.M. 1989. Sow replacement: A comparison of farmer's actual decisions and model recommendations. *Livestock Production Science 23*, 207-218.

Ducrocq, V., Quaas, R.L., Pollak, E.J. & Casella, G. 1988. Length of productive life of dairy cows. *Journal of Dairy Science 71*, 3061-3070.

Ducrocq, V. & Sölkner, J. 1998. *The Survival Kit - a Fortran package for the analysis of survival data*. In: Proceedings of the 6th World Congress on Genetics Applied to Livestock Production, Armidale, Australia, vol 27, pp. 447-450.

Einarsson, S. & Settergren, I. 1974. Fertility and culling in some pig breeding herds in Sweden. *Nordisk Veterinärmedicin 26*, 576-584.

Faust, M.A., Robison, O.W. & Tess, M.W. 1993. Genetic and economic analyses of sow replacement rates in the commercial tier of a hierarchical swine breeding structure. *Journal of Animal Science 71*, 1400-1406.

Friendship, R.M., Wilson, M.R., Almond, G.W., McMillan, I., Hacker, R.R., Pieper, R. & Swaminathan, S.S. 1986. Sow wastage: reasons for and effect on productivity. *Canadian Journal of Veterinary Research 50*, 205-208.

Grindflek, E. & Sehested, E. 1996. *Conformation and longevity in Norwegian pigs*. In: Proceedings of Nordiska Jordbruksforskares Förening, Seminar no. 265, Research Centre Foulum, Denmark, vol 111, pp. 77-84.

Heusing, M., Hamann, H. & Distl, O. 2005. Genetic analysis of lifetime performance and fertility traits in the pig breeds Large White, German Landrace and Pietrain. *Züchtungskunde 77*, 15-34.

Hultén, F., Persson, A., Eliasson-Selling, L., Heldmer, E., Lindberg, M., Sjögren, U., Kugelberg, C. & Ehlorsson, C.-J. 2003. Clinical characteristics, prevalence, influence on sow performance, and assessment of sow-related risk factors for granulomatous mastitis in sows. *American Journal of Veterinary Research 64*, 463-469.

Irwin, C.K., Geiger, J.O., Pretzer, S. & Henry, S. 2000. *Identifying causes of sow mortality*. In: Proceedings of the 16th International Pig Veterinary Society Congress, Melbourne, Australia, p. 290.

Jørgensen, B. 2000. Longevity of breeding sows in relation to leg weakness symptoms at six months of age. *Acta Veterinaria Scandinavica 41*, 105-121.

Jørgensen, B. & Sørensen, M.T. 1998. Different rearing intensities of gilts: II. Effects on subsequent leg weakness and longevity. *Livestock Production Science 54*, 167-171.

Kalbfleish, J.D. & Prentice, R.L. 1980. *The statistical analysis of failure time data*. John Wiley and sons. New York

Kangasniemi, R. 1996. *Reasons for culling of sows in the Finnish sow recording scheme*. In: Proceedings of Nordiska Jordbruksforskares Förening, Seminar no. 265, Research Centre Foulum, Denmark, vol 111, pp. 17-27.

Kemp, B., Soede, N.M. & Langendijk, P. 2005. Effects of boar contact and housing conditions on estrus expression in sows. *Theriogenology 63*, 643-656.

Knap, P.W. & Wang, L. 2006. *Robustness in pigs and what we can learn from other species*. In: Proccedings of the 8th World Congress on Genetics Applied to Livestock Production, Belo Horizonte, Minas Gerais, Brazil, 06-01. http://www.wcgalp8.org.br/wcgalp8/articles/paper/6_203-1825.pdf (accessed 27 January 2008).

Koketsu, Y. 2000. Retrospective analysis of trends and production factors associated with sow mortality on swine-breeding farms in USA. *Preventive Veterinary Medicine 46*, 249-256.

Koketsu, Y., Dial, G.D. & King, V.L. 1997. Returns to service after mating and removal of sows for reproductive reasons from commercial swine farms. *Theriogenology 47*, 1347-1363.

Koketsu, Y., Takahashi, H. & Akachi, K. 1999. Longevity, lifetime pig production and productivity, and age at first conception in a cohort of gilts observed over six years on commercial farms. *Journal of Veterinary Medical Science 61*, 1001-1005.

Langendijk, P., Soede, N.M. & Kemp, B. 2000. Effects of boar contact and housing conditions on estrus expression in weaned sows. *Journal of Animal Science 78*, 871-878.

Le Cozler, Y., Dagorn, J., Lindberg, J.E., Aumaitre, A. & Dourmad, J.Y. 1998. Effect of age at first farrowing and herd management on long-term productivity of sows. *Livestock Production Science 53*, 135-142.

Le Cozler, Y., Ringmar Cederberg, E., Rydhmer, L., Lundeheim, N., Dourmad, J.Y. & Neil, M. 1999. Effect of feeding level during rearing and mating strategy on performance of Swedish Yorkshire sows. 2. Reproductive performance, food intake, backfat changes and culling rate during the first two parities. *Animal Science 68*, 365-377.

Long, T.E., Stalder, K.J., Goodwin, R.N., Halstead, J., Anderson, J.M. & Wyatt, R.L. 1998. Effect of gilt development diet on stayability to fourth parity in sows. *Journal of Animal Science vol 76, supplement 2, sectional abstracts*, 52.

López-Serrano, M., Reinsch, N., Looft, H. & Kalm, E. 2000. Genetic correlations of growth, backfat thickness and exterior with stayability in Large White and Landrace sows. *Livestock Production Science 64*, 121-131.

Lucia, T., Dial, G.D. & Marsh, W.E. 2000a. Lifetime reproductive and financial performance of female swine. *Journal of the American Veterinary Medical Association 216*, 1802-1809.

Lucia, T., Dial, G.D. & Marsh, W.E. 2000b. Lifetime reproductive performance in female pigs having distinct reasons for removal. *Livestock Production Science 63*, 213-222.

Lundeheim, N. 1987. Genetic analysis of osteochondrosis and leg weakness in the Swedish pig progeny testing scheme. *Acta Agriculturae Scandinavica Section A- Animal Science 37*, 159-173.

Madsen, P. & Jensen, J. 2000. A user's guide to DMU. A Package for analysing multivariate mixed models. Danish Institute of Agricultural Sciences, Tjele, Denmark.

Morris, J.R., Hurnik, J.F., Friendship, R.M. & Evans, N.M. 1998. The effect of the Hurnik-Morris (HM) system on sow reproduction, attrition, and longevity. *Journal of Animal Science 76*, 2759-2762.

Neil, M., Ogle, B. & Annér, K. 1996. A two-diet system and ad libitum lactation feeding of the sow.1. Sow performance. *Animal Science 62*, 337-347.

Olsson, A.-C. 1996. *Longevity and causes of culling of sows comparative studies in two housing systems for sows in gestation*. In: Proceedings of Nordiska Jordbruksforskares Förening, Seminar no. 265, Research Centre Foulum, Denmark, vol 111, pp. 59-64.

Pedersen, L.J., Rojkittikhun, T., Einarsson, S. & Edqvist, L.-E. 1993. Postweaning grouped sows: effects of aggression on hormonal patterns and oestrus behaviour. *Applied Animal Behaviour Science 38*, 25-39.

Rasmussen, J. 2004. Udskiftning af søer. Faglig publikation. Notat nr. 0442. Landsudvalget for Svin, Danske Slagterier.

Razdan, P., Tummaruk, P., Kindahl, H., Rodriguez-Martinez, H., Hulten, F. & Einarsson, S. 2004. The impact of induced stress during days 13 and 14 of pregnancy on the composition of allantoic fluid and conceptus development in sows. *Theriogenology 61*, 757-767.

Reiland, S., Ordell, N., Lundeheim, N. & Olsson, S.-E. 1978. Heredity of osteochondrosis, body condition, and leg weakness in the pig. *Acta Radiologica Supplement 358*, 123-127.
Ringmar Cederberg, E. 1999. Environmental and genetic influence on sow longevity. *Licentiate thesis, Swedish University of Agricultural Sciences.* Uppsala, Sweden. ISSN 1401-7520, ISBN 91-576-5699-1.
Rodriguez-Zas, S.L., Southey, B.R., Knox, R.V., Connor, J.F., Lowe, J.F. & Roskamp, B.J. 2003. Bioeconomic evaluation of sow longevity and profitability. *Journal of Animal Science 81*, 2915-2922.
Rozeboom, D.W., Pettigrew, J.E., Moser, R.L., Cornelius, S.G. & El Kandelgy, S.M. 1996. Influence of gilt age and body composition at first breeding on sow reproductive performance and longevity. *Journal of Animal Science 74*, 138-150.
Sanz, M., Roberts, J.D., Perfumo, C.J., Alvarez, R.M., Donovan, T. & Almond, G.W. 2007. Assessment of sow mortality in a large herd. *Journal of Swine Health and Production 15*, 30-36.
Schneider, M.D., Strandberg, E., Ducrocq, V. & Roth, A. 2005. Survival analysis applied to genetic evaluation for female fertility in dairy cattle. *Journal of Dairy Science 88*, 2253-2259.
Scholman, G.J. & Dijkhuizen, A.A. 1989. Determination and analysis of the economic optimum culling strategy in swine breeding herds in Western Europe and the USA. *Netherlands Journal of Agricultural Science 37*, 71-74.
Sehested, E. 1996. *Economy of sow longevity*. In: Proceedings of Nordiska Jordbruksforskares Förening, Seminar no. 265, Research Centre Foulum, Denmark, vol 111, pp. 101-108.
Sehested, E. & Schjerve, A. 1996. *Aspects of sow longevity based on analyses of Norwegian sow recording data*. In: Proceedings of Nordiska Jordbruksforskares Förening, Seminar no. 265, Research Centre Foulum, Denmark, vol 111, pp. 9-16.
Serenius, T. & Stalder, K.J. 2004. Genetics of length of productive life and lifetime prolificacy in the Finnish Landrace and Large White pig populations. *Journal of Animal Science 82*, 3111-3117.
Serenius, T., Stalder, K.J. & Puonti, M. 2006. Impact of dominance effects on sow longevity. *Journal of Animal Breeding and Genetics 123*, 355-361.
Sigfridson, K. 1996. *Feeding for longevity - strategies for pregnant and lactating sows*. In: Proceedings of Nordiska Jordbruksforskares Förening, Seminar no. 265, Research Centre Foulum, Denmark, vol 111, pp. 46-51.
Simonsson, A. 1994. Näringsrekommendationer och fodermedelstabeller till svin. SLU Info rapporter. Husdjur 75. Swedish University of Agricultural Sciences, Uppsala.
Stalder, K.J., Lacy, R.C., Cross, T.L. & Conatser, G.E. 2003. Financial impact of average parity of culled females in a breed-to-wean swine operation using replacement gilt net present value analysis. *Journal of Swine Health and Production 11*, 69-74.

Stalder, K.J., Saxton, A.M., Conaster, G.E. & Serenius, T.V. 2005. Effect of growth and composational traits on first parity and lifetime reproductive performance in U.S. Landrace sows. *Livestock Production Science 97*, 151-159.

Stein, T.E., Dijkhuizen, A., D'Allaire, S. & Morris, R.S. 1990. Sow culling and mortality in commercial swine breeding herds. *Preventive Veterinary Medicine 9*, 85-94.

Sterning, M., Rydhmer, L. & Eliasson Selling, L. 1998. Relationships between age at puberty and interval from weaning to estrus and between estrus signs at puberty and after the first weaning in pigs. *Journal of Animal Science 76*, 353-359.

Tantasuparuk, W., Lundeheim, N., Dalin, A.M., Kunavongkrit, A. & Einarsson, S. 2001. Weaning-to-service interval in primiparous sows and its relationship with longevity and piglet production. *Livestock Production Science 69*, 155-162.

Tarrés, J., Bidanel, J.P., Hofer, A. & Ducrocq, V. 2006a. Analysis of longevity and exterior traits on Large White sows in Switzerland. *Journal of Animal Science 84*, 2914-2924.

Tarrés, J., Tibau, J., Piedrafita, J., Fabrega, E. & Reixach, J. 2006b. Factors affecting longevity in maternal Duroc swine lines. *Livestock Science 100*, 121-131.

Tholen, E., Bunter, K.L., Hermesch, S. & Graser, H.U. 1996. The genetic foundation of fitness and reproduction traits in Australian pig populations. 1. Genetic parameters for weaning to conception interval, farrowing interval, and stayability. *Australian Journal of Agricultural Research 47*, 1261-1274.

Tummaruk, P., Lundeheim, N., Einarsson, S. & Dalin, A.M. 2000. Reproductive performance of purebred Swedish Landrace and Swedish Yorkshire sows: I. Seasonal variation and parity influence. *Acta Agriculturae Scandinavica Section A-Animal Science 50*, 205-216.

Vestergaard, K., Baekbo, P. & Svensmark, B. 2006. *Sow mortality and causes for culling of sows in Danish pig herds*. In: Proceedings of the 19th International Pig Veterinary Society Congress, Copenhagen, Denmark, vol. 1, p. 255.

Xue, J.L., Dial, G.D., Marsh, W.E. & Lucia, T. 1997. Association between lactation length and sow reproductive performance and longevity. *Journal of the American Veterinary Medical Association 210*, 935-938.

Yazdi, M.H., Lundeheim, N., Rydhmer, L., Ringmar-Cederberg, E. & Johansson, K. 2000a. Survival of Swedish Landrace and Yorkshire sows in relation to osteochondrosis: a genetic study. *Animal Science 71*, 1-9.

Yazdi, M.H., Rydhmer, L., Ringmar-Cederberg, E., Lundeheim, N. & Johansson, K. 2000b. Genetic study of longevity in Swedish Landrace sows. *Livestock Production Science 63*, 255-264.

Yazdi, M.H., Visscher, P.M., Ducrocq, V. & Thompson, R. 2002. Heritability, reliability of genetic evaluations and response to selection in proportional hazard models. *Journal of Dairy Science 85*, 1563-1577.

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