A STUDY OF FACTORS INFLUENCING PIG HEALTH, PRODUCTIVITY, AND ECONOMICS OF INTERVENTIONS IN SMALLHOLDER PIG FARMS IN KIKUYU DIVISION, KIAMBU DISTRICT, KENYA

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university

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DEDICATION

To

My wife, Nancy, and my children, Solomon, Joseph, Beatrice and Jamie.

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ABSTRACT

In Kenya information on factors that limit optimal health and productivity in smallholder pig herds is lacking. The objectives of this study were therefore to: 1. Describe the herd -level characteristics and the farmers perception of pig production constraints; 2. Determine baseline pig health and productivity parameters; 3. Determine the herd-level factors associated with pig health and productivity; 4. Evaluate the relative cost-effectiveness of alternative health interventions against priority disease constraints.

Five administrative locations in a peri-urban Kikuyu Division, Kiambu District, were purposively selected for the three-phase study. The first phase was a cross-sectional study in which 87 herds were randomly selected and visited once in 1998. Farm-level constraints to production data were collected using semi-closed survey questionnaires. The second phase was a longitudinal study where 76 herds that previously participated in the first phase were visited once a month in 1999 for 12 months. Health and productivity data were recorded in specific record cards. During the visits, pigs up to 40 kg were weighed and faecal samples for faecal egg counts and earwax for mite detection were taken once. The third phase was a longitudinal intervention study where 40 herds that previously participated in the second phase were randomly allocated to 3 treatments and 1 control group. Various treatments against helminths and sarcoptic mange were administered to the different pig groups. The herds were visited on days, 0, 7, 14, 28, 68, and 96. Faecal samples for faecal egg

count and ear wax for mite detection were taken before the treatment and during subsequent visits.

Descriptive statistics, tests of associations, binary logistic regression and cost-effectiveness analysis were performed on the data.

All farmers cited 'source of income' as the reason for keeping pigs. Majority (78%) did not seek for any extension information and depended on family labour (90%) for pig production. The production constraints identified by the farmers were high cost of feeds that were of variable qualities, lack of credit, lack of genetically quality breeding boars, poor marketing and diseases. Sarcoptic mange, helminthosis, diarrhoea and pneumonia were highly ranked.

Pigs were kept indoors. Concrete, wooden and dirt floors were found in 66.7%, 24.1% and 9.2% of the herds respectively. Bedding, especially in the farrowing area, was used in 90.8% of the herds. Guard rails/piglet protection devices were present in 22% of the herds. Few (8%) farmers disinfected pig pens. Thirty three percent of farmers kept some written records on husbandry practices and production. None of the farmers reported use of vaccination against pig diseases. Majority (83.9%) of the farmers controlled mange and helminths (96%). Farmers controlled mange by use of acaricides (50%), used engine oil (37%) and a combination of the two (12%). All the farmers used anthelmintics to manage helminthosis.

All farmers practised restricted feeding and fed their pigs on commercial feed (69%), swill (26%), self-formulated feeds (1%), forage (4%) and creep feed (9.2%).

The production systems employed by the farmers were, farrow- to- finish (68%), farrow-to-weaner (16%) and feeder operation (5%). Majority (87%) of the farmers weaned the piglets at the age of 2 months. All the farmers practised natural mating but, majority (59.8%) did not keep a boar.

Overall, the preweaning crude morbidity cumulative incidence was 29%. The common diseases were pruritus (17.1%), skin necrosis (3%) and diarrhoea (2.5%). The crude mortality was 18.7% with the highest mortality occurring during the first week postpartum mainly due to overlying (9.9%). The average daily weight gain (ADWG) achieved by the piglets was 0.13 kg/day.

Preweaning piglet morbidity was not ($p>0.05$) associated with the herd-level factors investigated. Herds where sows were supplemented with protein rich feeds had reduced odds (OR=0.03) of having a low piglet mortality. Supplementation of sows with protein rich feeds was associated (OR=15) with a higher ADWG in piglets.

The grower crude morbidity cumulative incidence was 20% with the most common diseases being pruritus (21.1%), unknown causes (2.3%) and gut oedema (1.3%). The crude mortality was 3.8% with the most important causes being unknown causes (1.6%) and gut oedema (1.3%). The grower average weight:age ratio was 5.2 kg/month of age and the ADWG was 0.16 kg/day.

The grower morbidity was not ($p>0.05$) associated with the herd-level factors investigated. Good hygiene of the pig house was associated (OR=8) with reduced mortality. Weight:age ratio and ADWG were not ($p>0.05$) associated with the herd level risk factors investigated.

The weaning-to-service interval was 3.2 months and the interfarrowing interval (IFI) was 6.9 months. The mean number of live born piglets per farrowing (NLBP) was 9.2 and the mean number weaned was 6.9. The mean lactation length was 2.2 months.

Supplementation of the sow with protein rich feeds was associated (OR=14) with increased number of live born piglets (NLBP).

The results of the interventions revealed that the anthelmintic activity of ivermectin was significantly ($p<0.05$) higher than for piperazine from day 7 to day 68 post-treatment. The anthelmintic activity of ivermectin was not different ($p>0.05$) from that of levamisole.

Significantly ($p<0.05$) lower number of pigs positive for mites were observed on day 14 post-treatment with the ivermectin as compared to the control group. The proportion of pigs positive for mites was not different ($p>0.05$) between the ivermectin and amitraz treatment groups throughout the study period.

The costs of labour for the treatments were, ivermectin (\$0.25), piperazine/amitraz (\$0.04) and levamisole/amitraz (\$0.04). The overall costs for the treatments were ivermectin (\$0.5), piperazine/amitraz (\$0.31) and levamisole/amitraz (\$0.26).

Most of the health and husbandry aspects associated with productivity are amenable to manipulation and can be addressed by use of appropriate preventive methods and extension services. Therefore, the delivery of extension information to pig farmers should be improved. The limiting role of nutrition has been highlighted but the formulation of appropriate and cost-effective diets may prove problematic due to non-availability of on-farm alternative feed. However, attention could be paid to alternative cereals at the national level to supplement maize as this would lead to reduction in the prices of pig feeds. Supplementation of pigs with protein rich feeds, improvement of sow performance and reduction of grower pig mortality could considerably improve productivity of pigs in the smallholder herds.

CHAPTER 1

GENERAL INTRODUCTION

1.1 Background information

Kenya covers an area of approximately 582,600 km^2 and has seven agro-ecological zones (AEZ) (Jaetzold and Schimdt, 1983) that are based on various agro-climatic factors particularly, moisture supply and temperature. Administratively, the country is divided into eight provinces, which are divided into districts, divisions, locations and sub-locations. The country's human population is estimated at about 28 million (Kenya Government, Census Report , 2001). The highest population densities of more than 200 people per square kilometre in the rural areas is found in Central, Western and Nyanza provinces (Graaf. 1986). The country's economy is mainly dependent on agriculture which is the base for economic growth, employment creation and foreign exchange generation (Kenya Government. Development Plan, 1997).

Livestock are kept by different communities and contribute 10% to the national gross domestic product (Kenya Government, Development Plan, 1997). The sub-sector employs over 50% of agricultural labour force (Kenya Government, Development Plan, 1997). Dairy cattle, exotic chicken and pigs are mainly reared in high and medium potential lands (HMPLs) in agro-ecological zones (I-IV) which comprise 18% of the country's total area (Sombroek *et al.*, 1982). These areas are characterised by intensive mixed crop- livestock farming systems. The other livestock mainly beef cattle, goats, camels and indigenous chicken are kept in the arid and semi-arid lands

(ASALs) of the country in agro-ecological zones V-VII which comprise about 74% of the country's total area. In these areas pastoral and nomadic livestock production systems are practised. The livestock population per species is estimated at 13 million cattle, 8.7 million sheep, 10.3 million goats, 0.7 million camels, 0.4 million donkeys, 0.2 million pigs and 28 million chicken (Ministry of Agriculture Livestock Development and Marketing (MALD&M), Annual Report, 1993).

From the beginning of the 1970s to the mid 1990s the demand for animal products in the developing countries has been rising and is expected to increase substantially from low levels of consumption, relative to the developed world, well into the new millennium hence creating a veritable livestock revolution (Delgado *et al.*, 1999). The predicted increase is due to combination of rapid population growth, urbanisation and rising incomes (Winrock, 1992; Kenya Government, Development Plan, 1997; Delgado *et al.*, 1999). In Kenya, although the demand for livestock products keeps on rising in line with population growth, the available land per household is decreasing rapidly and the current consensus is that production of pigs and chicken that can be produced intensively in smallholder setups should be encouraged (Kenya Government, Development Plan, 1989).

Smallholder farms are generally small, varying in size from two to five acres (Nyangito, 1992). They tend to be located in the high potential areas of the country and contribute significantly to the Kenyan economy. Smallholder farming is practised as a component of subsistence agriculture whereby in addition to keeping livestock farmers also grow food and cash crops (Burger, 1994). Livestock and crop production serves the overall objective of providing food and cash income for the farm family. Often the farmer does not rely completely on this on-farm income, but also has a considerable off- farm income (Burger, 1994). Research and development efforts within the agricultural sector are best targeted towards the smallholder farming system (Walshe, 1987). The rationale of encouraging livestock production in smallholder farming systems include, the potential for improvement in productivity, the predominance of smallholder farmers in high and medium potential areas, the large social benefit for supporting smallholder agriculture and sustainability of smallholder farming systems (Ehui *et al.*, 1998).

Pigs are one of the important livestock species raised in smallholder farms in the high potential areas of Kenya. The pig population is estimated at 0.2 million (MALD&M, Annual Report, 1995), and the majority of the pigs are hybrids of Large White or Landrace breeds and a few of Hampshire. However, a few pure bred Landrace and Large White breeds are also kept on government owned stations and by some privately owned companies, such as East African Tanning Extract Company (EATEC) and Farmers Choice, Kenya Limited. Over half the pig population in Kenya are located around Nairobi and Central Province and smaller populations are found in Rift Valley and Western provinces. Smallholder farming system is the main pig production system in these areas (Gichohi *et al.*, 1988). These farmers keep small herds of between 2-10 sows and contribute 60% to the total pig production (Kenya Agricultural Research Institute (KARI) Manual, 1996). In addition, a few large-scale farms also make a significant contribution to the pig sub-sector especially through the sale of breeding stock to the smallholder farmers (MALD&M, Annual Reports, 1977-1996). In the smallholder farming systems, pigs protect the farmer's capital against inflation and the sales provide a readily available source of income to the family (Gichohi *et al.*, 1988).

1.2 Statement of the problem

The gain in production of pigs in the smallholder farming system has mainly been as a result of increased number of farmers. However, these farmers are subject to a number of pressures, including rapid human population growth and limited land resources. It is therefore clear that the relatively easy gains in production made-to-date cannot continue and intensive production systems are inevitable. Such intensification will demand improved management. Research and development efforts should therefore be made to sustain smallholder pig production. Research should identify priority constraints and opportunities as this will arguably lead to initiation of appropriate interventions.

Several constraints appear to limit pig production in tropical smallholder production systems. These constraints include poor nutritional quality, high feed prices, poor prices for pigs in relation to feed prices, inferior genetics, inadequate disease control practices and limitation in husbandry and management knowledge, (de Fredrick 1977a; de Fredrick and Osborne, 1977; Saseendran and Rajagopalan, 1981; Wilkins and Martinez, 1983; Gichohi *et al.*, 1988; Gatenby and Chemjong, 1992; More *et al.*, 1999). Consequently, productivity outputs are low compared to the commercial piggeries of the temperate countries (More *et al.*, 1999; Kunavongkrit and Heard, 2000).

In the past, well-structured epidemiological studies on livestock health and productivity in Kenya have mainly addressed dairy cattle (Gitau, 1992, 1997; Odima, 1994; Omore, 1997; O'Callaghan, 1998), small ruminants and indigenous chicken (Odoi, 1998; Okuthe, 1999). Little has been done to study the health and productivity of pigs in smallholder farming system. Munyua, *et al.* (1991), using secondary data and convenient samples, observed a poor sow reproductive performance in small- and medium-scale pig herds while Gichohi *et al.* (1988), using secondary data and convenient samples, identified high feed prices, inadequate marketing, poor breeding stock and poor pig extension service as the most important pig production constraints. Other studies on pigs carried out in Kenya have mainly been on-station trials on sow performance (Kabare, 1991; Wahome, 1998).

Additional information on pig health and productivity in Kenya is based on passively derived data from monthly and annual reports from MALD&M, Farmers Training Centres, KARI and from expert opinion of Farmers Choice, Kenya Limited. Data from these reports are not verified by any standard, well-structured epidemiological studies, so the data may suffer from unreliability and perhaps bias. This is because convenience sampling may lead to selective exclusion of some farms while passively derived data has shortcomings since not all the events in the farm are reported to the researcher or the veterinary department (Cameron, 2000). Passive data provides only information about reported events but gives no information on the population in which the events occurred. It is therefore evident that there is a need for a well-designed epidemiological study on pig health and productivity and the associated factors in smallholder farms in Kenya.

To this end, an epidemiological study was conducted to derive information on pig health and productivity and the associated factors in smallholder farming systems in high potential and peri-urban areas of Kenya. Kikuyu Division of Kiambu District in central Kenyan highlands with small land sizes and high number of smallholder pig farmers was chosen for the study. The smallholder pig production system in Kikuyu Division represents the probable future trends for other high potential and peri-urban areas that have increased intensification and better inputs and output markets.

1.3 Objectives of the study

The overall objective was to identify important health and production constraints and opportunities for improved pig production in smallholder farms. To achieve this objective the following specific objectives were developed:

1. Describe the herd -level characteristics and the farmers' perception of pig production constraints.

2. Determine baseline pig health and productivity parameters.

3. Determine the herd-level factors associated with pig health and productivity.

4. Evaluate the relative cost-effectiveness of alternative health interventions against priority disease constraints.

To achieve the objectives, a three-phase study was executed. The first phase was a cross-sectional study in form of structured questionnaires to describe farm-level characteristics and to identify production constraints as perceived by farmers. The second phase was a longitudinal study where pig health and productivity were monitored for 12 consecutive months. The third phase was a longitudinal intervention study on major disease constraint(s) identified in the ealier phases of the study. This study will provide a baseline assessment of health and productivity of pigs in peri-urban smallholder pig production systems in Kikuyu Division of Kiambu District and probably other high potential and peri-urban areas in Kenya. The results obtained will provide information on which to base research and development strategies that would improve and sustain the productivity of pigs in smallholder production systems.

CHAPTER 2

LITERATURE REVIEW

2.1 History of pig production in Kenya

The first pig breeding stocks in Kenya were imported by the colonial settlers from Europe. These were mainly of the Landrace, Large White and Hampshire breeds. Initially, production of pigs was mainly undertaken on large-scale farms up to the advent of political independence. The period immediately post independence saw a significant shift towards raising of pigs by the smallholder farmers. This was initially due to the Kenyan resettlement schemes programmes and later due to the Kenyan land tenure system and increasing population pressure (Wahome *et al.*, 1992).

During the early years the performance of the pig sub-sector was mainly influenced by the performance of the defunct Uplands Bacon Factory, then the main pig processing plant, which had been established in 1946 (Gichohi *et al.*, 1988). The factory was the main market for pigs produced in Kenya. Unfortunately, its performance was characterised by up and down trends until it closed down in 1985 (Gichohi *et al.*, 1988). Its performance in turn affected pig production in the country and by the time it closed down, pig production in Kenya was at its lowest. However, the entry of Farmers Choice, Kenya Limited, in processing of pork and pork products in addition to other local butcheries has been an incentive to pig production especially by the smallholder farmers (Wahome *et al.*, 1992).

2.2 Pig population, distribution and marketing

The majority of pigs are produced in Central, Rift-Valley and Nairobi provinces (Table 2.1). This is due to their favourable position for accessible market channels (Mainly Farmers Choice, Kenya Limited), feed availability, availability of veterinary and extension services and their favourable socio-economic and cultural environment (MALD&M, Annual Report, 1994). Pig production in North Eastern and, to some extent, in Coast provinces is restricted by the religious and social-cultural beliefs of the inhabitants who are mainly muslims. However, over the years there has been a general trend in the increase in pig production and consumption even in the none traditional provinces. This general trend is explained by changing socio-cultural beliefs due to education, urbanisation and increased incomes (MALD& M, Annual report, 1994). The major market for pigs in Kenya is Farmers Choice, Kenya Limited, and it is the major producer of pork and pork products with about 80% share of the local market (MALD&M, Annual Report, 1994). Other markets for pigs are the local mainly urban based butcheries and firms such as Nairobi Airport Services (NAS), Ndumbuini slaughter house, Kenya Bacon Company and Super Chef. Marketing in the urban centers especially around Nairobi is well organised with arrangements made by some market channels, especially by Farmers Choice, for delivery of pigs from farms to processing plants, compensation to farmers for delivery of pigs for slaughter and contract farming. However, farms away from Nairobi are discouraged from raising or continuing with rearing of pigs because of poor market and hence the lower prices offered by the middle men (commonly referred to by the farming community as brokers). Marketing of pigs is also influenced by the tourism sector with high demands

Table 2.1. Pig population and distribution over five years in the various administrative Provinces in Kenya

Province	1990	1991	1992	1993	1994	1995
Central	55,747	50,962	113,655	92,720	245,217	92,767
R/Valley	20,941	50,962	24,860	37,020	17,150	42,353
Western	9,126	15,901	16,370	14,680	21,880	26,571
Nairobi	26,849	29,677	34,245	29,580	39,410	34,581
Eastern	6,870	14,534	6,780	8,510	18,410	23,742
Nyanza	6,174	8,481	8,444	10,500	23,078	26,880
Coast	2,461	2,565	2,730	2,830	4,600	5,866
N/Eastern	-	-	-	-	-	-
Total	128,168	147,014	207,084	195,860	369,745	252,760

Source: Ministry of Agriculture, Livestock Development and Marketing, Annual reports, (1990-1995) for pigs being around July-December and a decline in tourist numbers visiting the country around this period has a negative impact on pig marketing (MALD&M, Annual report, 1992).

2.3 Pig production systems

Two broad categories of pig production systems are recognised, intensive and non-intensive (Radostits *et al.*, 1994; Kunavongkrit and Heard, 2000). In intensive production systems large numbers of pigs are kept per unit area and an attempt is made to make efficient utilization of the available resources (Radostits *et al.*, 1994; Svendsen and Svendsen, 1997). The non-intensive systems are characterised by farms with few number of pigs and the productivity levels in such farms is usually low (Gatenby and Chemjong, 1992; Kunavongkrit and Heard, 2000). In intensive pig production systems, pigs are mostly maintained indoors while in non-intensive systems both outdoor and indoor production systems are practised. Outdoor pig production system are common in many parts of the world largely due the low capital investment required as compared to indoor rearing. However, even in the intensive pig production systems, outdoor rearing has also expanded greatly due to animal welfare concerns (Svendsen and Svendsen, *1997*). These production systems are characterised by a high diversity with regard to management type and level of management and this is reflected by the difference in health and productivity levels (Radostits *et al.*, 1994).

In Kenya, majority of pigs are kept indoor with a few especially in Western Kenya kept outdoor (MALD&M, Annual report, 1995). In most farms, hybrids of Large White or Landrace breeds are kept. However, few pure bred Landrace and Large

White breeds are maintained by the Agricultural Development Corporation (A.D.C) and by some privately owned companies, such as East African Tanning Extract Company (EATEC) and Farmers Choice, Kenya Limited. Pig farms in Kenya can be divided into two categories, intensive large scale farming units and smaller scale farms (Gichohi *et al.*, 1988 ; KARI, 1996). A loose fusion of either farrow-to-finish, farrow-to-weaner or feeder systems of pig production can be found on these farms. In addition, an integrated system involving breeding stock, feed supply, fattening and slaughter processing is being practised by Farmers Choice, Kenya Limited. The kind of production system practised is determined by several factors that include, socio-economic, cultural values, marketing structures and input situations (MALD&M, Annual Report 1993).

2.4 Pig production constraints and opportunities

Many constraints are known to hinder improvement to productivity of pigs raised by smallholder farmers in tropical areas. Nutrition is probably the most important constraint to pig production (de Fredrick, 1977a; Gatenby and Chemjong, 1992). In the smallholder farms, pigs are frequently fed household waste (Gatenby and Chemjong, 1992) complemented with limited amounts of a range of other available feedstuffs including carbohydrate sources, leafy green material and occasional protein sources (de Fredrick, 1977a; Wilkins and Martinez, 1983). These feeds are substantially protein deficient (de Fredrick and Osborne, 1977) and in some cases supply of inadequate amount of water occurs (de Fredrick, 1977a).

In contrast to pigs under commercial conditions, infectious diseases are rarely considered a major constraint to smallholder pig production (de Fredrick, 1977b). However, as a consequence of climatic and management factors, high internal and external parasite burdens are common (de Fredrick, 1977b; Manuel *et al.*, 1989; Kambarage *et al.*, 1990; Esrony *et al.*, 1997). Limitations to husbandry and management, low level of inputs and marketing are also important constraints to pig production in the smallholder farms (de Fredrick, 1977a; Gatenby and Chemjong, 1992; Lanada *et al.*, 1999; More *et al.*, 1999; Kunavongkrit and Heard, 2000).

A number of opportunities have been identified for sustainable improvements to the production of smallholder pigs. Improvement of piglet management has been shown to be effective, efficient and cost-effective means to improve the sow reproductive performance (Taveros and More, 2001). Exotic breeds do not perform well under typical village conditions (Wongnarkpet *et al.*, 1994; Kunavongkrit and Heard, 2000). However, there is a general consensus that the animals are superior to indigenous breeds found in some smallholder production systems if the conditions can be improved (de Fredrick and Osborne, 1977; More *et al.*, 1999). The control of internal parasites and use of preventive methods has been shown to improve the growth performance of grower pigs and to increase the sow performance (Manuel *et al.*, 1989; Lanada *et al.*, 1999). These principles have been applied in Eastern Indonesia where a village animal-health programme was developed based on the training of village animal-health workers and the widespread distribution of anthelmintics (Smith, 1992). In Bolivia, differences in the performance of pigs from different villages were attributed to differing levels of access and activity provided by local extension workers (who provided farmers with vaccines, anti-parasitic drugs and information on their use) (Wilkins and Martinez, 1983). The formulation of appropriate and cost-effective diets has however, proved problematic, particularly because of the considerable overlap in the feedstuffs eaten by pigs and people (de Fredrick, 1977a). Nonetheless, significantly improved performance of pigs has been achieved following attention to the nutritive value of locally grown feedstuffs and the addition of sources of plant protein and carbohydrates to pig diets (de Fredrick and Osborne, 1977; Falvey, 1981; More *et al.*, 1999).

In Kenya, few studies have attempted to study pig health and productivity constraints and opportunities in smallholder farms (Gichohi *et al.*, 1988; Munyua *et al.*, 1991). In these studies passively derived data and convenience sampling methodologies were used. Poor sow reproductive performance, high feed prices, inadequate marketing, unavailability of breeding stock and poor pig extension services appeared to be important pig production constraints. However, the methodologies used may render the data to suffer from unreliability and perhaps bias (Cameron, 2000). Recent work in smallholder dairy production systems in Kenya indicate that passively derived information and information derived from convenient samples may lead to wrong conclusions and decisions (Gitau, 1997; O' Callaghan, 1998). Thus programmes to address smallholder pig production systems in Kenya will require a good understanding of constraints and opportunities in this system based on a well designed epidemiological study.

2.5 Measures of health and productivity in pigs

In order to optimize animal health management programmes, a need arises for the monitoring of health and productivity of the animals. For the programme to be effective, the parameters for assessing health and productivity selected should be those that not only measure production but also act as economic indicators and hence are of value in decision making (Martin *et al.*, 1987; Rougoor *et al.*, 1996). In health management programmes, a hierarchy of parameters to monitor or investigate health and production is normally used because each of the parameters may be influenced by the disease or intervention differently (Martin *et al.*, 1987).

In sow breeding herds , the number of pigs weaned per sow per year is from the economic point of view the most important measure of productivity (Radostits *et al.*, 1994). This production parameter depends on litters/sow/year, farrowing rate, culling rate, weaning to service interval (WSI), number of live-born piglets (NLBP) and preweaning piglet mortality (PWPMT) (Wilson *et al.*, 1986; Radostits *et al.*, 1994; Polson, 1996; Svendsen and Svendsen, 1997).

The number of litters per sow per year is determined by the farrowing interval (Radostits *et al.*, 1994; Polson, 1996). Farrowing interval depends upon lactation length, gestation period, and the number of days from weaning to the next pregnancy (Radostits *et al.*, 1994). While the length of gestation period in sows is independent of most external factors, the length of lactation and period from weaning to pregnancy depends upon a series of factors such as age of the sow, litter size, boar, season of the year, management, housing, animal handling, feed and diseases of boar and sow (Radostits *et al.*, 1994; Tantasuparuk, 2000).

The litter size is evaluated as the number of live-born and weaned pigs and depends upon ovulation rate, fertilization, embryonic and fetal morbidity and mortality, piglet mortality at farrowing, and the morbidity and mortality of suckling pigs (Radostits *et al.*, 1994). These events may be influenced by many 'internal' and 'external' factors such as the age of the sow, boar, husbandry management practices, housing systems, environment, feed, feeding methods, diseases, and preventive measures (Radostits *et al.*, 1994).

In pig production, sow longevity is considered an important economic trait (de Vries, 1989) as parity of culled sows (Dagorn and Aumaitre, 1979), average parity (Stein *et al.*, 1990), and average parity of farrowed sows may be associated with the performance of the breeding sow herd. Sows culled at an older age, have a higher mean annual productivity than sows that are culled at a younger age (Lucia *et al.*, 2000; Tantasuparuk, 2000). The most common removal reasons for sows are attributed to reproductive disorders and suboptimal litter performance (Radostits *et al.*, 1994; Lucia *et al.*, 2000). However, planned culling in sow herds is inevitable and this is commonly recommended to take place after approximately 3-4 years of breeding life or after parity 7-8 in order to benefit from genetic gain and obtain the ideal parity profile in the herd (Tantasuparuk, 2000).

Thus, the sow reproductive performance will vary from one region to another and from one farm to the other depending on the management system and management levels in place. The sow reproductive performance in tropical areas is lower than in subtropical or temperate areas (Wongnarkpet *et al.*, 1994; Kunavongkrit and Heard, 2000; Tantasuparuk, 2000). The main problem being the comparatively lower litter size at birth (Kunavongkrit and Heard, 2000; Tantasuparuk, 2000). The poor performance is attributed to climatic conditions which are hot, presence of pig diseases, substandard management, the difficulty of obtaining quality feeds and inappropriate service delivery systems (de Fredrick, 1977b; Lanada *et al.*, 1999; Kunavongkrit and Heard, 2000; Tantasuparuk, 2000; More *et al.*,1999).

In grower pigs, the objective is to grow and to finish the pigs as rapidly as possible and to obtain a pig that will yield the highest carcass score at slaughter for maximum economic returns (Radostits *et al.*, 1994). The important measures of productivity in the growing period are average daily weight gain, feed conversion efficiency, the mortality rate from weaning to the end of the finishing period and the cost per unit of live-weight gain (Radostits *et al.*, 1994). The monitoring of average daily weight gain and feed conversion efficiency is important as this would allow prompt identification and the control of factors that may affect the output of the grower pig herds (Radostits *et al.*, 1994; Rinaldo *et al.*, 2000). Several factors affect the efficient growth of grower pigs. They include genetic factors, husbadry and management practices, housing systems, environment, feeds and feeding methods, diseases, and disease management practices (Radostits *et al.*, 1994).

Studies carried out on grower pig performance in the smallholder farms in the tropics have indicated a lower performance as compared to the commercial intensive production systems of the subtropics and temperate areas (de Fredrick and Osborne 1977; More *et al.*, 1999). The poor performance is attributed to inadequate and poor quality feeds, diseases and poor genetics (de Fredrick and Osborne 1977; More *et al.*, 1999).

2.6 Monitoring health and productivity

To efficiently monitor pig health and productivity, a record-keeping system is a prerequisite (Polson, *et al.*, 1992). A regular analysis and interpretation of the records combined with regular clinical examination of the pig herds will allow the identification of problems that are interfering with production (Muirhead, 1980). In the intensive pig production systems of the temperate countries, this is becoming increasingly met through the implementation of production information systems such as the pigCHAMP program (Dept. of Clinical and Population Sciences, University of Minnesota College of Veterinary Medicine, St. Paul, MN). Such systems are essential for the accurate collection and evaluation of physical output as well as the evaluation of changes in biologic variables resulting from changes made in the production system (Polson *et al.*, 1992). In smallholder farming system in Kenya written record keeping is poor (Gitau *et al.*, 1992) and no records are available to allow a proper monitoring of health and productivity and associated risk factors in these farms. Therefore, data for the determination of health and productivity in these farms is lacking.

2.7 Economic analysis of disease control measures

2.7.1 Importance of evaluating disease control measures

The principal purpose of animal health economic analysis is to aid decision making regarding limited resource allocation in optimizing animal health management (Amir and Knipscheer, 1989; Dijkhuizen *et al.*, 1995). It provides a basis for making rational choices from among alternative procedures available under various circumstances (Dijkhuizen *et al.*, 1995). Controlling the cost of production is becoming criticallay important in modern livestock farming and improving animal health can play a major role in achieving efficient and economically rewarding production. Usually several measures of programmes are available, each of them offering a different degree of protection and requiring a different level of investment (Dijkhuizen *et al.*, 1995). Determining the optimal input level, therefore, is to a large extent a matter of economic decision making.

2.7.2 Economic models for evaluating alternative disease control measures.

Several modelling techniques are available to help perform economic analysis of animal diseases and their control (France and Thornley, 1984). The main methods available for economic analysis of alternative disease control measures are budgeting techniques and simulation modelling (Amir and Knipscheer, 1989; Dijkhuizen *et al.*, 1995). Budgeting is a simple tool available for deriving preliminary estimates of profitability of single interventions (Amir and Knipscheer, 1989). The most commonly used budgeting approaches to quantify economic benefits of alternative disease control technologies are partial budget analysis and benefit-cost analysis (Martin *et al.*, 1987; Amir and Knipscheer, 1989; Huirne and Dijkhuizen, 1997). These two techniques are best used when the change occurs in one component of the farm with no major change in farmers' resources or overall farming plan (Amir and Knipscheer, 1989).

Partial -budget analysis provides information about short-term changes in costs and benefits caused by following a given practice (Boehlje and Eidman, 1984). It is the method of choice when the analysis concerns a simple economic comparison of disease control measures on a farm and when the outcome does not involve a specific time pattern nor a great degree of chance (Dijkhuizen *et al.*, 1995). Since partial- budget analysis is relevant only for component technology, it is not suitable for answering questions in which several factors determine the contribution of a treatment. The partial budget essentially isolates the impact of any management intervention into each of four basic areas (Boehlje and Eidman, 1984): reduced expenses (RE), additional income (AI), increased expense (IE), and reduced income (RI). The difference in these four areas are all relative to the actual overall budget, affording a measure of the net effect of the intervention in the equation :

Net difference = [(RE + AI) - (IE+ RI)]

The change is adopted if the sum of (RE and AI) is greater than that of (IE and RI).

When long–term disease control programmes are involved, then, benefit-cost analysis is the economic model of choice (Dijkhuizen *et al.*, 1995). Since the time at which costs or benefits occur may differ between the alternatives, it is important that the future costs or benefits are 'discounted' to make them completely comparable, which results in the present value of costs and benefits (Dijkhuizen *et al.*, 1995). The reason for discounting is the time preference of money (Dijkhuizen *et al.*, 1995). The formula used to calculate the present value (PV) of a future cost or benefit (FV), where r is the annual 'interest rate' (in %) and n is the number of years in the future, is:

$$PV = FV/(1+r/100)^n$$

The 'interest rate' used in cost-benefit analysis is called the discount rate, since it makes future values smaller than the present values. In benefit-cost analysis cash and non cash costs and benefits are used to derive the appropriate benefit-cost ratio. The benefit -cost ratio is the ratio of the present values of cash and non cash inflows to the present values of cash and non cash outflows. The alternative technologies are accepted or rejected using the benefit-cost ratio on the basis of the size of the values. Sensitivity analysis is then undertaken on the benefit-cost ratio to examine the effect of changes in the parameters under consideration (Huirne and Dijkhuizen, 1997). Sensitivity analysis has disadvantages that include the inability to specify the likelihood of alternative outcomes (Huirne and Dijkhuizen, 1997). This constraint is overcome by the use of risk analysis in simulation models (Dijkhuizen *et al.*, 1995).

The cost-effectiveness ratio, the ratio between the cost of a programme and its quantifiable and non quantifiable benefits can also be used to evaluate alternative disease control measures. Cost-effectiveness analysis overcomes some of the difficulties involved in putting monetary value on all benefits of a disease control programme (Martin *et al.*, 1987). The numerator is often the cost part of the benefit-cost analysis. The estimation of the value of the denominator may be strictly political and in some cases it may not be easily determined. In such cases, the purpose of the analysis may be to determine how the desired result may be achieved at minimum cost (Martin *et al.*, 1987). In this study, the latter approach of cost-effectiveness analysis was used to evaluate the health interventions.

CHAPTER 3

GENERAL MATERIALS AND METHODS

3.1. Introduction

This chapter gives an overview of the methodology used to study health and productivity of pigs in smallholder farms in Kikuyu Division, Kiambu District, Kenya. The details that are relevant to each aspect of the study are described in the respective chapters. The study was carried out in three-phases. The first phase was a cross-sectional study to describe the farm -level characteristics and the farmers' perception of pig production constraints. The second phase was a longitudinal observational study to determine baseline pig health and productivity parameters and the associated herd-level factors. The third phase was a longitudinal intervention study where alternative health interventions against priority disease constraints as identified in the earlier phases of the study were evaluated for their relative cost-effectiveness.

3.2 Study area

This study was undertaken in a high potential peri-urban area in Kikuyu Division of Kiambu District, Kenya. The division is located to the west of the capital city, Nairobi and has an area of 232 km^2 out of which 179 km^2 is the stable area. It is spread over altitudes of between 1800 and 2200 metres above sea level. It has a bimodal rainfall with the long rains falling between mid-March and May and the short rains between October and mid-December. The annual rainfall is between 800 and 1200 mm. The division has six administrative locations with estimated 20,000 smallholder farms that occupy about 56% of the available agricultural land (Ministry of Planning and National Development, Development Plan, 1994). In these smallholder farms mixed agricultural farming is practised. The smallholder production system in Kikuyu Division of Kiambu District of the Kenyan highlands represents the probable trends for other high potential and peri-urban areas that is increased intensification and better inputs and outputs markets. The main livestock enterprises in the smallholder farms are dairying, poultry production and pig farming (Ministry of Planning and National Development, Development Plan, 1994).

3.3 Selection of study farms

The study farms comprised of smallholder pig farms in the peri-urban and high potential area of Kikuyu Division in Kiambu District, central Kenya. The sampling unit of interest was the individual smallholder pig farm. For the purpose of this study, a smallholder pig farm was defined as a pig farm that raised equal or less than ten breeding sows and /or gilts or equal or less than 100 grower pigs. Five administrative locations in the division, (Kikuyu, Kinoo, Muguga, Kabete and Nyathuna) (Figure 3.1), were purposively selected; one location (Karai) located in an area of less potential (sparsely populated and with very few farms raising pigs) was omitted. A sampling frame listing all the smallholder pig farms in the five locations who met the selection criteria was provided by the government extension officers in charge of each of the locations. The total number of smallholder pig farms in the five locations was 179. Because farm variations were of main interest, a simple random sampling procedure (using a random number table) was used to select 87 farms from the list of the 179

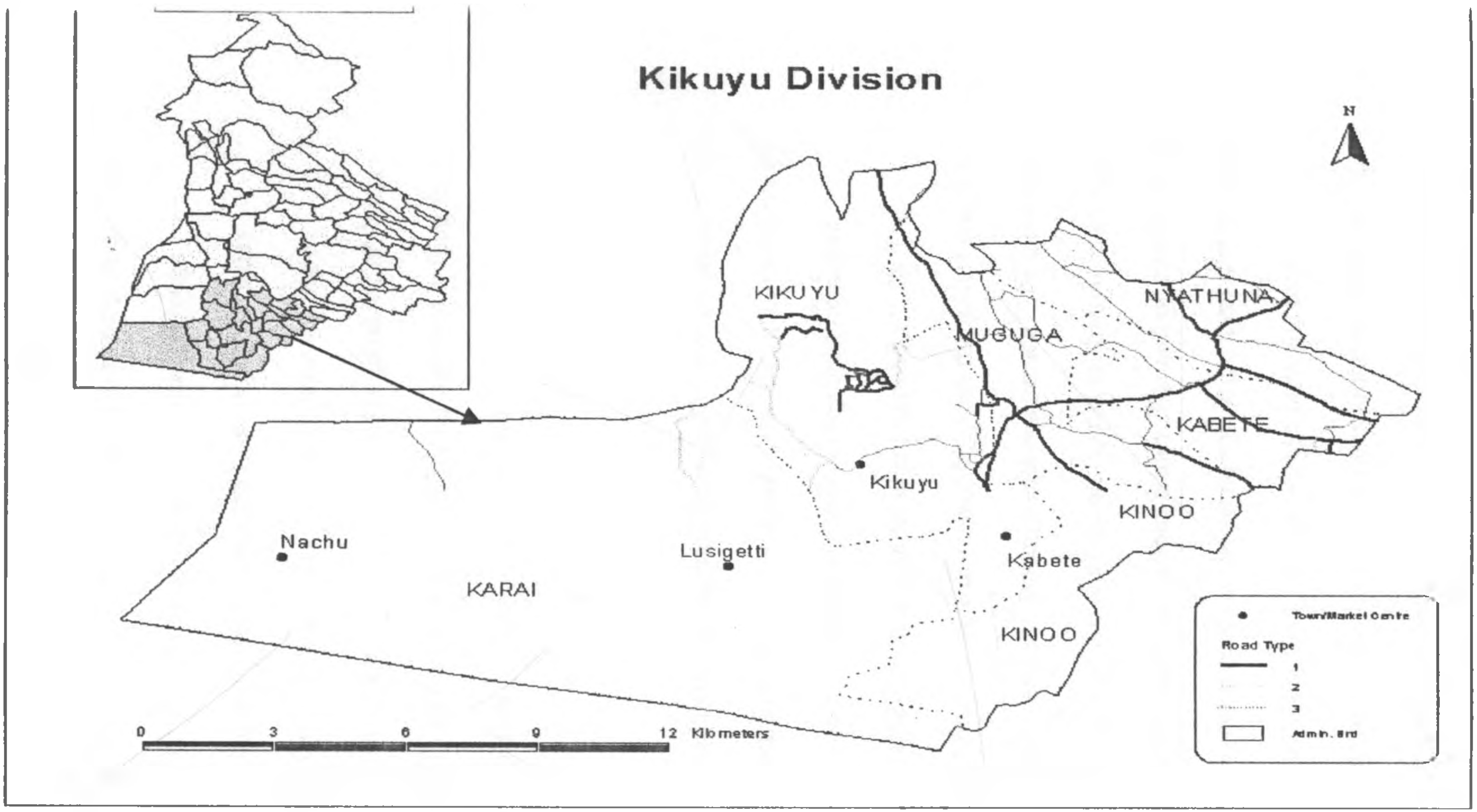

Figure 3.1 A map of Kikuyu Division, Kiambu District, Kenya, showing the selected locations for the study on pig health and productivity in smallholder farms (June 1998-August 1998).

farms. The sample size of 87 farms was the practical limit because that was all that could be visited monthly during the subsequent longitudinal phase of the study. The owners of the selected farms were invited to participate in the study through personalised letters that also included a brief introduction describing the study objectives. In the first visit, the farmers were interviewed and those willing to participate were enlisted for the study. Other farmers from the original list of farms were randomly selected and replaced the selected farmers who were not willing to participate or had sold all their pigs at the time of the first visit.

3.4 Cross-sectional study

Farm visits were conducted between the months of June 1998 to August 1998. The farm characteristics and constraints to pig production data were gathered through face-to-face personal interviews using semi-closed, farm survey questionnaires (Appendix 1.1) and constraint identification questionnaires (Appendix 1.2). The wording and clarity of the questionnaires were discussed between the author and the extension staff before administration and any amendments were made. The questions were constructed in the English language but were administered in Kikuyu (the local dialect) by the author to improve on clarity on various issues. The author conducted all the interviews to help improve on consistency as he could speak the local dialect. The questionnaires were administered during the first visit in each farm and took about 21\2 hours. In general, the aspects covered in the farm survey questionnaires included, farm-management practices, source and type of feeds and feeding practices, housing, disease management practices, marketing and labour. Where the opportunity arose, the validity of the answers given was cross-checked by physical inspection at the farm. Production constraints were listed according to the order of their importance while disease constraints were listed according to the magnitudes of their prevalences.

3.5 Longitudinal study

A total of 87 herds that previously participated in the cross-sectional study were recruited. In order to pretest the research methodology, a pilot study was initiated in these farms and was carried out between October 1998 and December 1998. At the end of the pilot study, a total of 76 farms that were still active in keeping pigs were recruited for the longitudinal observational study. The selected farms were visited once a month by the author and two recruited enumerators between January 1999 and December 1999. During these visits, data on health and productivity were collected and recorded on prescribed record cards as described in Chapter 5. The health and productivity parameters monitored in the study were as described below.

3.5.1 Measures of health in pigs

The health measures used in this study were morbidity and mortality (Martin *et al.*, 1987) and are described in details in Table 3.1. During the monthly visits, the author made detailed physical examinations of the pigs and recorded the morbidity data. Additional information on morbidity and mortality occurring in between the visits was provided by the farmers. Clinical diagnosis of sick or dying pigs was mainly based on the antemortem clinical signs.

Table 3.1. The definitions of the health measures as used in the longitudinal study on pig health and productivity in smallholder farms in Kikuyu Division, Kiambu District, (January1999- December 1999).

Measure	Definition
Morbidity	Any disease with recognisable signs
Mortality	Death of a pig from whatever cause
Morbidity or mortality true rate	$\frac{\text{Number acquiring event of interest (sickness or dying)}}{\text{(Number initially at risk+ number at risk at the end)x1/2 x TC}^{a}}$
Crude morbidity cumulative incidence	$\frac{\text{Number of pigs sick from all reasons in the time period}}{\text{Initial number at risk} - \frac{1}{2}\text{ withdrawals}}$
Cause-specific morbidity cumulative incidence	$\frac{\text{Number of pigs sick form a particular cause in the time period}}{\text{Initial number at risk} - \frac{1}{2}\text{ withdrawals}}$
Proportional morbidity rate	$\frac{\text{Number of pigs sick from a specific cause}}{\text{Total number of pigs sick from all reasons}}$
Proportional mortality rate	$\frac{\text{Number of pigs dying from a specific cause}}{\text{Total number of pigs dying from all reasons}}$
Age- specific morbidity cumulative incidence	$\frac{\text{Number of pigs becoming sick in a specified age-group}}{\text{Number at risk for a particular age}}$
Age- specific cumulative mortality incidence	$\frac{\text{Number of pigs dying in a specified age-group}}{\text{Number at risk for a particular age}}$
Preweaning mortality	$\frac{\text{Number of piglets dying before weaning}}{\text{Number of live-born piglets}}$

[a]Time component, that is the time in months the group of grower pigs were monitored.

In addition, rectal faecal samples and ear wax scrapings from pigs from each of the selected herds were sampled once for faecal egg counts and mite identification respectively. Faecal samples were taken from a total of 598 pigs of various age categories. The samples were analysed using the modified McMaster technique (Ministry of Agriculture, Fisheries and Food, 1986). Ear wax scrapings were taken from a total of 476 pigs of various age categories by scraping the inner aspects of the ear until traces of blood could be seen. The material was examined under the light microscope for the presence of mites after digestion with 10% potassium hydroxide.

3.5.2 Measure of productivity in piglets and grower pigs

During the monthly visits, piglets and grower pigs up to a maximum weight of 40 kg were weighed. Productivity in piglets was measured as average daily weight gain (ADWG) in kilogrammes per day (Radostits *et al.*,1994). For grower pigs, productivity was measured as, average daily weight gain (ADWG) in kilogrammes per day, the ratio of the measured weight and the reported age (weight:age ratio) and days to market (Radostits *et al.*,1994; More *et al.*, 1999).

3.5.3. Measures of sow reproductive performance

Measures of sow performance used were preweaning piglet mortality, weaning to service interval (WTSI), interfarrowing interval (IFI), number of live-born piglets (NLBP), number of piglet weaned per farrowing (NWF), litters per sow per year (L/S/Y) and the number of piglets weaned per sow per year (PW/S/Y) (Dial *et al.*, 1992).

3.5.4 Herd-level factors influencing health and productivity of pigs

The herd-level factors investigated for association with health and productivity of pigs are shown in Table 3.2.

3.6 Intervention study

The third phase was a longitudinal intervention study where alternative health interventions against priority disease constraints as identified in the earlier phases of the study were evaluated for their relative cost-effectiveness.

Sarcoptic mange and helminthosis were found to be the most prevalent diseases. In consultation with the smallholder pig farmers a study to evaluate the relative cost-effectiveness of alternative drugs available for the control of the two diseases was carried out. A total of 40 herds that previously participated in the longitudinal study were randomly allocated, by simple random strategy using random number table, to 3 treatment groups and 1 control group. Each group comprised of 10 herds.

3.6.1 Study design

Four intervention groups were designed. These were the control with no intervention (Group 1), use of Ivermectin (Cevamec® 1%, Sanofi, Hungary), at 300μg /kg body weight , subcutaneously, once in all the pigs to control both worms and mange (Group 2), Simultaneous use of an acaricide, amitraz (Tactic® 12.5 w/v, Hoescht, Germany) to control mange and the use of piperazine hydrochloride (Piperazine® , Dopharma, Holland), at 440mg/kg body weight, orally, once in all the

Table 3.2. Herd-level factors investigated for association with pig health and productivity outcomes in smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999-December 1999).

Variable
Disease management practices
Mange controlled (No/yes)
Helminth controlled (No/yes)
Hygiene (Poor, fair, good)
Piglet anaemia prophylaxis (No/yes)
Piglet protection devices (Present, absent)
Nutrition of the pigs
Feed provided to the dry sow (Commercial pigs feed, swill, Pollard)
Feed provided to the lactating sow (Commercial pigs feed, swill, Pollard)
Protein supplementation for the sow (No/Yes)
Feed provided to the grower pig (Commercial pigs feed, swill, Pollard)
Protein supplementation for the grower pigs (No/yes)
Housing
House design (Open/semi-closed)
Size of farrowing pen (adequate/inadequate)
Husbandry practices
Average parity of the sows in the herd
Herd size
Weaning to service interval
Lactation length
Stockperson (Family, hired)
Ownership of boar (No/yes)

pigs to control gastro-intestinal worms (Group 3), and simultaneous use of amitraz to control mange and the use of levamisole hydrochoride (Leva® 20, Agrar, Holland), at 8 mg/kg body weight, orally, once to all the pigs to control gastrointestinal worms (Group 4). Amitraz application was boosted after 7 days for group 3 and 4.

Piglets aged 4 weeks and above and grower pigs less than 40 kg live weight were recruited for the study (all pigs in the herd, except piglets aged less than 4 weeks, were treated just like the study group). Rectal faecal samples and ear wax scrapings were taken before the treatment (Day 0) and at days, 7, 14, 28, 68 and 96 post-treatment for faecal egg counts and mite identification respectively.

3.7 Data management

Data files were managed in Dbase (DBASE IV Plus, Ashton Tate, Torrance, California, USA), Access® 1997 (Microsoft Corporation, USA), and in Excel® 1997 (Microsoft Corporation, USA). The files were screened for any errors that might have occurred during data entry and errors were corrected by rechecking against the original data forms.

3.8 Data analysis

Data analyses were performed using Statistix® for windows (analytical software, Tallahassee, FL, USA), Excel® 1997 (Microsoft Corporation, USA) and Minitab Statistical Software, version 13 for windows (Minitab Statistical Software, Minitab Inc, USA). Desriptive statistics were used to generate the descriptive tables. Unconditional associations between the health or productivity outcomes and the independent herd-level variables were determined using Chi-square test for independence for categorical variables and Kruskal-Wallis test for non-normally distributed continuous independent variables. Binary logistic regression analysis was used to model the health and productivity outcomes and the independent herd-level variables that were found significant during the univariable analyses.

The faecal egg counts were transformed to their natural logarithms, Ln (count +1), before the analysis. The effects of the various treatments on the faecal egg count, proportion of pigs positive for mites, and scratching index by visit were analysed using one way analysis of variance. The costs of the alternative interventions against sarcoptic mange and helminthosis that included the cost of labour and drugs were computed. The costs of the drugs were calculated by multiplying the retail price of each drug with the amount used in the study. Family labour costs were calculated as opportunity costs. The technical and economic data were then compared.

CHAPTER 4

CROSS-SECTIONAL STUDY

4.1 Introduction

This chapter describes a cross-sectional study carried out in smallholder pig herds in a peri-urban Kikuyu Division of Kiambu District, Kenya. The aim of the study was to provide an overview of pig management and husbandry practices in smallholder pig herds. In addition, identification and ranking of production and health constraints as perceived by the pig farmers was also carried out. The information obtained in this phase of the study was used to guide the subsequent longitudinal observational study.

4.2 Materials and Methods

4.2.1 Study area

This study was undertaken in a high potential peri-urban area in Kikuyu Division of Kiambu District, Kenya. The study site characteristics are described in Chapter 3 subsection 3.2.

4.2.2 Selection of study farms

The smallholder herd was the sampling unit and the unit of interest as described in Chapter 3 subsection 3.3.

4.2.3 Data collection

4.2.3.1 Description of the smallholder pig production systems

Farm visits were conducted between the months of June 1998 to August 1998. The farm-characteristics data were gathered as described in Chapter 3 subsection 3.4.

4.2.3.2 Ranking of production and disease constraints

The constraints to pig production data were gathered as described in Chapter 3 subsection 3.4. The constraints to production as listed in the questionnaires were ranked in the following order of importance; first, second, third, fourth, fifth, sixth and seventh and were then weighted by awarding scores from 1-7 respectively to each of the respondent. Highly prevalent diseases were considered to be of major health constraint to efficient pig production. Using the criteria, the disease constraints were ranked in the following order; first, second, third and fourth and were weighted by awarding scores from 1-4 respectively to each of the respondent. Using the weighting score the cumulative sum of all the responses was then calculated and this was taken as the weighted score for the particular constraint. The constraint with the highest score was considered to be the most important.

4.2.4 Data management

Separate data files for the responses on the farm survey questionnaires and the constraint identification questionnaires were created in Dbase (DBASE IV Plus, Ashton Tate, Torrance, California, USA) and Microsoft Access® 1997 (Microsoft

Corporation, USA) respectively. The files were screened for any errors that might have occurred during the data entry and errors were corrected by checking against the original questionnaires.

4.2.5 Data analysis

The data files were then transferred to Statistix® for windows (analytical software, Tallahassee, FL, USA) for descriptive analysis.

4.3 Results

4.3.1 Response percentage

Of the 87 farms initially contacted only one farmer declined to participate in the study; 10 farmers had already sold their pigs. The initial voluntary enrollment among the eligible farms was therefore 99%. Other farms from the original list of farms were selected using the random number table and replaced the 11 farms.

4.3.2 Description of the smallholder pig production systems

4.3.2.1 Farm/Farmer characteristics

The important farm/farmer characteristics are summarized in Table 4.1 and Table 4.2. The median farm size was 1 acre. The pigs kept in the farms were crossbreed of Large White, Landrace and Hampshire breeds with a median of 9 pigs per herd. About 7% (6/87) of the farmers had been keeping pigs for less than 1 year and 61% (53/87) for more than 5 years. Source of income was cited as the reason for keeping pigs by all the farmers.

Most (78% or 68/87) of the farmers did not seek for any extension information on pig farming. A few (8% or 7/87), of the farmers who sought advice got it from livestock extension officers while 5% (4/87) got it from other farmers. Majority (90% or 78/87), of the farmers depended on family labour for pig production and 51% (44/87) employed non-family members to assist with pig production.

In addition to keeping pigs about 77% (67/87) of the farmers grew subsistence crops such as kale, cabbages, maize and beans while 7% (6/87) grew cash crops (Table 4.2). Most (53% or 46/87), farmers had an off farm income-generating activity.

Table 4.1. The descriptive statistics for farm-level continuous variables of 87 smallholder pig herds in Kikuyu Division, Kiambu District, (June 1998-August 1998)

	Mean	Min[a]	25th Percentile	Median	75th Percentile	Max[b]
Farm size (acres)	1.6	0.1	0.5	1.0	2	8.5
Pigs	16	1	5	9	24	115
Boars	0	0	0	0	1	5
Gilts	0	0	0	0	1	3
Growers	7	0	0	2	9	75
Piglets	3	0	0	0	0	24
Sows	2	0	1	1	2	10
Weaner	4	0	0	0	5	41
Other livestock						
Beef cattle	0	0	0	0	0	8
Chicken	103	0	0	0	26	3000
Dairy cattle	2	0	1	2	4	15
Goat	1	0	0	0	0	30
Sheep	1	0	0	0	0	17

[a]Minimum value

[b]Maximum value

Table 4.2. The descriptive statistics for farm/farmer -level categorical variables of 87 smallholder pig herds in Kikuyu Division, Kiambu District, (June1998-August 1998)

	Number of farms	Percentage
Farming activities only	41	47.1
Owner employed off-farm		
Full-time	42	52.9
Part-time	4	4.6
Subsistence crops grown	67	77.0
Cash crop grown		
Coffee	4	4.6
Horticultural produce	3	3.4
Market outlets		
Farmers choice	34	39.0
Local butchery	30	34.0
Home slaughter	10	11.0
Others	12	14.0
Credit accessibility		
No	43	49.0
Yes	44	51.0

4.3.2.2 Farm management characteristics.

4.3.2.2.1 Pig housing

In all the farms, pigs were confined and fed the year round in simple pens. The floor typically was concrete (Table 4.3), the roof of the pens was made of iron sheets and the walls were either of wood, iron sheets or stones. Some form of bedding especially in the farrowing area was used in 90.8% (79/87) of the herds. Few (9% or 8/87), farmers provided a creep area.

Table 4.3. The descriptive statistics for housing categorical variables of 87 smallholder pig herds in Kikuyu Division, Kiambu District, (June 1998-August 1998)

	Number of farms	Percentage
Pigs housed	87	100
Floor type		
Dirt	8	9.2
Concrete	57	65.5
Concrete\slatted	1	1.2
Wood\slatted	8	9.2
Wood	13	14.9
Bedding		
None	8	9.2
Saw-dust	34	39.1
Wood-shavings	41	47.1
Dry grass	4	4.6
Farrowing/rearing area		
Dunging area present	84	96.5
Creep area present	8	9.2
Availablity of artificial heating		
No	87	100

4.3.2.2.2 Preventive medicine practices

The preventive medicine practices by the farmers are as shown in Table 4.4. Guard rails/piglet devices were present in 22% (19\87) of the herds in the farrowing/rearing area. Few (8% or 7/87) farmers disinfected pig pens (especially the farrowing area) and 33% (29/87) of the farmers kept some written records. None of the farmers reported the use of vaccination against pig diseases. The majority of farmers, (83.9% or 73/87 and 96% or 83/87), indicated that they controlled for mange infestation and worm infections respectively. To control mange, use of acaricides was the most popular and was practised by 50%, (43/87) of the farmers. Use of used engine oil was the second most popular practice and was practised by 37% (62/87) of the farmers. A few farmers (12% or 10/87) combined acaricides and used engine oil to control mange. Helminths were controlled by the use of various anthelmintics. There was no particular programme for the control of mange and worms in all the farms.

Table 4.4. The descriptive statistics for preventive medicine categorical variables of 87 smallholder pig herds in Kikuyu Division, Kiambu District, (June 1998-August 1998)

	Number of farms	Percentage
Sow observed at farrowing		
No	20	23
Yes	67	77
Vaccination practised	0	0
Iron deficiency prophylaxis		
No	40	46
Yes	47	54
Mange control		
No	14	16.1
Yes	73	83.9
Helminthes control		
No	4	4.6
Yes	83	95.4
Written records	29	33.3
Cleaning done	29	33
Disinfection done	7	8
Piglet protection devices present	19	21.8

4.3.2.2.3 Feeds and feeding systems

The feeds and feeding systems used in smallholder farms is shown in Table 4.5. Restricted feeding was practised in all the herds. Most farms fed their pigs on commercial feeds that were not specifically formulated for pigs. The feed mainly consisted of maize and rice bran, maize germ and wheat pollard. Commercial feed, swill, self-formulated feed and forage were fed to the pigs in, 69% (60/87); 26% (23/87); 1.0% (1/87), and 4.0% (3/87) of the herds, respectively. Swill consisted of home and hotel remains and brewer's mash. Only a few farms (9.2% or 8/87) provided creep feed to the piglets.

Table 4.5. The descriptive statistics for feeds and feeding systems categorical variables of 87 smallholder pig herds in Kikuyu Division, Kiambu District, (June 1998-August 1998)

	Number of farms	Percentage
Feeds provided		
Commercial	60	69
Swill	23	26
Self formulated	1	1.0
Forage	3	4.0
Feeding method		
Ad lib	0	0
Restricted	87	100
Creep feed provided		
No	79	90.8
Yes	8	9.2
Feed additives used		
No	57	65.5
Yes	30	34.5

4.3.2.2.4 Pig production system

The pig production systems in the smallholder farms are shown in Table 4.6. Pig production in these farms consisted of a lose fusion of farrow-to-finish (68%, or 59/87), farrow-to-weaner (16% or 14/87) and feeder operation (5% or 4/87). Most (87% or 76/87) farmers weaned the piglets at the age of 2 months. Natural mating was practised in all the farms but most (59.8% or 52/87) farmers did not own breeding boars. Majority (99% or 86/87) of the farmers practised controlled mating (pen mating) where the farmer took the sow to the boar or the boar was brought to the sow for mating.

Table 4.6. Descriptive statistics for pig production systems categorical variables of 87 smallholder pig herds in Kikuyu Division, Kiambu District, (June 1998-August 1998)

Production system	Number of farms	Percentage
Farrow-to-finish	59	67.8
Farrow-to-weaner	14	16.1
Feeder operation	4	4.6
Farrow-to-finish, farrow-to-weaner and feeder	5	5.7
Farrow-to-finish and farrow-to-weaner	1	1.2
Farrow-to-weaner and feeder	1	1.2
New farmers (not decided on the system)	3	3.4
Piglet weaning age		
Six weeks	2	2.3
Eight weeks	76	87.4
Twelve weeks	5	5.8
Until sow resents	1	1.1
Not decided (new farmer)	3	3.4
Mating method		
Hand mating	1	1
Pen mating	86	99
Boar owned by farmer	35	40.2

4.3.3 Pig production constraints

The production constraints as perceived by the farmers in order of importance were high cost of feeds which were of variable qualities, lack of credit, lack of genetically quality breeding boars, limited marketing channels and diseases (Table 4.7). Among the diseases, sarcoptic mange, helminthosis, diarrhoea and pneumonia were highly ranked by the farmers (Table 4.8).

Table 4.7. Pig production constraint identification and ranking in 87 smallholder pig herds in Kikuyu Division, Kiambu District, (June 1998-August 1998)

Constraint	Production constraint ranking							Respondents	Total score
	1st	2nd	3rd	4th	5th	6th	7th		
High cost of feed	40	25	9	3	0	3	7	87	500
Lack of finance	32	25	13	2	5	5	5	87	477
Lack of good breeding stock	4	19	26	26	5	5	2	87	401
Disease	0	10	19	23	35	0	0	87	351
Limited marketing channels	6	5	17	25	25	7	2	87	351
Lack of labour	3	0	2	3	12	32	35	87	179
Inadequate water	2	3	2	3	6	34	37	87	177

Table 4.8 Pig diseases constraint identification and ranking in 87 smallholder pig herds in Kikuyu Division, Kiambu Disrtict, (June 1998-August 1998).

Disease	Disease constraint ranking				Respondents	Total score
	1st	2nd	3rd	4th		
Mange	44	33	10	0	87	295
Helminthosis	27	40	17	0	84	262
Diarrhoea	2	8	20	22	52	94
Pneumonia	6	2	17	17	42	81
Infertility	2	2	15	28	47	72
Gut oedema	5	2	6	5	18	43
Lameness	2	0	2	3	7	15
Skin necrosis	0	0	0	7	7	7
Abscesses	0	0	0	2	2	2

4.4. Discussion

In this study, the response percentage was excellent. It was attributed to the good rapport that had been created between the pig farmers and the extension staff during farm recruitment and the willingness of the farmers to participate. In addition, involvement of the extension officers who worked among the farmers was found useful during the interviews as any suspicion the farmers might have had was easily overcome.

The median farm size of 1 acre was considered small and this was attributed to the peri-urban nature of the study area and the land tenure system of inheritance with subsequent subdivisions. Crossbreed exotic pigs mainly of Large White, Landrace or Hampshire were kept in these farms. Such breeds have been shown to perform well even under tropical conditions if properly managed (de Fredrick and Osborne, 1977; Kunavongkrit and Heard, 2000). In the study farms, pigs were raised as part of a complex mixed farming system and majority of the farmers depended on family labour for pig production and had an off-farm income generating activity. These findings were consistent with previous observations about smallholder farming systems (Amir and Knipscheer, 1989; Burger, 1994; Van Schaik *et al.*, 1996).

Among the studied farms, majority of the farmers did not seek for any extension information on pig farming. Appropriate extension services about pig health and production to smallholder pig farmers in tropical areas (Wilkins and Martinez, 1983; More *et al.*, 1999) have improved pig performance. Thus, the lack of extension information in the study farms may lead to inadequate pig management and husbandry practices. During the time of the study, the tourism industry (the principal outlet of pigs in Kenya) was experiencing a slump. Therefore, many farmers were not breeding their sows as reflected by the small number of piglets in these farms. A slump in tourists visiting the country has previously been associated with reduced pig production by the farmers (MALD&M, Annual Report, 1992).

Pigs were confined the year round in simple houses that were of varied design. Housing of pigs in low input houses is common in smallholder pig production systems in tropical areas (de Fredrick, 1977a; Gichohi *et al.*, 1988). As no artificial heating was available in any of the farms, farmers protected the piglets from cold and draught by providing some form of bedding in the farrowing area and by sheltering it with locally available materials such as gunnysacks and polythene papers.

Only a few farmers kept written production records. Therefore the data gathered during this phase of the study was only on those aspects the farmers were likely to recall easily. Quantitative data on health and productivity was to be collected during the subsequent longitudinal observational study in order to provide reliable data.

Although majority of the farmers indicated that they controlled for mange, high numbers of clinical cases of mange were observed in most of the farms. Further interviews with the farmers revealed that most did not have control programmes in place. Control of pig parasitic diseases in smallholder production systems has been achieved through appropriate preventive methods and extension services (Wilkins and Martinez, 1983; Manuel *et al.*, 1989; Smith, 1992) and as a consequence to this, improved performance of pigs has been achieved (Wilkins and Martinez, 1983; Lanada *et al.*, 1999). Therefore, there is a need for the smallholder farmers in Kikuyu Division to acquire both extension services and knowledge on pig production in order to apply appropriate preventive practices.

Nutritional status of pigs in majority of the farms was poor as reflected by poor body conditions of pigs in most of the farms. Similar observations have been made in the past in similar production systems (Wilkins and Martinez, 1983; Gatenby and Chemjong, 1992). In this study, pigs were normally fed once or twice a day and the bulk of the feed mainly consisted of inferior commercial feeds, that were not specifically formulated for pigs, and swill. Feeding of pig formulated feeds was not practised by majority of the farmers probably due to their high costs (Gichohi *et al.*, 1988). Some farmers complemented the feeds with farm weeds, kale, green vegetables, sweet potato vines, pumpkin leaves and nappier grass. Feeding leafy green materials to pigs in smallholder farms is a common practice (de Fredrick, 1977a; Wilkins and Martinez, 1983) and the agro-products might act as a source of proteins to supplement the normally protein deficient pig feeds.

Delayed weaning was practised in all the farms with most farmers weaning the piglets at the age of 2 months. Delayed weaning has also been noted from studies of smallholder farms in Nepal (2.2 months), (Gatenby and Chemjong, 1992), Solomon Islands (2 months), (de Fredrick and Osborne, 1977) and Philippines (1.7 months), (Lanada *et al.*, 1999). Since lactation length influences the interfarrowing interval (IFI), the weaning of piglets at the age of two months, as reported by most farmers, might give rise to prolonged IFI and hence reduce the sow performance (Taveros and More, 2001). Weaning of piglets at an earlier age would however require provision of high quality feeds to the piglets (Taveros and More, 2001).

Most farmers did not own a breeding boar although natural mating was practised in all the farms. This was because keeping of a boar was considered uneconomical due to the small number of sows in each farm. Similar observation has been reported elsewhere in tropical smallholder pig farms (Gatenby and Chemjong, 1992; Lanada *et al.*, 1999). Thus most pig farmers in Kikuyu Division relied on hired boars for breeding their sows, which at times were hired from distant places due to lack of boars in their neighbourhood. The consequences of this are that the boar may not be available when required and this could prolong non-productive days. In addition, a young uncastrated boar may be used to serve sows that are close relatives leading to inbreeding. Since most farmers were paying for service by a boar, a chance for breed improvement exists in form of provision of an artificial-insemination programme or availability of a superior boar that may be owned communally or individually. Such an arrangement would go along way in improving pig productivity in the smallholder farms through genetic diversity and timely service.

The production constraints as perceived by farmers were high cost of feeds that were of variable qualities, lack of credit, lack of genetically quality breeding boars, limited marketing channels and diseases. Similar constraints have been identified in smallholder pig production systems (de Fredrick 1977a; de Fredrick and Osborne, 1977; Gichohi *et al.*, 1988; Gatenby and Chemjong, 1992; More *et al.*, 1999). Among the diseases, sarcoptic mange and helminthosis were considered to be the most important health constraints. These results are consistent with findings in similar production systems (de Fredrick, 1977b; Manuel *et al.*, 1989; Kambarage *et al.*, 1990; Esrony *et al.*, 1997). High infestations by these parasites have been reported to increase with the poor nutritional status of the pigs and poor environmental hygiene (de Fredrick, 1977b; Manuel *et al*., 1989; Cargill and Davis, 1997; Corwin and Stewart, 1997) and these were quite apparent in the surveyed farms.

CHAPTER 5

LONGITUDINAL OBSERVATIONAL STUDY

5.1 Introduction

The assessment of factors associated with pig health and production in smallholder herds is necessary in order to help identify health and production constraints and opportunities in pig production. Such information may lead to application of appropriate pig production practices that may lead to increased productivity and profitability. This will directly contribute to the social and economic wellbeing of households in smallholder pig production systems.

In Kenya, the quantitative assessment of herd-level factors associated with pig production in smallholder herds has not been studied to-date. This chapter describes a longitudinal observational study carried out with the following objectives; (1) determine the baseline health, production and productivity parameters of pigs; (2) identify the important herd-level risk factors associated with pig health and productivity; (3) quantify the relationship between these factors and health and productivity outcomes of pigs in smallholder herds in Kikuyu Division of Kiambu District, Kenya.

5.2 Materials and methods

5.2.1 Study herds

The study herds were as described in Chapter 3, subsection 3.5.

5.2.2 Data collection

5.2.2.1 Pilot study

The pilot study was carried out as described in Chapter 3 subsection 3.5. During the study, the content and validity of the data collection cards and the general research methodology were evaluated and the necessary modifications were carried out.

5.2.2.2 Longitudinal study

The longitudinal observational study was carried out as described in Chapter 3 subsection 3.5. A total of 76 herds were recruited and the initial participation rate was 100%.

5.2.2.2.1 Health and productivity of preweaning piglets

5.2.2.2.1.1 Data collection

Data on piglet health and productivity were collected using a sow-litter record card (Appendix 1.3). The data collected included, farrowing date, number of piglets born alive, number of piglets born dead or mummified, date weaned, number weaned, age at weaning, piglet morbidity and mortality, sow morbidity and mortality and feed provided. The farm visits and sampling of faecal material for faecal egg count and ear wax scrapings for mites identification were carried out as described in Chapter 3 subsection 3.5.1. Health and production data were recorded on the sow-litter record card, from the recall of the events that occurred between the visits or from records scribbled on the pen walls by some farmers. In addition, during the monthly visits, piglets were weighed up to weaning using a suspended weighing scale (Salter®, Salbrave, Kenya Limited).

5.2.2.2.1.2 Measure of health in preweaning piglets

Morbidity risk that measure the probability of disease occurrence in a group of animals and mortality risk that describe the quantitative impact of death in an animal population (Martin *et al.*,1987) were used as measures of health in preweaning piglets. The period from farrowing to weaning was taken as the biologic period of risk. The amount of disease (morbidity) was determined by recording any disease/condition with a recognisable clinical sign(s) while mortality was determined by recording all cases of death in piglets. During the monthly visits, the author made detailed physical examinations of the piglets and recorded the morbidity data. Additional information on piglet morbidity and mortality occurring in between the visits was provided by the farmers. Farmers had been motivated to keep close watch on the piglets by being offered free treatment for any sick pig. Additionally, whenever possible, the author also attended sick pigs at the farms at the request of the farmers. Clinical diagnosis of sick or dying piglets was mainly based on the antemortem clinical signs observed by the author during the monthly visits or from the clinical history presented by the farmers.

5.2.2.2.1.3 Herd-level factors associated with piglet morbidity and mortality

The herd-level risk factors thought to influence piglet morbidity and mortality were, disease management and husbandry practices that included, endo- and ectoparasites control, hygiene status at the farm, prophylaxis for piglet anaemia, and presence or absence of piglet protection devices in the farrowing area. Nutrition of the sow and the piglets and the person who frequently attended to the pigs were also considered as important risk factors (Chapter 3, Table 3.2).

5.2.2.2.1.4 Measure of productivity in preweaning piglets

Productivity in piglets was measured as average daily weight gain (ADWG) in kilogrammes per day (Radostits *et al.*, 1994)

5.2.2.2.1.5 Herd-level factors associated with piglet productivity

The investigated risk factors for piglet productivity were nutrition of the sow, disease management practices and the person who frequently attended to the piglets (Chapter 3, Table 3.2)

5.2.2.2.2. Health and productivity of grower pigs

5.2.2.2.2.1 Data collection

Data on grower pig health and productivity were collected using a grower pig record card (Appendix 1.5). The data collected included, date weaned, morbidity and mortality and feed provided. The farm visits and sampling of faecal material for faecal egg count and ear wax scrapings for mites identification were carried out as described in Chapter 3 subsection 3.5.1.

Health and production data were recorded on the grower pig record card from the recall of the events that occurred between the visits or from records scribbled on the pen walls by some farmers. In addition, during the monthly visits, grower pigs up to maximum weight of 40kg were weighed using a suspended weighing scale (Salter®, Salbrave, Kenya Limited).

5.2.2.2.2.2 Measure of health in grower pigs

The measures of health used for the grower pigs were the same as those described for piglets in subsection 5.2.2.2.1.2. The amount of disease (morbidity) was determined by recording any disease/condition with a recognisable clinical sign(s) while mortality was determined by recording all cases of death in the grower pigs. During the monthly visits, the author made detailed physical examinations of the grower pigs and recorded the morbidity data. Additional information on grower morbidity and mortality occurring in between the visits was provided by the farmers. Clinical diagnosis of sick or dying grower pigs was mainly based on the antemortem clinical signs observed by the author during the monthly visits or from the clinical history presented by the farmers.

5.2.2.2.2.3 Herd-level factors associated with grower pig morbidity and mortality

The herd-level risk factors thought to influence grower pig morbidity and mortality were, disease management and husbandry practices that included, endo- and ectoparasites control and hygiene status at the farm. The person who frequently attended to the pigs was also considered an important risk factor (Chapter 3, Table 3.2).

5.2.2.2.2.4 Measure of productivity in grower pigs

The measures of productivity used for the grower pigs were as described in Chapter 3 subsection 3.5.2.

5.2.2.2.2.5 Herd-level factors associated with grower pig productivity

The investigated risk factors for grower pig productivity were nutrition, disease management practices and the person who frequently attended to the pigs (Chapter 3, Table 3.2).

5.2.2.2.3 Sow reproductive performance

5.2.2.2.3.1 Data collection

Data on sow reproductive performance were collected by the use of sow-litter (Appendix 1.3) and dry-sow (Appendix 1.4) record cards. For the dry-sow, the data collected included, service date, farrowing date, date weaned, morbidity and mortality and feed provided. The data collected for the lactating sow was as described in subsection 5.2.2.2.1.1.

The farm visits were as described in Chapter 3 subsection 3.5. The data were recorded on the cards either from the recall of the events that occurred between the visits, or from records scribbled on the pen walls by some farmers.

5.2.2.2.3.2 Measure of sow reproductive performance

The measures of the sow reproductive performance as used in this study are described in Chapter 3 subsection 3.5.3.

5.2.2.2.3.3 Herd-level factors associated with sow reproductive performance

The herd-level risk factors for sow reproductive performance investigated included nutrition of the dry or lactating sow, disease management practices, lactation length, ownership of boar, average parity of sows in the herd and the person who frequently attended to the pigs (Chapter 3, Table 3.2).

5.2.3 Data management

Data were entered in the data collection cards at the farm during each visit. Later, separate, sow-level, piglet-level, grower pig-level and farm- level, files were created in Excel® 1997 (Microsoft Corporation, USA). The files were screened for any errors that might have occurred during data entry and the errors were corrected by rechecking against the original data collection cards.

5.2.4 Data analysis

Data analyses were performed using Excel® 1997 (Microsoft Corporation, USA) and Minitab Statistical Software, version 13 for windows (Minitab Statistical Software, Minitab Inc, USA). Normality tests on the variables, that test the null hypothesis that the data are a random sample drawn from a normal population, were carried out using Ryan-Joiner Test (Minitab Inc., USA), and were then handled accordingly in the subsequent analysis.

5.2.4.1 Health and productivity of preweaning piglets

5.2.4.1.1 Measure of health in preweaning piglets

The cause-specific, age-specific and crude morbidity cumulative incidences and mortality for each litter in a farm were used as the litter-level measure of health. The mean values of crude morbidity cumulative incidences and mortality in all the litters at the farm were used as herd-level measures of health.

For crude morbidity, any preweaning piglet with more than one disease/condition was taken as a case. For the cause-specific morbidity, only new cases arising during the monitoring period were considered. Due to the small herd sizes in most farms, the farmers were able to identify the piglets in a litter and this minimised the chance of considering a case twice. The morbidity cumulative incidence and mortality were calculated for the preweaning period of 8 weeks.

5.2.4.1.2 Herd-level factors associated with morbidity and mortality in preweaning piglets

For each measure of health, any herd-level value less than the median value was coded as 1 (good health status) while a herd-level value more than the median value was coded as 0 (poor health status). Since simultaneous evaluation of a large number of risk factors may be complicated by the problems of multicollinearity, confounding and interactions (Dohoo *et al.*, 1996), a preliminary screening of associations between the independent variables (herd-level risk factors) and the dependent variables (morbidity or mortality) was carried out. Chi- square test of independence was used for categorical variables and Kruskal-wallis test was used for non-normally distributed continuous variables. Subsequently, binary logistic regression analysis was used to identify the important associations for those predictor variables that showed unconditional associations.

5.2.4.1.3 Measure of productivity in preweaning piglets

The average daily weight gain (ADWG) for piglets in a litter was used as the measure of productivity. The ADWG was calculated as the difference in total litter weights between two consecutive monthly visits divided by the total number of piglets in the litter and the number of days between the two visits.The mean ADWG for all the litters in a herd was used as the herd-level measure of productivity.

5.2.4.1.4 Herd-level factors associated with productivity in preweaning piglets

Prior to the analysis, the measures of preweaning piglet productivity, ADWG, were collapsed into two categories, less than or equal to, and greater than, the median value for all the farms. Herd-level productivity value more than the median value was coded as 1 (good productivity) while a herd-level value less than the median value was coded as 0 (poor productivity). The magnitude of the association between each herd-level risk factor and ADWG was evaluated using the chi- square test of independence for categorical variables and Kruskal-wallis test for non-normally distributed continuous independent variables. Only herd-level risk factors that showed unconditional associations with ADWG were included in the subsequent binary logistic regression analysis.

5.2.4.2 Health and productivity of grower pigs

5.2.4.2.1 Measure of health in grower pigs

The cause-specific, age-specific and crude morbidity cumulative incidences and mortality for each litter in a farm were used as the litter-level measure of health. The mean value of crude morbidity cumulative incidences and mortality in all the litters at the farm were used as herd-level measures of health

For crude morbidity, any grower pig with more than one disease/condition was taken as a case. For the cause-specific morbidity, only new cases arising during the monitoring period were considered. Due to the small herd sizes in most farms, the farmers were able to identify the grower pigs in a litter and this minimised the chance of considering a case twice.

For the individual litters of grower pigs, the monitoring period lasted between 2 to 5 months. Grower pigs could not be followed for equal lengths of time due to censoring which was as a result of sale of the grower pigs or due to the end of the study. In order to take care of the different time-at-risk for the different litters of grower pigs, incidence rates were used to determine the grower pig morbidities and mortality per grower pig month-at-risk. Estimated cumulative incidence ($CI_{(t)}$) was then calculated using the formula ($CI_{(t)} = 1\text{-}e^{(-IR*t)}$ where e is the base of the natural logarithm, and t indicates the time-unit of concern as described in Noordhuizen *et al.* (1997).

5.2.4.2.2 Herd-level factors associated with morbidity and mortality in grower pigs

Prior to the analysis, each of the measures of grower pig health, morbidity and mortality were handled as described in subsection 5.2.4.1.2. Preliminary screening of associations between the independent variables (herd-level risk factors) and the dependent variables (morbidity or mortality) was carried out. Chi- square test of independence was used for categorical variables and Kruskal-wallis test was used for non-normally distributed continuous variables. Subsequently, binary logistic regression analysis was used to identify the important associations for those predictor variables that showed unconditional associations.

5.2.4.2.3 Measure of productivity in grower pigs

The average daily weight gain (ADWG) for the grower pigs in a litter was used as the measure of productivity. The ADWG was calculated as the difference in total litter weight between two consecutive monthly visits divided by the total number of pigs in the litter and the number of days between the two visits. In addition, the ratio of the measured weight and the reported age of each grower pig (weight:age ratio) in kilogrammes per month was also used as a measure of productivity. This measure of productivity was used in order to increase the number of herds where productivity of grower pigs could be determined, as the number of herds where ADWG could be determined was small. For each of the productivity measures, ADWG and weight:age ratio, the means of the parameter for all the litters in a herd were used as the herd-level measures of productivity.

5.2.4.2.4 Herd-level risk factors associated with productivity in grower pigs

Prior to the analysis, each of the measures of grower pig productivity, ADWG and weight:age ratio, were handled as described in subsection 5.2.4.1.4. The magnitude of the association between each herd-level risk factor and ADWG was evaluated using the chi-square test of independence for categorical variables and Kruskal-wallis test for non-normally distributed continuous variables. Only herd-level risk factors that showed unconditional associations with ADWG were included in the subsequent binary logistic regression analysis.

5.2.4.3 Sow reproductive performance

5.2.4.3.1 Measure of sow reproductive performance

In addition to the preweaning piglet mortality (subsection 5.2.4.1.1), the Interfarrowing Interval (IFI) and the number of live-born piglets per litter (NLBP) were used as measures of sow reproductive performance. The mean values of these measures for all the sows within a herd were used as the herd-level measure of sow performance.

5.2.4.3.2 Herd-level factors associated with sow reproductive performance

Prior to the analyses, each of the herd-level measures of sow reproductive performance were dichotomised as, less than or equal to, and greater than, the median value for the parameter. For IFI, any herd-level value shorter than the median value was coded as 1 (good performance) while a herd-level value longer than the median value was coded as 0 (poor performance). NLPB and PW/S/Y were dichotomised as 1 and 0 if the herd-level value was bigger than or smaller than, the median value for each parameter respectively. The magnitude of the associations between each herd-level risk factor and each of the measures of sow reproductive performance were evaluated using the chi- square test of independence for categorical variables and Kruskal-wallis test for non-normally distributed continuous variables. Only herd-level risk factors that showed unconditional associations with the measures of sow reproductive performance were included in the subsequent binary logistic regression analysis.

5.3 Results

5.3.1 Pilot study

During this study, 12.6% (11\87) of the farmers withdrew. Ten farmers (11.5%) had sold all their pigs and one farmer (1.1%) had died. Most (99% or 86/87) farmers were not keen on recording events that occurred between the visits on the designed record cards and majority of them had misplaced the record cards by the second visit.

5.3.2 Longitudinal study

5.3.2.1 General pig and herd-level information

A total of 76 herds were enrolled out of which 97.4% (74/76) kept breeding pigs (sows and gilts) while 2.6% (2/76) kept grower pigs only. Of the 74 farms where breeding pigs were kept, 64.9% (48/74) kept both breeding and grower pigs while 33.8% (25/74) farms kept breeding pigs only. A total of 155 breeding pigs were enrolled in the study with a herd median of 1 and a range of 1-10. A total of 920 live-born piglets, 37 stillbirths and 6 mummified foetuses were farrowed in 99 farrowings. Thirteen litters with 119 live-born piglets were not followed for the entire period up to weaning due to censoring as the study ended before they could be weaned. The number of grower pigs enrolled in the study was 795 with a herd median of 8 and a range of 1-106.

5.3.2.2 Farm participation

During the study period for 12 months, 33% (25/76) of the farms withdrew. The withdrawal reasons included death of the pigs (2.6% or 2/76) and sale of all the pigs at the farm (30.3% or 23/87). The one year voluntary percent participatory rate was 67.1% (51/76).

5.3.2.3 Health and productivity of preweaning piglets

5.3.2.3.1 Measure of health in preweaning piglets

The overall litter- and herd-level crude morbidity cumulative incidence for the preweaning pigs was 29% (95% CI; 20.3, 37.7) and 35.3% (95% CI; 22.5, 48.1), respectively (Table 5.1 and Table 5.2). The distributions of cases of preweaning morbidity, age-specific and cause-specific cumulative incidence are shown in Table 5.1, Figure 5.1 and Figure 5.2. The litter-level cause-specific cumulative incidence from birth up to 4 weeks was highest for skin necrosis (3%) and diarrhoea (2.5%). From 4^{th} week postpartum to weaning the cause-specific morbidity was highest for pruritis (17.1%).

The overall litter- and herd-level crude cumulative mortality of preweaning piglets was 18.67% (95% CI; 13.40, 23.94) and 18.74% (95% CI; 11.74, 25.73), respectively (Table 5.2 and Table 5.3). At least 25% of the herds had a preweaning piglet mortality of not more than 2.1%, although mortality in some herds was as high as 100%. The distribution of cases of preweaning mortality, cause-specific and age-specific cumulative incidences is shown in Table 5.3. Preweaning piglet mortality was highest during the first week postpartum; thereafter, there was a general decrease in mortality until the 6^{th} week postpartum when a slight increase was noted (Figure 5.3). Among the piglets born alive, overlying was the most frequent cause of death (9.9%) followed by savaging (2.4%).

Overall, 78.8% of the total liveborn piglet mortality occurred during the first week with 69% of these deaths being caused by overlying. The proportional preweaning piglet mortality due to overlying and savaging was 54.4% and 15%, respectively (Table 5.4).

Table 5.1. The distribution of morbidity cases by clinical manifestations, age in weeks, cause-specific and age-specific cumulative incidence for 801 preweaning piglets in 40 out of 76 smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999–December 1999).

Disease/condition	Age in weeks								Cause-specific CI[a]
	1	2	3	4	5	6	7	8	
Diarrhoea	6	9	9	0	0	4	8	0	4.3
Pneumonia	0	0	0	0	0	4	2	2	1.3
Pruritis	0	3	0	28	33	27	29	14	17.1
Unthriftiness	4	0	0	0	1	0	0	0	1.3
Hernia[c]	1	0	0	0	0	0	0	0	-
Skin necrosis	16	3	6	1	0	1	8	0	4.2
Callus on carpus	0	0	8	9	0	0	0	0	2.4
Loss of claw	0	0	0	0	0	0	0	1	0.14
Deformity[c]	1	0	0	0	0	0	0	0	-
Unknown	2	2	0	2	1	0	1	0	0.77
Total	30	17	23	40	35	36	48	17	29(35.3)[d]
CI[b]	3	2	3	4	5	6	7	3	

[a]Litter-level cumulative incidence(%)

[b]Age-specific cumulative incidence(%)

[c]The cumulative incidence was not calculated as the conditions were present at birth

[d]Overall litter- and herd-level (in parenthesis) crude morbidity cumulative incidence(%)

Table 5.2. The descriptive statistics for litter and herd-level crude preweaning piglet morbidity cumulative incidence and mortality (%) for 86 litters in 40 out of 76 herds in Kikuyu Division, Kiambu District, (January 1999– December 1999).

	N	Mean	Min[a]	25th Percentile	Median	75th Percentile	Max[b]
PWPMB[c]	86	29(20.3, 37.7)[e]	0	0	0	69.5	100
PWPMB[c]	40	35.3(22.5, 48.1)	0	0	16	77.8	100
PWPMT[d]	86	18.7(13.4, 23.9)	0	0	10	29.3	100
PWPMT[d]	40	18.7(11.7, 25.7)	0	2.1	12	26.5	100

[a]Minimum

[b]Maximum

[c]Preweaning piglet crude morbidity cumulative incidence

[d]Preweaning piglet crude cumulative mortality

[e]The numbers in parenthesis refers to 95% confidence interval

Table 5.3. The distribution of mortality cases by clinical manifestations, age in weeks, cause-specific and age-specific cumulative mortality for 801 preweaning piglets in 40 out of 76 smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999–December 1999).

Disease/condition	Age in weeks								Cause-specific CI[a]
	1	2	3	4	5	6	7	8	
Overlying	87	0	0	0	0	0	0	0	9.9
Unviable piglets	13	0	0	0	0	0	0	0	2.0
Starvation	4	3	0	0	0	0	0	0	1.2
Scours	0	0	0	0	0	1	0	0	0.1
Savaging	20	2	0	2	0	0	0	0	2.4
Pneumonia	0	0	0	0	0	2	0	0	0.2
Predation	0	8	0	0	0	0	0	0	0.8
Unknown	2	2	2	1	1	1	5	4	1.9
Total	126	15	2	3	1	4	5	4	18.67(18.74%)[c]
CI[b]	14.3	2.5	0.2	0.6	0.1	0.6	0.7	0.6	

[a]Litter-level crude cumulative mortality (%)

[b]Age-specific cumulative incidence(%)

[c]Overall litter and herd-level (in parenthesis) crude cumulative mortality (%)

[d]The 2 piglets in the 4th week were just found missing and the cause could not be ascertained

Table.5.4. Proportional preweaning piglet mortality from a total of 160 cases of deaths recorded in smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999-December 1999).

Disease/ condition	Number dead	Percentage
Overlying	87	54.3
Unviable piglets	13	8.1
Starvation	7	4.4
Diarrhoea	1	0.6
Savage by the dam	24	15
Pneumonia	2	1.3
Unknown causes	18	11.3
Predation	8	5

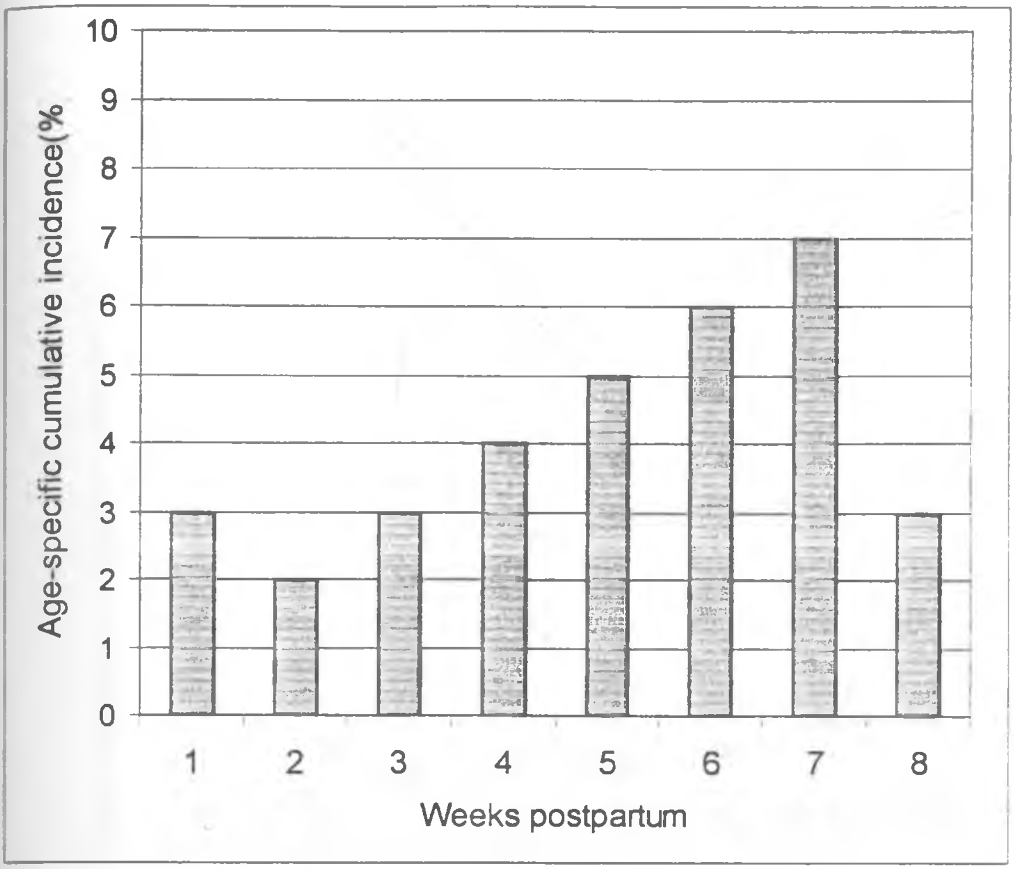

Figure 5.1. Age-specific morbidity cumulative incidence for preweaning pigs as determined in a longitudinal study in smallholder herds in Kikuyu Division, Kiambu District, (January 1999- December 1999).

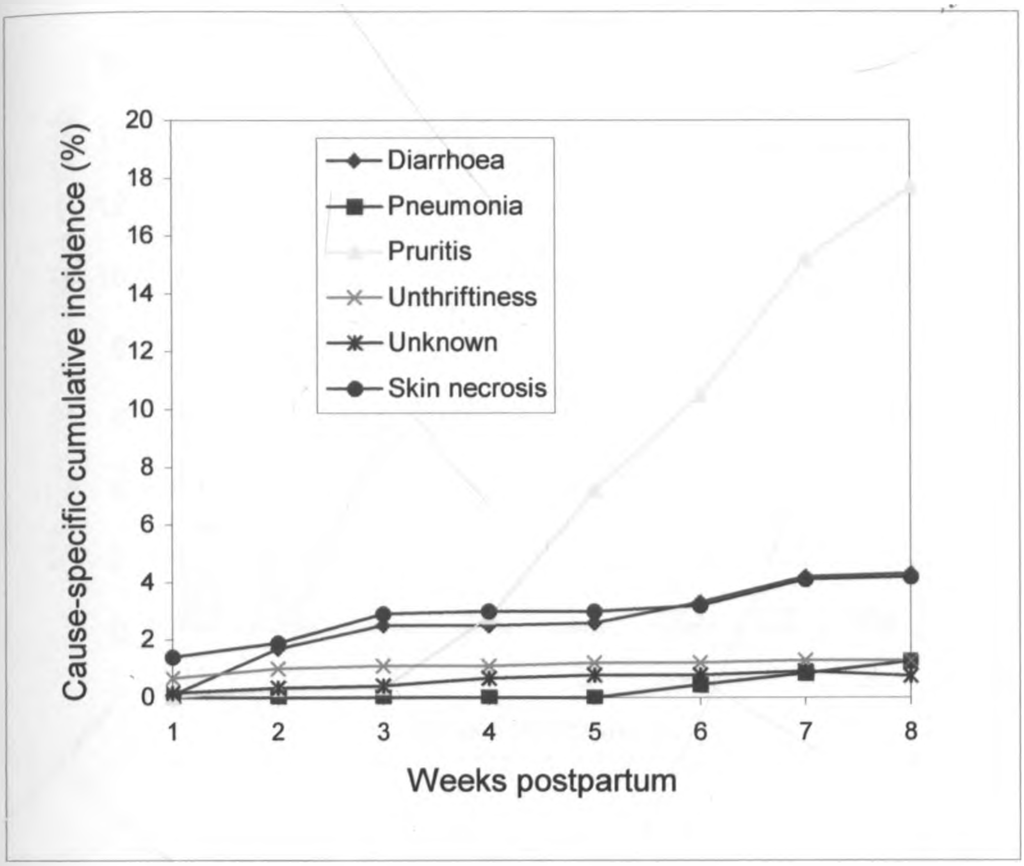

Figure 5.2. Cause-specific cumulative incidence of preweaning piglet morbidity as determined in a longitudinal study in smallholder herds in Kikuyu Division, Kiambu District, (January 1999-December 1999).

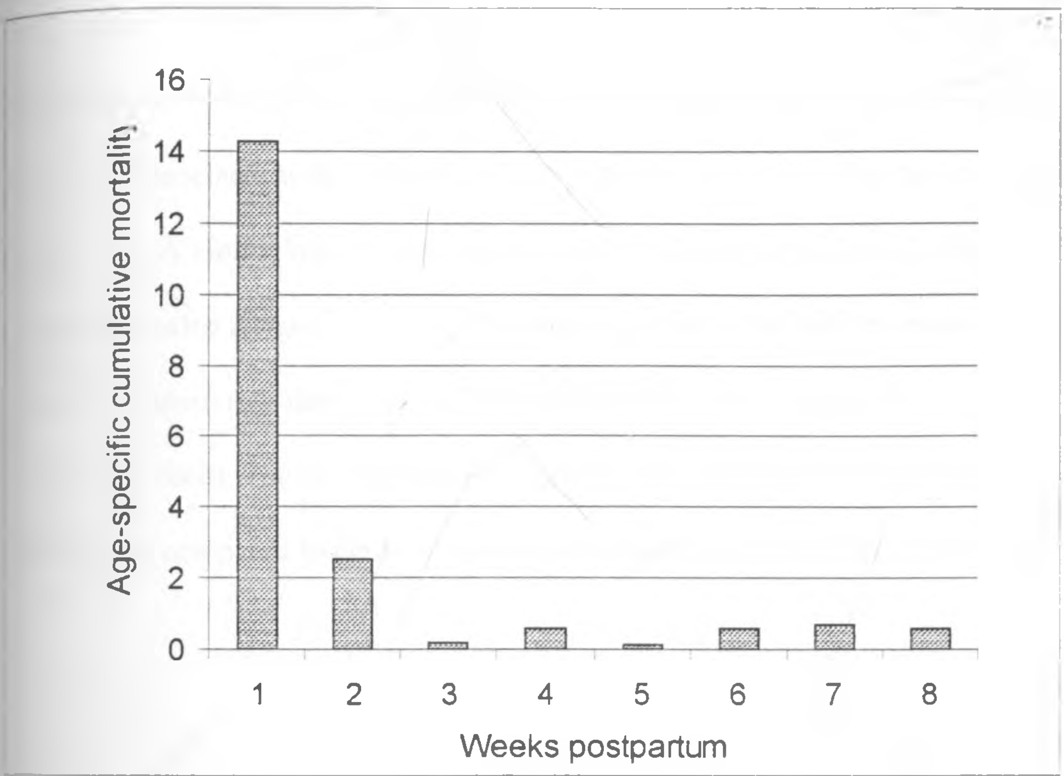

Figure 5.3. The distribution of age-specific crude cumulative mortality of preweaning piglets in smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999- December 1999).

5.3 2.3.2 Herd-level factors associated with preweaning piglet morbidity and mortality

Preweaning piglet morbidity was not significantly ($p>0.05$) associated with any of the herd-level factors investigated (Table 5.5). Piglet mortality was unconditionally ($p=0.022$) associated with supplementation of the lactating sow with protein rich feeds (Table 5.5). A binary logistic regression model produced for this single predictor variable revealed a significant ($p<0.05$) association between supplementation of the sow with protein rich feeds and piglet mortality. Supplementation of the sow with protein rich feeds reduced the odds (odd ratio 0.18) of having a low preweaning mortality as compared to herds where no supplementation was done (Table 5.6).

Table.5.5. The herd-level factors investigated for unconditional associations with piglet morbidity and mortality in smallholder pig herds Kikuyu Division, Kiambu District, (January 1999- December. 1999).

Variable	PWPMB[a] P- value	PWPMT[b] P- value
Mange controlled	0.677	0.270
Hygiene status	0.711	0.316
Stockperson[c]	0.752	0.516
Helminth worms controlled	0.525	0.356
Feed fed to the lactating sow	0.621	0.188
Protein supplement provided to the sow	0.288	0.022[d]
Anaemia prophylaxis in piglets	0.147	0.432
House open or semi-closed	0.185	0.816
Size of farrowing pen	0.548	0.489
Presence of piglet protection device	0.288	0.385

[a]Preweaning piglet morbidity

[b]Preweaning piglet mortality

[c]Family or hired labour

[d]Significant at $\alpha = 0.05$

Table 5.6. Herd-level logistic regressions for measures of sow reproductive performance and grower pig health in Kikuyu Division, Kiambu District, (January 1999- December 1999)

Variable	estimate(β)	Se(β)	P	OR	95% CI (OR)	
Number of live-born piglets						
Model for 26 sow herd						
Intercept	-0.6931	0.5000	-	-	-	
Sow supplemented	2.639	1.180	0.025	14.0	1.39	141.49
Interfarrowing interval						
Model for 17 sow herds						
Intercept	0.6931	0.6124	-	-	-	
Sow was supplemented	-2.079	1.275	0.103	0.13	0.01	1.52
Preweaning mortality						
Model for 39 sow herds						
Intercept	0.3483	0.3770	-	-	-	
Sow was supplemented	-1.7346	0.8759	0.048	0.18	0.03	0.98
Piglet weight gain						
Model for 28 sow herds						
Intercept	-0.9163	0.4830	-	-	-	
Sow was supplemented	2.708	1.183	0.022	15.0	15.0	152.50
Grower pig mortality						
Model for 51 herds						
Intercept	-0.4700	0.5701	-	-	-	
Hygiene status was fair	1.9051	0.7567	0.012	6.72	1.52	29.61
Hygiene status was good	2.0794	0.9618	0.031	8.00	1.21	52.69

5.3.2.3.3 Measure of productivity of preweaning piglets

The litter-level- and the herd –level ADWG was 0.13, with median of 0.14 (25th percentile 0.07, 75th percentile 0.19, range 0.02-0.4, 95% CI; 0.11, 0.16) and 0.15, with a median of 0.14 (25th percentile 0.07, 75th percentile 0.2, 95% CI; 0.12, 0.18) kg/day, respectively.

5.3.2.3.4. Herd-level factors associated with productivity of preweaning piglets

The preweaning pig ADWG was unconditionally (p=0.008) associated with supplementation of the sow with protein rich feeds (Table 5.7). A binary logistic regression model produced for this single predictor variable revealed a significant ($p<0.05$) association between ADWG and supplementation of the sow with protein rich feeds. Piglets from herds where sows were supplemented with protein rich feeds had higher odds (odd ratio 15) of having a higher ADWG than those from herds where no supplementation was done. (Table 5.6).

Table.5.7 The herd-level factors investigated for unconditional associations with preweaning piglet productivity in smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999- December. 1999).

Variable	Average daily weight gain[a] P-value
Mange controlled at least once in the sow	0.161
Helminths controlled at least once in the sow	0.129
Hygiene status of the pen	0.343
House open or semi-open	0.350
Stockperson[b]	0.152
Feed fed to the lactating sow	0.453
Protein supplementation for the sow	0.008[c]

[a]Twelve and 16 herds were considered to have achieved above –median and below-median daily weight gain respectively

[b]Family or hired labour

[c]Significant at $\alpha = 0.05$

5.3.2.4 Health and productivity of grower pigs

5.3.2.4.1 Measure of health in grower pigs

The liter- and herd-level crude morbidity cumulative incidences for the grower pigs during the period of the study were 20% (95% CI; 16.69, 24.1) and 24.0% (95% CI; 19.3, 28.7) (Table 5.8 and Table 5.9). The cause-specific cumulative incidence was highest for pruritis (21.1%) while that due to unknown causes was 2.3%. The suspected cases of gut-oedema had a cumulative incidence of 1.3% (Table 5.8).

The litter- and the herd-level crude cumulative mortalities for the grower pigs were 3.8% (95% CI; 1.3, 4.9) and 3.8% (95% CI; 0.9, 5.4), respectively (Table 5.9 and Table 5.10). The cause-specific mortality due to the unknown causes was 1.6% while that due to suspected cases of gut oedema was 1.3%.

Table 5.8. The distribution of morbidity cases by clinical manifestations, age in months, cause-specific incidences and cumulative incidences for 795 grower pigs in 50 out of 76 smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999–December 1999).

Disease/condition	Age in months						Cause-specific CI	
	2≤3	3≤4	4≤5	5≤6	6≤7	7≤8	IR[a]	CI[b]
Diarrhoea	4	1	0	10	0	0	0.22	0.22
Pneumonia	12	0	0	0	0	3	0.4	0.4
Pruritis	133	95	31	17	24	18	23.6	21.1
Unthriftiness	1	2	0	0	0	0	0.2	0.2
Ear necrosis	0	0	1	0	0	0	0.001	0.001
Abscess	0	0	0	1	0	0	0.1	0.1
Gut oedema[d]	14	0	0	0	0	0	1.3	1.3
Unknown	19	2	3	0	0	1	2.1	2.3
Total cases	183	100	35	19	24	21	(27.9	20.41)[c]

[a]Litter-level cause-specific morbidity incidence (%) per pig-month-at-risk

[b]Estimated litter-level cause-specific morbidiy cumulative incidence(%)

[c]Overall litter-level crude morbidity incidence and cumulative incidence(%)

[d]Neurological disorder, characterised by hoarse squeal, ataxia, swelling of the eyelids, drooping ears, paresis and paralysis was tentatively diagnosed as gut oedema.

Table 5.9. The descriptive statistics for litter and herd-level crude morbidity and mortality cumulative incidence(%) for 116 grower pig litters in 50 out of 76 smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999– December 1999).

	N	Mean	Min[a]	25th Percentile	Median	75th Percentile	Max[b]
GPMBT[c]	116	20(16.7, 24.1)[e]	0	0	21	33	87
GPMBT[c]	50	24(19.3, 28.7)	0	10	28.5	33	60
GPMT[d]	116	3.8(1.3, 4.9)	0	0	0	0	60
GPMT[d]	50	3.8(0.9, 5.4)	0	0	0	2.1	48

[a]Minimum

[b]Maximum

[c]Grower pig crude morbidity cumulative incidence

[d]Grower pig crude cumulative mortality

[e]The numbers in parenthesis refers to 95% confidence interval

Table 5.10. The distribution of cases by clinical manifestations, age in months, cause-specific and cumulative mortalities for 795 grower pigs in 50 out of 76 smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999– December 1999).

Disease/condition	Age in months						Cause-specific CI	
	2≤3	3≤4	4≤5	5≤6	6≤7	7≤8	IR[a]	CI[b]
Diarrhoea	0	4	1	0	0	0	0.19	0.19
Pneumonia	6	6	0	0	0	0	0.3	0.3
Gut oedema[d]	13	0	0	0	0	0	1.3	1.3
PSS[e]	0	0	0	0	1	0	0.1	0.1
Unknown	3	10	2	4	0	1	1.7	1.6
Total deaths(%)	43	39.2	5.9	7.8	2	2	(3.9	3.8)[c]

[a]Litter-level cause-specific mortality (%) per pig-month-at-risk

[b]Estimated litter-level cause-specific mortality (%)

[c]Overall litter-level crude cumulative mortality (%)

[d]Neurological disorder, characterised by hoarse squeal, ataxia, swelling of the eyelids, drooping ears, paresis and paralysis was tentatively diagnosed as gut oedema.

[e]Porcine stress syndrome, tentative diagnosis based on the history of death after exhaustion

5.3.2.4.2 Herd-level factors associated with grower pig morbidity and mortality

Grower pig morbidity was not significantly ($p>0.05$) associated with any of the herd-level factors investigated (Table 5.11). Grower pig mortality was on the other hand unconditionally associated ($p=0.013$) with the hygiene status of the pig houses (Table 5.10). Binary logistic regression model revealed a significant ($p<0.05$) association between grower mortality and the hygiene status of the pig houses. Growers from herds where the hygiene status of the pig houses was good had higher odds (odd ratio of 8) of having a low mortality than growers from herds where the hygiene status was poor (Table 5.6).

Table.5.11. The herd-level factors investigated for unconditional associations with grower pig morbidity and mortality in smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999- December 1999).

Variable	GPMBT[a]	GPMT[b]
	P-value	P-value
Mange controlled	0.952	0.253
Hygiene status	0.823	0.013[d]
Stockperson[c]	0.121	0.971
Helminths worms controlled	0.657	0.343
House open or semi-closed	0.692	0.514

[a]Grower pig morbidity

[b]Grower pig mortality

[c]Family or hired labour

[d]Significant at $\alpha = 0.05$

5.3.2.4.3 Measure of productivity in grower pigs

The ratio weight:age was calculated for a total of 396 grower pigs in 26 herds. The mean weight:age for all the grower pigs in the herd was used as the herd level measure of productivity.The mean rather than the median was used though the values were not normally distributed since there were only few grower pigs per farm. The mean at the animal-level weight:age was 5.2, with a median of 5.1 (25^{th} percentile 3.8, 75^{th} percentile 6.2, range 1.0- 11.9, 95% CI; 5.0, 5.4) kg/month of age. The mean herd-level weight:age was 5.3, with a median of 5.1 (25^{th} percentile 4.1, 75^{th} percentile 6.0, range 1.5-10.6, 95% CI; 4.4, 6.1) kilogramme per month of age.

The litter-level mean ADWG was 0.16 with a median of 0.13 (25^{th} percentile 0.11, 75^{th} percentile 0.21, range 0.01-0.36, 95% CI; 0.13, 0.18) kg/ day. The herd-level mean ADWG was 0.15 with a median of 0.15 (25^{th} percentile 0.12, 75^{th} percentile 0.19, 95% CI, 0.12, 0.19).

5.3.2.4.4 Herd-level factors associated with grower pig productivity

The grower pig productivity was not significantly ($p>0.05$) associated with the farm-level factors investigated (Table 5.12). However, at $p<0.2$, there was unconditional association between protein supplementation, hygiene status, helminths control and weight:age ratio (Table 5.12).

Table.5.12. The herd-level factors investigated for unconditional associations with grower pig productivity in smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999- December. 1999).

Variable	ADWG[a] P-value	Weight-for-age[b] P-value
Mange controlled at least once	0.622	0.778
Helminths worms controlled at least once	0.585	0.131
Hygiene status	0.692	0.152
Housing	0.402	0.648
Stockperson[c]	0.402	0.648
Feed fed to the grower	0.858	0.230
Protein supplementation	0.482	0.143

[a]Six and 11 herds were considered to have achieved above –median and below-median daily weight gain respectively.

[b]Nine and 17 herds were considered to have achieved above-median and below-median weight for age respectively

[c]Family or hired labour

5.3.2.5 Sow reproductive performance

5.3.2.5.1 Measure of sow reproductive performance

The animal- and herd-level mean weaning-to-service interval (WTSI) was 3.2 and 3.5 months, respectively. At least 25% of the sows and herds achieved a WTSI interval of not more than 1 and 1.3 months, respectively. The animal- and herd-level mean interfarrowing interval (IFI) was 6.9 and 7.4 months, respectively. Twenty five percent of the sows and herds achieved an IFI of not more than 5.9 and 6 months, respectively. The animal- and herd-level mean number of live-born piglets per farrowing (NLBP) was 9.2 and 9.5, respectively (Table 5.13 and Table 5.14). The animal- and herd-level mean lactational lengths were similar at 2.2 months (Table 5.15 and 5.16).

Table 5.13. Descriptive statistics for sow-level productivity in smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999-December 1999).

	N	Mean	Minimum	25th Percentile	Median	75th Percentile	Maximum
WTSI[a]	33	3.2	0.2	1	3	4.1	10.5
IFI[b]	29	6.9	5	5.9	6.4	7.5	13
NLBP[c]	95	9.2	0	7	9	12	20
NWF[d]	95	6.9	0	5	7.5	9	14
L/S/Y[e]	95	1.2	1	1	1	1	2
PW/S/Y[f]	76	8.4	0	6	8	11	23

[a]Weaning to service interval in months

[b]Interfarrowing interval in months

[c]Number of live-born piglets

[d]Number of piglets weaned per farrowing

[e]Litters per sow per year

[f]Piglets weaned per sow per year

Table 5.14. Descriptive statistics for herd-level sow productivity in smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999-December 1999).

	N	Mean	Minimum	25th Percentile	Median	75th Percentile	Maximum
WTSI[a]	22	3.5	0.2	1.3	3.1	5.1	10.5
IFI[b]	17	7.4	5.7	6	6.9	7.8	13
NLBP[c]	39	9.5	4.5	7.6	9	10.4	17
NWF[d]	39	7.6	1.5	6.0	7	9	14
L/S/Y[e]	39	1.1	1	1	1	1.2	2
PW/S/Y[f]	39	8.6	1.5	7	8.5	10	17

[a]Weaning to service interval in months

[b]Interfarrowing interval in months

[c]Number of live-born piglets

[d]Number of piglets weaned per farrowing

[e]Litters per sow per year

[f]Piglets weaned per sow per year

Table 5.15. Descriptive statistics for predictor variables on sow-level productivity in smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999-December 1999).

	N	Mean	Minimum	25th Percentile	Median	75 Percentile	Maximum
Lactation length[a]	85	2.2	1	2	2	2.4	4.1
Parity	162	2.1	0	0	1	3	9
Parity at removal	69	1.2	0	0	1	2	5

[a]Lactation length in months

Table 5.16. Descriptive statistics for predictor variables on herd-level sow productivity in smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999-December 1999).

	N	Mean	Minimum	25th Percentile	Median	75 Percentile	Maximum
Lactation length[a]	39	2.2	1.8	2	2	2.4	4.1
Parity	37	2.5	0.5	1	2	3.3	8
Parity at removal	20	2.3	0.3	1.3	2.0	3	5

[a]Lactation length in months

5.3.2.5.2 Herd-level factors associated with sow reproductive performance

Protein supplementation to the sow was unconditionally associated with IFI ($p=0.079$) and NLBP ($p=0.011$) (Table 5.17). A logistic regression analysis revealed a significant ($p<0.05$) association between NLBP and supplementation of the sow with protein rich feeds. Sows from herds where supplementation with protein rich feeds was done had higher odds (odd ratio of 14) of farrowing higher number of live-born piglets than sows from herds where no supplementation was done. Sows from herds where sows were supplemented with protein rich feeds had reduced odds (odd ratio 0.13) of having a short interfarrowing interval as compared to sows from herds where no supplementation was done (Table 5.6).

Table.5.17. The herd-level factors investigated for unconditional associations with interfarrowing interval and number of live-born piglets in smallholder pig herds in Kikuyu Division, Kiambu District, (January 1999- December 1999).

Variable	IFI[a] P-value	NLBP[b] P-value
Average parity of the sows in the herds	0.517	0.558
Herd size	0.716	0.543
Weaning to service interval	0.446	0.397
Lactational length	0.242	0.699
Mange controlled at least once	0.453	0.135
Helminths controlled at least once	0.148	1.000
House design	0.232	0.107
Owner kept own boar	0.819	0.691
Stockperson[c]	0.858	0.621
Feed provided to the sow during lactation	0.667	0.326
Protein supplementation	0.079[d]	0.011[e]

[a]Nine and 8 herds were considered to have achieved below–median and above-median value for the Interfarrowing Interval

[b]Nineteen and twenty farms were considered to have achieved above-median and below-median for the number of live-born piglets

[c]Family or hired labour

[d]Significant at $\alpha = 0.1$

[e]Significant at $\alpha = 0.05$

5.4 Discussion

The pretesting of the record cards for content and validity and the general research methodology was assessed in the study farms. This allowed the author to assess whether what was conceptualized at the beginning of the study (that farmers would record the disease and production events on the prescribed cards) agreed with the actual practice at the farms. It has previously been emphasised that in data collection exercises in the field, the context of the social setting should be considered while implementing a study (Malhotra and Grover, 1998) as this would allow the collection of appropriate information. After the pilot study, areas of deficiency in the research methodology became apparent. It was observed that farmers were not keen on recording events that occurred between the visits on the prescribed record cards. Therefore, in the subsequent longitudinal study, the disease and production events at the farms were recorded by the author and the enumerators during the monthly visits.

The ownership of pigs in the smallholder farms was sporadic. During both the pilot and the longitudinal phases of the study, majority of the farmers withdrew from the study as they had sold all the pigs at the farm. This was an indication of the ease with which the smallholder farmers dispose off the pigs as a source of income as has been suggested previously (Gichohi *et al.*, 1988). In addition, financial difficulties in purchasing pig feeds, though not quantified in this study, forced the farmers to dispose of the pigs. Sporadic ownership of pigs as a result of various socio-economic factors has been observed in other tropical smallholder areas (de Fredrick, 1977a; Gatenby and Chemjong, 1992; Lanada *et al.*, 1999).

The participation by the farmers throughout the study was good. This was attributed to several factors that included, general willingness to participate, the good rapport that was created by the author, and the incentive given in form of treatment for the sick pigs. The willingness to participate in the study made it possible for the farmers to have a keen interest on health and production in their herds and this allowed the author to collect appropriate information.

In this study, a high crude morbidity risk was observed in preweaning pigs. The general patterns of occurrence of diseases as observed in this study were similar to the observations made in commercial piggeries in temperate countries (Straw *et al.*, 1997). The crude morbidity increased with age with the cause-specific risk being highest for scours and facial necrosis in the early preweaning period. Scours in the preweaning pigs are common and have multifactorial causes (Straw *et al.*, 1997; Radostits *et al.*, 1999). Facial skin necrosis is commonly observed during the first week postpartum and is as a result of infection by *Staphylococcus hyicus and Fusobacterium necrophorum* of wounds inflicted by piglets on each other during feeding (Cameron, 1997). From the 4th week postpartum until weaning, the cause-specific morbidity was highest for pruritis (manifested by rubbing against objects and scratching the body with the limbs). Several factors are known to cause pruritis in pigs. The most common and important cause of pruritis in pigs is sarcoptic mange (Cargill and Dobson, 1979; Cargill *et al.*, 1996; Hollanders *et al.*, 1995; Cargill and Davis, 1997). The pruritis is as a result of the development of delayed- and immediate-type hypersensitive reactions to mites (Davis and Moon, 1990). However, other factors also influence the degree of pruritis in pigs. Increased stocking density appears to reduce the degree of rubbing in a group of pigs

(Davies, 1995), whereas wetting pigs increases rubbing activity even in the absence of mites (Davis and Moon, 1990). Sampling of randomly selected pigs revealed high herd infestation rates with sarcoptic mange and therefore pruritis in the studied herds was probably caused by mites infestation. The high morbidity risk due to sarcoptic mange as observed in the current study was consistent with findings in other tropical smallholder pig herds (Kambarage *et al.*, 1990). However, the pattern of occurrence of pruritis in the preweaning pigs differed with the pattern observed in commercial piggeries in the temperate countries where a lower morbidity risk in the preweaning period was observed (Straw *et al.*, 1997).

The preweaning piglet mortality (18.7%) observed in the current study differs from that reported by Munyua *et al.*(1991) and Masembe, (1985). They reported preweaning piglet mortalities of liveborn piglets of 15.8% and 17.1%, respectively. The difference between the current study and the previous studies done in Kenya could be due to the sampling strategies used. The current study used a random sample of smallholder herds while the previous studies were based on convenient samples that also included both medium and smallholder herds. The preweaning piglet mortality observed in the current study was higher than the one observed in commercial piggeries in Bosnia Herzegovina (14.7%), USA (14.2%), New Zeland (14.1%) and Thailand (12.3%) (Wongnarkpet *et al.*, 1994; Vrbanac *et al.*, 1995). However, it was similar to that observed in the tropical smallholder pig herds in the Philippines (19%) (Lanada *et al.*, 1999). Higher preweaning piglet mortalities in smallholder herds have been observed in other tropical areas in Bolivia (31%) (Wilkins and Martinez, 1983), Nepal (21.5%) (Gatenby and Chemjong, 1992) and also in Philippines (37%) (Taveros and More, 2001). In addition, high (26.6%) preweaning piglet mortality has been recorded in commercial piggeries in temperate regions in sows farrowing in open systems (Marchant *et al.*, 2000). The level of management influences the preweaning piglet mortality (Radostits *et al.*, 1994) and this could explain the differences observed between the tropical smallholder herds and the commercial piggeries.

In the current study, over three quarters of the overall mortality (78.8%) occurred during the first week of life and more than half of these deaths (69%) were caused by "overlying". Although this study classified this as a category on its own, "overlying" is interellated with other factors, for example a piglet which is getting little milk is likely to become weak and be "overlaid" by the sow (Vaillancourt *et al.*, 1992; Cutler *et al.*, 1997). The pattern of preweaning piglet mortality observed in this study differs from that observed in a previous study in Kenya (Munyua *et al.*, 1991). In the latter study, gastrointestinal sydrome, starvation and pneumonias were the most important causes of preweaning piglet mortality in small and medium scale pig herds. These authors used convenient samples and relied more on secondary data. With secondary data, not all cases are reported to the researcher and the information obtained from convenient samples is only representative of that sample of herds used and cannot be extrapolated to the population (Cameron, 2000). The pattern observed in the current study was, however, in agreement to that observed in commercial piggeries in the temperate regions (Vaillancourt and Tubbs, 1992; Vrbanac *et al.*, 1995; Cutler *et al.*, 1997; Marchant *et al.*, 2000). In this study the proportional preweaning piglet mortality due to predation was high (5%) and this was in contrast to commercial pig production where predation is rarely considered as an important cause of piglet mortality.

The classification of the causes of preweaning mortality in this study was mainly based on the pig owners recorded causes of mortality between the monthly visits. These causes may need validation by performing post mortem examinations as has been suggested (Vaillancourt *et al*., 1990; Vrbanac *et al*., 1995; Cutler *et al*., 1997). Due to the nature of the study design, this could not be accomplished. However, a study in smallholder herds focusing on preweaning mortality may further provide information on this important aspect of pig production.

There was no significant influence of the studied herd-level factors on preweaning piglet morbidity contrary to previous observations (Cutler *et al*., 1997; Radostits *et al*., 1999). The lack of association between these variables and preweaning piglet morbidity could have been due to similar management practices across the different herds studied and the fact that all the herds were in the same region. These two factors could have reduced the amount of variability among farms. Although a few herds/owners practised some form of preventive medicine, the lack of association between morbidity incidences in the preweaning pigs and the preventive practices could have been due to the haphazard applications of the disease management practices.

Supplementation of sows with protein supplements have been associated with low preweaning mortality (Lanada *et al*., 1999). This is due to the fact that unsupplemented sows are likely to have low amounts of milk during lactation and this may predispose the piglets to starvation, hypothermia, infection and therefore a higher risk of being overlaid (Vaillancourt and Tubbs, 1992; Cutler *et al*., 1997). In the current study, herds that supplemented the sows with proteins tended to have a higher than herd-level median value of preweaning piglet mortality. This unexpected finding could not be explained but it would appear that survival of the piglets may be due more to environmental factors than individual sow nutrition as has been observed previously (Pettigrew *et al.*, 1986).

The average daily weight gain achieved by the piglets (0.13kg/day) was lower than the average daily weight gain (0.21kg/day) observed in commercial pig herds in Kenya (Kabare, 1991). It was far below the average daily weight gain attained in the intensive production systems in the temperate countries (Radostits *et al.*, 1994). The findings were, however, consistent with observations in other tropical smallholder herds where slow growth of pigs as a result of severe malnutrition was observed (de Fredrick, 1977a; More *et al.*, 1999). Optimal growth performance of piglets depends on the management of the sow and piglets (Radostits *et al.*, 1994). In the smallholder herds, improved management of the piglets that included, provision of heat during the first few nights following farrowing, administration of vitamin/iron injection and provision of creep feeds resulted in improved growth performance of the preweaning piglets (Taveros and More, 2001).

In the current study a significant influence of sow supplementation with protein rich feeds on mean daily weight gain of piglets was observed. Piglets from sows that were supplemented with protein rich feeds achieved a higher mean daily weight gain than those from herds where no supplemention was done. The benefits of protein supplementation are understandable given the nutritional problems commonly associated with pigs in most smallholder herds (de Fredrick, 1977a; Gichohi *et al.*, 1988, More, *et al.*, 1999). Protein supplementation to the sows was likely associated with increased milk available to the piglets.

In the current study, a high morbidity risk (20%) in grower pigs was observed. The high morbidity risk may directly or indirectly contribute to grower pig mortality or compromise the growth performance of grower pigs (Radostitis *et al.*, 1994; Cutler *et al.*, 1997). The high cause-specific morbidity due to pruritis (sarcoptic mange) was in agreement with findings in other tropical smallholder pig herds (Kambarage *et al.*, 1990). However, this was in contrast to observations made in commercial piggeries in temperate countries where pneumonias and gastro-intestinal diseases are the most prevalent (Straw *et al.*, 1997; Radostits *et al.*, 1994). Nevertheless, low prevalences of these diseases have also been observed in other tropical smallholder pig production systems (de Fredrick 1977b). Pruritis in grower pigs, due to sarcoptic mange, is a commom problem especially in pigs kept in unhygienic conditions and where mange control measures are inadequate (Cargill and Davis, 1997) as was the case in the studied herds.

In this study, a high number of cases of a neurological disorder, suspected to be gut oedema from clinical presentation, were observed. Gut oedema is a common problem in grower pigs especially immediately after weaning (Radostits *et al.*, 1999). The "unknown causes" contributed a significant morbidity of the grower pigs and they deserve further research to identify them. The other diseases recorded, for example, ear necrosis, unthriftiness and abscesses, are common disease/conditions in pigs (Straw *et al.*, 1997).

The overall percent grower pig mortality (3.8%) observed in this study was higher than the recommended target (<2%) in intensive pig production systems (Radostits *et al.*, 1994; Losinger *et al.*, 1998). The "unkown diseases" contributed the highest mortality risk and future recommendations to specifically delineate them are indicated. The pattern of diseases causing mortality was different from the pattern observed in intensive pig production systems in the temperate countries (Radostits *et al.*, 1994) and this was probably due to differences in management.

Grower pig morbidity was not associated with any of the plausible herd-level risk factors investigated. The lack of association between these variables and grower pig morbidity could have been due to similar reasons as described in section 5.4.2.3.2. However, for grower pig mortality, there was a positive relationship between the hygienic status of the herd and the mortality risk. The mortality risk was higher for grower pigs in herds that had a poor hygiene status as compared to herds with good hygiene status. Strong relationships between the incidences of grower pig diseases especially pneumonias and gastro-intestinal syndromes and the environmental factors in the herd have been documented (Lindqvist; 1974; Backstrom and Bremer, 1978; Smith *et al.*, 1998; Stege *et al.*, 2001). The environmental factors associated with a high incidence of these diseases include poor hygiene and sanitation, continuous occupation of pens instead of the all-in, all-out system and inefficient ventilation system (Lindqvist, 1974).

The mean daily weight gain (0.16kg/day) and weight:age ratio (5.2kg /month of age) for the grower pigs recorded in this study were poor. The mean daily weight gain was a quarter that reported in commercial piggeries in the temperate countries

(Radostits *et al.*, 1994). However, the mean weight:age ratio observed in the current study was similar to that observed in tropical smallholder herds in the Phillipines (More *et al.*, 1999). Poor growth of pigs in smallholder herds has been attributed to poor feeding both in quality and quantity (de Fredrick and Osborne, 1977; More *et al.*, 1999).

A significant effect of nutrition of the grower pigs on the measures of productivity was not demonstrated in contrast to previous observations in other tropical smallholder herds and commercial piggeries (de Fredrick and Osborne 1977; Radostits *et al.*, 1994; More *et al.*, 1999). One reason for this observation could have been due to the low variability of the smallholder grower pig diets in the study herds in Kikuyu Division, Kiambu District. Majority of the farmers fed the grower pigs on a low quality commercial feed referred to as "pollard" which was likely to have been from same sources since farmers came from the same area. In addition, the small number of grower pig herds where the two parameters were determined could have reduced the statistical power of the comparison (Martin *et al.*, 1987).

In the current study, the reproductive performance of the sow was low as compared to commercial piggeries in the temperate (Dial *et al.*, 1992; Radostits *et al.*, 1994) and tropical countries including Kenya (Kabare, 1991; Wongnarkpet *et al.*, 1994; Kunavongkrit and Heard, 2000; Tantasuparuk, 2000). The sows raised fewer number of live-born piglets than in commercial piggeries in the temperate regions (Radostits *et al.*, 1994). However, the number of live-born piglets observed was similar to the one observed in commercial piggeries in Kenya and other tropical regions (Kabare, 1991; Lanada *et al.*, 1999; Kunavongkrit and Heard, 2000). Lower number of live-born piglets has been reported in other smallholder piggeries in tropical regions (de Fredrick, 1977a; Gatenby and Chemjong 1992). The climatic stress due to high temperatures especially from weaning until early gestation is the cause of low litter size in tropical regions (Tantasuparuk, 2000).

The number of piglets weaned per litter (6.9) in the current study was lower than in commercial piggeries in both temperate and tropical areas (Kabare, 1991; Radostits *et al.*, 1994) due to high preweaning mortality. Lower number of piglets weaned per litter has been reported in the Solomon Island (de Fredrick, 1977a).

A weaning to service interval (WTSI) of 3.2 months as observed in this study was much longer than what is observed in commercial piggeries in both tropical and temperate countries (Radostits *et al.*, 1994; Kunavongkrit and Heard, 2000; Tantasuparuk, 2000). In commercial pig production, weaning to service interval is indirectly used as a measure of lactation management, particularly feed intake (Tubbs and Dyer, 1996).

A prolonged IFI (6.9 months) was observed in the current study. It was in agreement with observations in smallholder herds in Bolivia (7.1 months) (Wilkins and Martínez, 1983), Nepal (7.9 months) (Gatenby and Chemjong, 1992), the Philippines (7 months) (Lanada *et al.*, 1999) and the Solomon Islands (10.4 months) (de Fredrick and Osborne, 1977).

The number of litters weaned per sow per year in the current study was low as compared to the recommended target in the commercial piggeries in the temperate regions (Radostits *et al.*, 1994). The suckling period (2.2 months) observed in the current study was substantially longer than that recorded in commercial piggeries both in the temperate and tropical areas (Radotits *et al.*, 1994; Kunavongkrit and Heard, 2000). However, it was in agreement with that recorded in other smallholder herds in Nepal (2.2 months) (Gatenby and Chemjong, 1992), Solomon Islands (2 months) (de Fredrick and Osborne, 1977) and the Philippines (1.7 months) (Lanada *et al.*, 1999).

The mean parity of sows observed in this study was 2.1 while the mean parity at removal was 1.2. The mean parity was lower than in commercial piggeries in the temperate countries (Radostits *et al.*, 1994). In the temperate commercial piggeries, removal of breeding animals (culling) is usually carried out as a strategy to renew the herd and is carried out by culling the non- pregnant sows and old sows (D□ Allaire and Drolet, 1997). In this study, removal of the breeding sows was mostly associated with management problems such as housing and feed supply. A significant proportion of the herd owners sold the breeding sows when they were in financial need regardless of the status of the sows and only a few mentioned diseases for example infertility as a reason for culling/removal from the herd. Thus the average parity was low and this might have led to low herd productivity (Dagorn and Aumaitre, 1979; Stein *et al.*, 1990). A high turnover of pigs in smallholder herds has been observed previously in other tropical areas (de Fredrick, 1977a).

There was some substatial variation in the reproductive performance of the sows among herds. Although the median IFI for the herds was 6.9, at least 25% of the herds achieved an IFI that was not greater than 6 months. Similarly, although the median NLBP for the herds was 9, at least 25% of the herds achieved the NLBP greater than 10.4. The study attempted to exploit this variability in reproductive performance to identify the herd-level practices that were most closely associated with the most productive herds. The understanding of these factors would allow recommendations, that are effective and locally proven to be made to the pig farmers in the smallholder pig farming systems.

The IFI is influenced by the lactation length, number of non-productive days and the gestation length (Dial *et al.*, 1992; King *et al.*, 1998). In the current study lactation length was not associated with IFI. One reason could be due to the low variation in length of lactation among the studied herds. The majority (90%) of these herds practised a lactation length of 2 months. Although a short lactation length has a positive effect on IFI, only in a few herds where owners practised a lactation length shorter than two months to allow any significant effect of lactation length on IFI to be determined. Another reason could be the poor nutrition that was offered to the sows. Poor nutrition may have masked any benefit that otherwise would have been realised with short lactation length. The knowledge and ability of farmers is likely to influence the non-productive days when the sows are neither lactating nor pregnant. In tropical smallholder herds, improved IFIs have been recorded with farmers who kept at least some written records (Lanada *et al.*, 1999). The lack of variation in this variable as all farmers were not keeping records could not allow the assessment of the effect of this variable on the IFI. In addition, the availability of the boar (though not quantified) was limited in the study area and this could have contributed to the prolonged IFI. Furthermore, there were only few farmers who kept a boar and this could explain the lack of significance of this variable on IFI.

Nutrition of the sows around the time of conception influences litter size in the commercial piggeries (Dial *et al.*, 1992). In the smallholder herds, the nutrition of the sows is poor both in terms of quality and quantity and the protein content is grossly inadequate (Gatenby and Chemjong, 1992; de Fredrick and Osborne, 1977; Lanada *et al*., 1999). Therefore, the observation in the current study that higher number of live-born piglets were farrowed from sows in herds where protein rich feeds supplementation was done as compared to those where no supplementation was done is understandable given the fact that the bulk of feeds provided to the sows in most smalholder herds were of low protein value.

CHAPTER 6

INTERVENTION STUDY

6.1 Introduction

Sarcoptic mange and gastrointestinal helminthosis were identified as the most prevalent health constraints during the cross-sectional and longitudinal phases of the study. These diseases manifest themselves primarily through a decrease in production efficiency (Cargill and Davis, 1997; Corwin and Stewart, 1997). Among livestock diseases, such highly prevalent endemic diseases are considered the major constraints to efficient production (Radostits *et al.*, 1999). Sarcoptic mange and helminthosis can be controlled through improved management practices and strategic use of acaricides and anthelmintics, respectively (Cargill and Davis, 1997; Corwin and Stewart, 1997).

In consultation with the smallholder farmers, a study to compare the efficacy of various acaricides and anthelmintics to reduce sarcoptic mange and worm burdens in the smallholder farming system within a period of three months was undertaken. The technical data were combined with cost estimates for the various treatments (cost-effectiveness approach) to allow an assessment for the most cost-effective treatment for the two diseases.

6.2 Materials and methods

6.2.1 Study herds

The study herds were as described in Chapter 3 subsection 3.6.

6.2.2 Intervention design

This was a randomised, placebo-controlled intervention study. The number of herds selected and the randomisation procedure was carried out as described in Chapter 3 subsection 3.6. In the selected herds, piglets more than 4 weeks old and grower pigs not more than 40kg (approximately 4 months of age) were recruited.

Group 1

A placebo consisting of 0.5 ml of physiological saline was administered subcutaneously to all the pigs in the herd. These herds acted as control group for intervention groups 2, 3 and 4 as detailed below. In this group, there were a total of 44 pigs, that comprised 29 growers and 15 piglets.

Group 2

In this group of herds simultaneous control of helminths worms and mange was carried out by the use of ivermectin (Cevamec® 1%, Sanofi, Hungary) at 300μg /kg body weight subcutaneously in all pigs (except those that were to be sold for slaughter within the next 21 days). The group consisted of 71 pigs comprising 32 growers and 39 piglets.

Group 3

In this group of herds helminths and mange were simultaneously controlled by using an anthelmintic and an acaricide respectively. All pigs were treated for worms once by use of piperazine hydrochloride (Piperazine® , Dopharma, Holland) at 440mg/kg body weight, orally. For control of sarcoptic mange an acaricide, amitraz (Tactic® 12.5 w/v, Hoescht, Germany) at 0.1% was used twice at an interval of 7 days. The group consisted of 66 pigs comprising 44 growers and 12 piglets. All the pigs in the herd except those that were to be sold for slaughter within the next 21 days were treated. In addition, the pig houses were sprayed with the acaricide.

Group 4

In this group of herds helminths and mange were simultaneously controlled by using an anthelmintic and an acaricide respectively. All pigs were treated for worms once by using levamisole hydrochoride (Leva® 20, Agrar, Holland), a broad spectrum anthelmintic, at 8 mg/kg body weight, orally. For sarcoptic mange control, an acaricide, amitraz (Tactic® 12.5 w/v, Hoescht, Germany) at 0.1% was used twice at an interval of 7 days. The group consisted of 80 pigs, comprising 64 growers and 16 piglets. All the pigs in the herd, except those that were to be sold for slaughter within the next 21, days were treated. The pig pens were treated as for group 3.

6.2.3 Data and sample collection

Rectal faecal samples for faecal egg counts and ear wax scrapings for mite detection were taken before the treatment (Day 0) and at days, 7,14, 28, 68, and 96 post-treatment. The samples were processed as described in Chapter 3, subsection 3.5.1. During the visits, the behaviour of the recruited piglets and grower pigs was observed for signs indicative of pruritis, such as rubbing against the walls and troughs, and scratching of the flanks or ears with the hind legs. In each herd the pigs were observed for 15 minutes and the scratching index (SI) was calculated as the number of scratching/rubbing episodes divided by the number of pigs observed. The SI was used to assess mite infestation/hypersensitivity in the group (Cargill and Dobson, 1979; Davies, 1995; Smets and Vercruysse, 2000).

6.2.4 Data management

A data file was created in Excel® 1997 (Microsoft Corporation, USA). The file was screened for data errors and plausibility. Errors were corrected by rechecking against the original data collection forms.

6.2.5 Data analysis

6.2.5.1 Technical data analysis

Data analyses were performed using Minitab Statistical Software, release 13 for Windows (Minitab Statistical Software, Minitab Inc, USA). Before the analysis, the faecal egg counts were transformed to their natural logarithms. Descriptive statistics for the scratching index, for proportions of pigs positive for mites and faecal egg counts per gram of faeces (epg) for each treatment group and visit were carried out. The differences among the treatment groups by visit on the scratching index, the proportion of pigs positive for mites and faecal egg counts were determined, using the one way analysis of variance. Since the F-test and pairwise multiple comparison can sometime conflict (Minitab Inc, USA), pairwise comparisons for significant differences of the means ($p<0.05$) was not conditioned upon significance ($p<0.05$) of the F-test. Tukey's LSD (Least Significant Difference) was used for the post-hoc comparisons.

6.2.5.2 Economic Analysis of the interventions

A relative cost-effectiveness analysis was used to determine how the desired result, the control of the two parasitic diseases, (the reduction of sarcoptic mange and helminthosis to levels that may not compromise health and productivity of the pigs) could be achieved at minimum cost. For this, the costs of the different treatment groups were computed and compared. The costs considered were those of labour and drugs.

The cost of family labour was included in all computations in order to reflect the real cost of each treatment and to allow a valid comparison across the different treatment groups. Family labour costs were calculated as opportunity costs. For hired labour, the prevailing wage paid to a casual labourer per day, equivalent to Kshs. 150 ($1.9), was used. In the case of ivermectin treatment, where professional veterinary involvement was required, the appropriate professional fee of about KShs 20 per pig was used to compute the labour costs. The time required to deworm and to control mange per litter was estimated and used to calculate the man-days for hired and for family labour. Man-days were multiplied with the prevailing wage rate per day to get the cost of labour. The opportunity cost for the time spent on the purchase of drugs was taken as zero, since the smallholder farmers do go to the market place for purchases and sales of their produce at least once a week; it was assumed that they could buy the drugs at the same time. The costs of drugs were calculated by multiplying the retail price of each drug with the amount used in the study.

6.3 Results

6.3.1 Voluntary participatory rate

During the farm selection, the initial sample size was 40 herds; one farm selected had all the pigs sold in the morning of the intended first visit, this farm eventually was not replaced. Therefore, the initial voluntary participation rate was 97.5% (39/40). In the course of the study, a total of six farms withdrew at different times; the reasons for the withdrawals included death of all the pigs in the herd (one farm), sale of all the pigs (4 farms) and one farmer withdrew for reasons related to the interventions. The voluntary participatory rate throughout the study correspondingly reduced to 84.6% (33/39). Data collected from these farms until the date of withdrawals were included in the analysis.

6.3.2 Technical data

6.3.2.1 Helminth control

The arithmetic mean faecal egg counts (FEC) from Day 0 to Day 96 are presented in Figure 6.1. The pre-treatment mean faecal egg counts (FEC) of the four groups did not differ significantly ($p>0.05$). On day 7 post-treatment the FEC for the ivermectn-treated group was significantly ($p<0.05$) lower than for piperazine-treated group. Both ivermectin- and levamisole-treated groups had significantly ($p<0.05$) lower FEC on day 14 post-treatment as compared to the control group. On day 28 post-treatment the FEC for ivermectin-treated group was significantly ($p<0.05$) lower than that for piperazine-treated and control groups. The high mean FEC for piperazine-treated group on day 14 and 28 was due mostly to *Trichuris suis* (Figure 6.2). From day 68 post-treatment the FEC among the groups did not differ significantly ($p>0.05$). However, the FEC for ivermectin- and levamisole-treated groups remained consistently lower numerically than the FEC of the control and the piperazine-treated groups. The FEC for ivermectin- and levamisole-treated groups did not differ significantly ($p>0.05$) at any time. However, the FEC for ivermectin-treated group remained consistently lower numerically than that of levamisole-treated group.

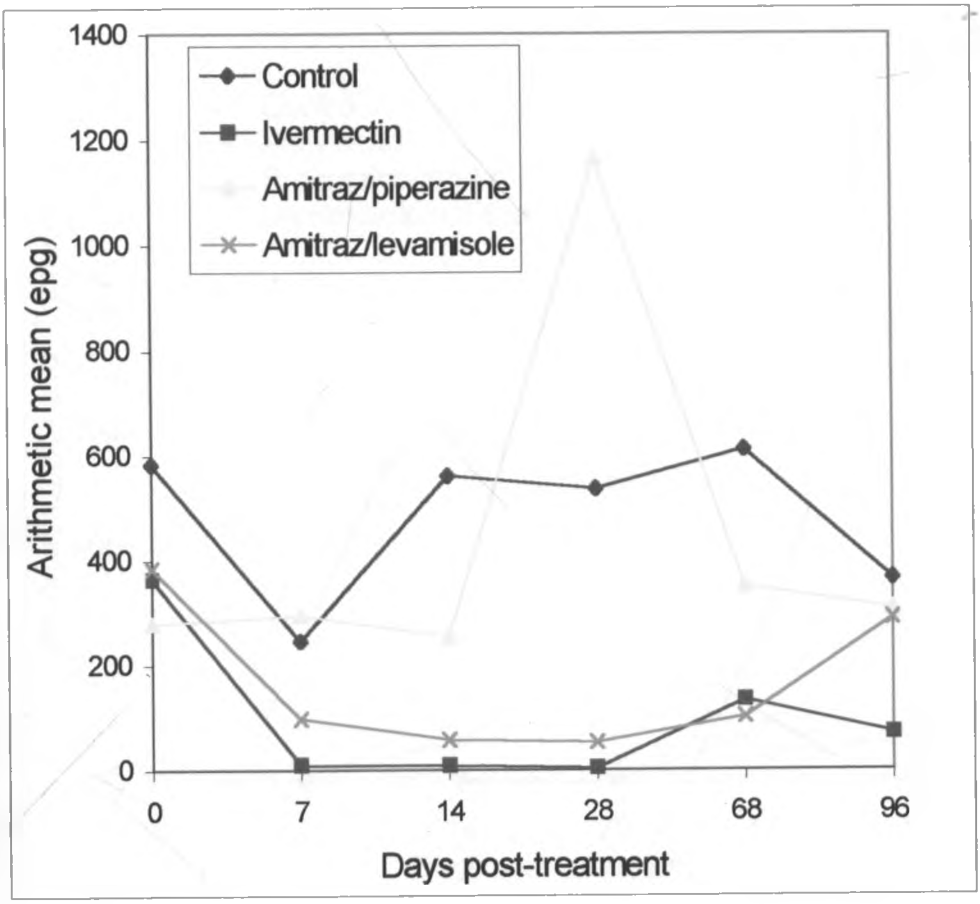

Figure 6.1 Arithmetic mean faecal egg counts for ivermectin-treated, amitraz/piperazine- treated, amitraz/levamisole-treated and control pigs in smallholder farms in Kikuyu Division, Kiambu District (August 2000- December 2000)

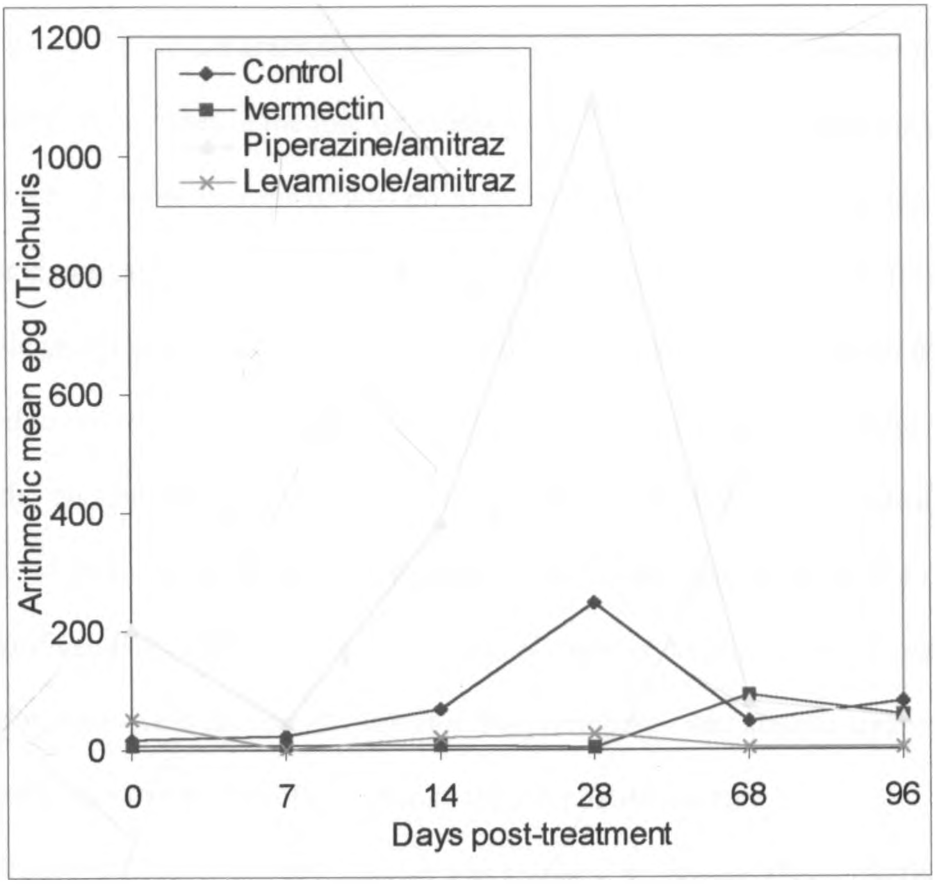

Figure 6.2 Arithmetic mean *Trichuris* faecal egg counts for ivermectin-treated, amitraz/piperazine-treated, amitraz/levamisole-treated and control pigs in smallholder herds in Kikuyu Division, Kiambu District (August 2000- December 2000)

6.3.2.2 Sarcoptic mange control

The mean proportion of pigs positive for mites as determined by ear scrapings from Day 0 to Day 96 are presented in Figure 6.3. The pre-treatment mean proportion of pigs positive for mites in the four treatment groups did not differ significantly ($p>0.05$). The mean proportion of pigs positive for mites on day 7 post-treatment did not differ significantly ($p>0.05$) among the treatment groups. On day 14 post-treatment ivermectin group had significantly ($p<0.05$) lower proportion of pigs positive for mites compared to the control group. The proportion of pigs positive for mites in the ivermectin- and amitraz-treated groups did not differ significantly ($p>0.05$) at any time. From day 14 post-treatment the mean proportion of pigs positive for mites did not differ significantly ($p>0.05$) among the groups. However, the proportions of pigs positive for mites were consistently lower in the ivermectin- and amitraz-treatment groups compared to the control group up to day 68 post-treatment.

From day 28 post-treatment, there was a drastic increase in the proportion of pigs positive for mites in the Amitraz/levamisole-treatment group while the increase for the amitraz/piperazine- treatment group was noted on day 68 post-treatment. The increse in the proportion of pigs positive for mites in the ivermectin-treated group occurred as from day 14 post-treatment. However, the increase was gradual and the proportion of pigs positive for mites on day 96 post-treatment was lower than that for the other groups though this was not significant ($p>0.05$). A drastic drop in the proportion of pigs positive for mites in the control group was noted from day 68 post-treatment up to day 96.

The mean scratching index (SI) for the pigs from Day 0 to Day 96 post-treatment are presented in Figure 6.4. The pre-treatment SI did not differ significantly ($p>0.05$) for the four treatment groups. On day 7 post-treatment the SI for ivermectin- and amitraz/levamisole-treatment groups were significantly ($p<0.05$) lower than the SI for the amitraz/piperazine-treatment group. Significantly ($p<0.05$) lower SI was noted in the ivermectin- and amitraz-treated groups compared to the control group on day 28 post-treatment. The SI for the four groups did not differ significantly ($p>0.05$) from day 68 post-treatment. The SI of the control group dropped drastically from day 14 post-treatment.

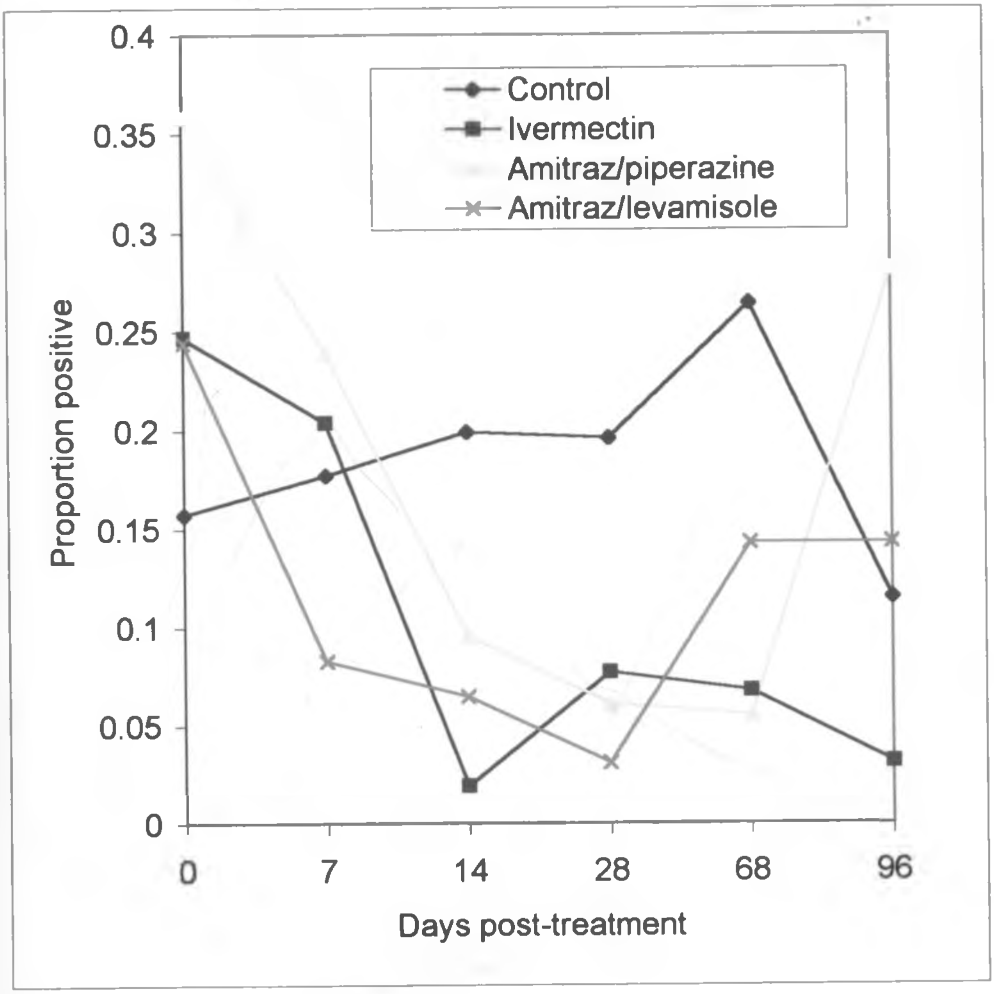

Figure 6.3. Proportion of pigs positive for mites in the ivermectin-treated, amitraz/piperazine- treated, Amitraz/levamisole-treated and control pigs in smallholder farms in Kikuyu Division, Kiambu District (August 2000- December 2000)

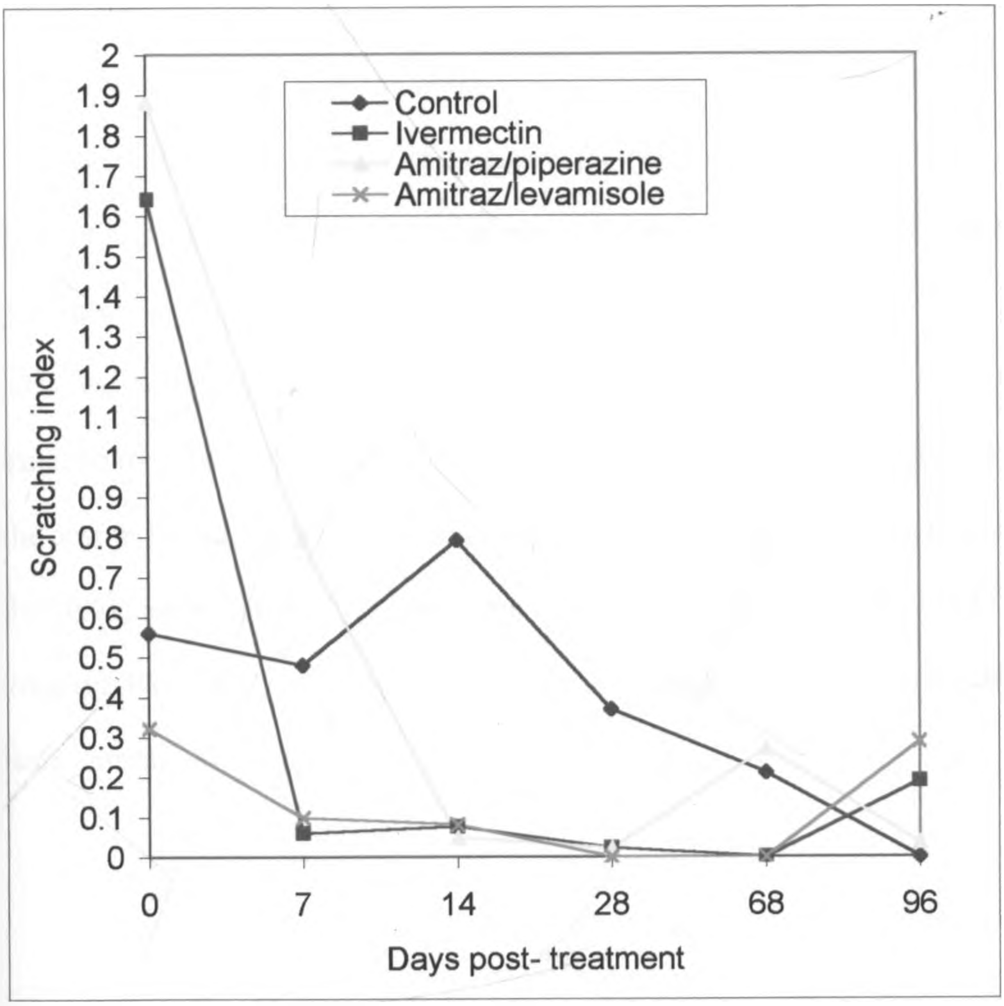

Figure 6.4. Scratching index for pigs in, ivermectin-treated, amitraz/piperazine-treated and amitraz/levamisole- treated and control pigs in smallholder farms in Kikuyu Division, Kiambu District, (August 2000- December 2000)

6.3.3 Economic analysis of the interventions

6.3.3.1 Relative cost-effectiveness analysis

The control group comprised of 44 pigs while the ivermectin-, piperazine/amitraz- and levamisole/amitraz-treatment groups comprised of 71 ,66 and 80 pigs, respectively.

The various inputs used are shown in Table 6.1. The cost of labour per pig for the ivermectin treatment group was calculated as Kshs 20 ($ 0.25, 1 US$ = Kshs 80) while the cost of labour for both the piperazine/amitraz and levamisole/amitraz were Kshs. 3 ($ 0.04) each (Table 6.2). Overall, the total costs per pig were Kshs 40 ($ 0.5) for ivermectin, Kshs 25 ($ 0.31) for piperazine/amitraz and Kshs 21 ($ 0.26) for the levamisole/amitraz.

Table 6.1. Drug and labour inputs for the control of helminths and sarcoptic mange in pigs in smallholder herds in Kikuyu Division, Kiambu District, (August 2000 - December 2000).

Inputs	Group 2	Group 3	Group 4
Amitraz (Tactic®) (in millilitres)	-	520	580
Piperazine DHC (in grams)	-	303	-
Levamisole (Leva® 20) (in grams)	-	-	137
Ivermectin (Cevamec® (in millitres)	37	-	-
Labour (hours)	2.8	10.5	13
Labour (Man-days)	0.4	1.3	1.6

Table 6.2. Cost of drugs and labour in Kshs for the control of helminths and sarcoptic mange in pigs in smallholder herds in Kikuyu Division, Kiambu District, (August - December 2000).

Inputs	Group 2	Group 3	Group 4
Amitraz (Tactic®)	-	936	1044
Piperazine DHC	-	509	-
Levamisole (Leva® 20)	-	-	369
Ivermectin (Cevamec®	1443	-	-
Labour	1420	197	247
Average cost per pig	40	25	21

6.4 Discussion

This was a randomised placebo-controlled intervention study to evaluate the cost-effectiveness of various treatments against helminths and sarcoptic mange in pigs. The lack of statistical differences for both disease complexes among the various study groups before the commencement of the treatments obviously did reduce pre-treatment bias; the randomisation procedure was effective. This did allow a fair comparison of the treatment effects across the herds. The participation by the farmers throughout the study was excellent. The general willingness of the farmers to participate was accelerated by the use of free intervention drugs for their pigs.

A low (9%) reduction of FEC at day 14 was noted with piperazine and this was attributed to the low efficacy of piperazine against *Trichuris suis* (Corwin and Stewart, 1997). However, the significant reduction (>85%) of FEC at day 14 in pigs treated with ivermectin and levamisole suggested that both products were therapeutically effective against the helminths found in the smallholder herds. These results are expected given that they confirm the current understanding (Radostits *et al.*, 1999; Corwin and Stewart, 1997) about the efficacy of the studied anthelmintics against gastro-intestinal worms of pigs.

The rise in FEC for piperazine was noted from day 7 while that of ivermectin and levamisole was from day 28 post-treatment. The FEC for ivermectin-treated group remained consistently lower than that for levamisole-treated group throughout the study. From these results, it would appear that ivermectin was superior to the other anthelmintics and this was consistent with previous findings (Corwin and Stewart, 1997).

The rise of FEC from day 28 for ivermectin and levamisole indicated that reinfection occurred about 2 weeks after treatment and this was similar to observations with ivermectin in calves (Ranjan *et al.*, 1997).

The treatment with amitraz was repeated after 7 days in order to kill both mites and eggs. A seven day period was used so as to booster the dose within the life cycle of the parasite, which is 10-15 days from egg to adult (Cargill and Davis, 1997). On day 14 no significant difference in the proportions of pigs positive for mites between the ivermectin and the amitraz treatment groups could be determined; however, a significant difference was noted between ivermectin-treatment group and the control group, with the latter having a higher number of pigs positive for mites. It would appear that, using the application protocol as used in this study, the efficacy of ivermectin and amitraz are comparable. However, ivermectin activity appeared to persist for much longer time than that of amitraz. These results were consistent with previous observations about the efficacy of these acaricides against sarcoptic mange in pigs (Hollanders *et al.*, 1995; Cargill and Davis, 1997).

From day 68 post-treatment up to the end of the study on day 96, there was a drastic decrease in the the proportion of pigs positive for mites in the control group. Decreasing mite recoveries during the course of an infestation has been observed. It has been suggested that mites initially multiply unchecked until infested pigs develop a hypersensitivity response, as a result of which mite numbers decline (Courtney *et al.*, 1983).

There was a decrease in the values of calculated scratching indices after treatment with the acaricides. This observation confirms the usefulness of using scratching index as an indirect measure of mange infestation (Davies, 1995; Hollanders *et al.*, 1995; Cargill and Davis, 1997). Thus smallholder farmers could use the pruritic behaviour as a low-cost means of evaluating the mange status in their herds.

The benefits of gastro-intestinal worm and mange control in pigs are well documented (Davies, 1995; Cargill and Davis, 1997; Corwin and Stewart, 1997). They include improved growth performance in grower pigs and improved reproductive performance in breeding animals. Previous field observations and results of controlled experiments indicate that effect of mange in both growing and breeding pigs is variable, probably as a result of differences in the severity of the disease in the affected pigs (reviewed by Davies, 1995). This study concentrated on the cost-effectiveness of different drugs. The benefits of the interventions for example in terms of improved growth performance were not a concern in this study, partly due to the expected variability in infestation levels as observed in other studies. More important the erratic, non-standard diets used in the smallholder herds and severe under-nutrition of pigs in most of the herds did not permit a realistic comparison across the herds. In addition, inbreeding and crossbreeding observed to occur in the smallholder herds (Gichohi *et al.*, 1988) would inevitably also have led to considerable variability in growth rates. Therefore, comparison of the effect of treatment for the two parasitic diseases in terms of production parameters may have given erroneous results across the different herds. It has been suggested that such evaluations of changes in biological and production variables, resulting from interventions, are best achieved in individual herds with homogeneous characteristics; variability between herds would be largely excluded (Polson *et al.*, 1992). In the smallholder production systems studied, the number of pigs per herd, however, was a limiting factor for this kind of approach, especially because of the number of interventions that were to be tested simultaneously.

Cost-effective control of livestock diseases is achieved when the marginal return from disease reduction is equal or higher than the marginal cost of a given increment in disease control efforts (Dijkhuizen *et al.*, 1995). Theoretically, the preferred type of a health economic evaluation is the benefit-cost approach in which costs as well as benefits are measured in monetary units (Dijkhuizen *et al.*, 1995). However, due to the limitations outlined earlier, solely a relative cost-effectiveness analysis was carried out to determine how a reduction of the two parasitic diseases could be achieved at minimum cost. Ivermectin and amitraz/levamisole combinations were the most effective drugs against mange and gastro-intestinal worms in the study herds. Though not significantly different the efficay of ivermectin was superior to that of amitraz/levamisole on the two parasitic diseases. However, its cost is probably prohibitive in the smallholder system. In this production system, the aim would be to optimise production by reduction of worm and mange burdens rather than maximising output by eradication of the parasites, an exercise not sustainable in this production system currently. The cost of piperazines was comparable to that of levamisole; however, piperazine had low efficacy against *Trichuris suis* which appeared to be prevalent in the smallholder herds. Therefore, from the technical and economic data the amitraz/levamisole combination appeared to be the most cost-effective treatment against gastro-intestinal worms and mange in pigs in the smallholder herds.

The costs presented were calculated for a period of three months. They represent the short-term costs arising from a deworming/mange control programme applied to a group of pigs. Estimation of the costs during this short-evaluation period was thought to be reasonable as deworming and mange control were not likely to have long-term effects and both costs and the biological effects/benefits of treatments were realised within the short-evaluation period. The short-cycle period for pigs and the management practices of stall feeding of pigs all the year round, thus minimizing the year-to-year variation, further justified the calculation scheme for costs for this period.

In other studies carried out in smallholder farming systems, the cost of family labour is assumed to be abundant and is normally not incorporated in the computation of the costs leading to an underestimation of the real costs (Amir and Knipscheer, 1989). In the current study, the cost of the family labour was included in all computations in order to approximate the real cost of each treatment and to allow a valid comparison across the farms.

CHAPTER 7

GENERAL DISCUSSION

In the current study, extension information on pig farming was not available to majority of farmers. In other tropical smallholder pig herds, availability of extension information on pig farming has been associated with improved pig performance (Wilkins and Martinez, 1983; Smith, 1992). Thus, the unavailability of extension information as observed in the current study could have led to the observed ignorance on preventive medicine practices and pig husbandry. Other constraints as perceived by farmers were, high cost of feeds which were of variable qualities, lack of credit, lack of genetically quality breeding boars, unreliable markets and diseases. The highly ranked diseases in order of importance were, sarcoptic mange, helminthosis, diarrhoea and pneumonia. These findings were largely in accordance with findings in other tropical smallholder pig production systems (de Fredrick, 1977a; Manuel *et al.*, 1989; Kambarage *et al.*,1990; Gatenby and Chemjong, 1992; Esrony *et al.*, 1997; Lanada *et al.*, 1999; More *et al.*, 1999; Kunavongkrit and Heard, 2000). The production constraints as identified in this work hinder improvement of productivity of pigs raised by the smallholder farmers and this explains the low productivity of pigs in the smallholder herds.

The overall reproductive performance of the sow observed in this study was low compared to that observed in commercial piggeries in the temperate (Dial *et al.*, 1992; Radostits *et al.*, 1994) and tropical countries including Kenya (Kabare, 1991;

Wongnarkpet *et al.*, 1994; Kunavongkrit and Heard, 2000; Tantasuparuk, 2000). The WTSI (3.2 months) and the IFI (6.9 months) were much longer than those recorded in commercial piggeries, both in tropical and temperate countries (Radostits *et al.*, 1994; Kunavongkrit and Heard, 2000; Tantasuparuk, 2000). However, the observed IFI was in agreement with those recorded in smallholder herds in other tropical areas (Wilkins and Martinez, 1983; Gatenby and Chemjong, 1992; Lanada *et al.*, 1999; de Fredrick and Osborne, 1997). A prolonged IFI is associated with low number of litters weaned per sow per year (Dial *et al.*, 1992; Radostits *et al.*, 1994) and this explains the low number of litters weaned per sow per year in the current study.

The mean number of live-born piglets (9.2) was comparable to the levels achieved in commercial herds in Kenya and other tropical countries (Kabare, 1991; Lanada *et al.*, 1999; Kunavongkrit and Heard, 2000). However, the mean number of piglet weaned (6.9) per litter was lower than the levels achieved in commercial piggeries in Kenya (Kabare, 1991). This was due to the high preweaning piglet mortality in the smallholder herds as compared to commercial herds.

The preweaning piglet crude cumulative morbidity risk was considered high as compared to observations in commercial piggeries in temperate regions (Straw *et al.*,1997). The observed high morbidity risk due to sarcoptic mange was in agreement with observations in other tropical smallholder herds (Kambarage *et al.*, 1990) but in contrast to observations in commercial piggeries in temperate regions (Straw *et al.*, 1997). The other diseases that were encountered, such as scours and facial necrosis, are common diseases during the preweaning period (Straw *et al.*, 1997). The high morbidity risk negatively influences the performance of piglets by contributing directly or indirectly to mortality or by reducing feed conversion efficiency (Radostits *et al.*, 1994; Cutler *et al.*, 1997).

The ADWG of the piglets (0.13 kg/day) was lower than that (0.21 kg/day) observed in commercial pig herds in Kenya (Kabare, 1991). It was much lower than the ADWG attained in commercial piggeries in temperate countries (Radostits *et al.*, 1994). However, the poor growth rate was consistent with observations in other tropical smallholder herds where slow growth of pigs as a result of severe malnutrition has been observed (de Fredrick, 1977a; More *et al.*, 1999).

Supplementation of the sow with protein rich feeds was associated with improved ADWG of piglets. The benefits of protein supplementation were understandable given the nutritional problems that were encountered in this study and in other studies in tropical smallholder pig herds (de Fredrick, 1977a; Gichohi *et al.*, 1988; More *et al.*, 1999).

Nutrition of the sows around the time of conception influences litter size in commercial piggeries (Dial *et al.*, 1992). In the current study, supplementation of the sows with protein rich feeds was associated with increased number of live-born piglets. This observation would be expected given the fact that the bulk of feeds provided to the sows in most of the smallholder herds were of low protein value and this was consistent with previous observations (Gatenby and Chemjong, 1992; de Fredrick and Osborne, 1977; Lanada *et al.*, 1999).

In the current study the observed crude morbidity risk of grower pigs was considered high as compared to commercial piggeries in temperate regions (Radostits *et al.*, 1994). High morbidity risk would compromise the performance of grower pigs by contributing directly or indirectly to mortality or by reducing feed conversion efficiency (Radostits *et al.*, 1994).

The grower pigs crude mortality risk (3.8%) as observed in the current study was higher than the below 2% reported in commercial piggeries in temperate regions (Radostits *et al.*, 1994; Losinger *et al.*, 1998). The high mortality risk of grower pigs would reduce pig productivity in the smallholder herds.

Good hygienic status of pig houses was in this study associated with comparatively reduced mortality of grower pigs. Previous studies have shown strong relationship between grower pig morbidity, mortality and hygiene (Lindqvist, 1974; Backstrom and Bremer, 1978; Smith *et al.*, 1998; Stege *et al.*, 2001).

The ADWG (0.16 kg/day) of the grower pigs as observed in this study was low compared to that (0.60 kg/day) achieved in commercial piggeries in temperate regions (Radostits *et al.*, 1994). However, the growth performance observed in the current study was in agreement with observations in tropical smallholder herds in the Phillipines (More *et al.*, 1999). The poor growth performance of grower pigs in smallholder herds was due to poor feed quality and quantity. This was in agreement with the findings of previous studies in smallholder herds (de Fredrick and Osborne, 1977; More *et al.*, 1999).

The various phases of the study identified sarcoptic mange infestation and gastro-intestinal helminthosis as the most important health constraints in the smallholder herds. The field trials found that both ivermectin and levamisole effectively controlled the commonly encounterted gastro-intestinal worms. The commonly used piperazine was ineffective against *Trichuris suis*. The results were in agreement with previous observations about the efficacy of the studied anthelmintics against gastro-intestinal worms of pigs (Radostits *et al.*, 1999; Corwin and Stewart, 1997)

The efficacy of ivermectin and amitraz against sarcoptic mange were comparable as measured by the proportion of pigs positive for *Sarcoptes scabiei* after treatment with the acaricides. However, ivermectin activity persisted for much longer time than that of amitraz. The results were consistent with previous observations about the efficacy of these acaricides against sarcoptic mange in pigs (Hollanders *et al.*, 1995; Cargill and Davies, 1997).

Scratching index has been found useful as an indirect measure of mange infestation (reviewed by Davies, 1995). The decrease in values of calculated scratching indices observed in this study in pigs treated with above acaricides was in agreement with findings of previous workers (Davies, 1995; Hollanders *et al.*, 1995; Cargill and Davis, 1997). It is therefore envisaged that scratching behaviour can be used by farmers as a low-cost means of assessing the degree of mange infestations.

The cost per pig of using ivermectin to control sarcoptic mange and gastro-intestinal worms was double the cost of using amitraz/levamisole drugs combination. Although ivermectin appeared superior (the difference was not significant) compared to amitraz/levamisole drugs combination, its cost is prohibitive in the smallholder farming system. The cost per pig for controlling gastro-intestinal worms using piperazine was comparable to that of levamisole but the latter would be preferrable since it had broader activity which included *Trichuris suis*. Therefore, from the technical and economic data the amitraz/levamisole drugs combination was the most cost-effective combination against sarcoptic mange and gastro-intestinal worms of pigs in the studied smallholder herds.

CHAPTER 8

SUMMARY OF OBSERVATIONS, CONCLUSIONS AND RECOMMENDATIONS

SUMMARY OF OBSERVATIONS AND CONCLUSIONS

- Extension information on pig farming was not available to majority of the farmers.
- The important production constraints as perceived by the farmers were, high cost of feeds that were of variable qualities, lack of: credit, genetically quality breeding boars,and reliable market, and diseases
- Sarcoptic mange, helminthosis, diarrhoea and pneumonia were highly ranked by the farmers as the most important health constraints.
- The reproductive performance of the sow as measured by, weaning to service interval (3.2 months), interfarrowing interval (6.9 months), number of piglets weaned per farrowing (6.9), preweaning piglet crude mortality (18.67%) and average daily weight gain of the piglets (0.13 kg/day) was poor.
- The preweaning piglet crude morbidity cumulative incidence of 29% was high.
- Nutrition of the pigs was poor both in quality and quantity.

- Supplementation of the sow with protein rich feeds was associated with increased number of live-born piglets and improved average daily weight gain of piglets.
- The grower pig crude morbidity cumulative incidence (20%) and crude mortality (3.8%) were high.
- The growth performance of the grower pigs as measured by weight:age ratio (5.2 kg/month of age) and the ADWG (0.16 kg/day) was poor.
- Good hygienic status of the grower pig houses was associated with reduced mortality of grower pigs.
- The various phases of the study identified sarcoptic mange infestation and gastro-intestinal helminthosis as the most important health constraints in smallholder herds
- Ivermectin and amitraz/levamisole drugs combination were effective against sarcoptic mange and gastro-intestinal worms of pigs. However, amitraz/levamisole drugs combination was the most cost-effective.

RECOMMENDATIONS

- Most of the health and husbandry aspects associated with productivity are amenable to manipulation and can be addressed by use of appropriate preventive methods and extension services. Therefore, the delivery of extension information to pig farmers should be improved.
- The limiting role of nutrition has been highlighted but the formulation of appropriate and cost-effective diets may prove problematic. This is particularly

so because of the considerable overlap in the feedstuffs eaten by pigs and people and the non-availability of on-farm alternative feeds. However, . attention could be paid to alternative cereals at the national level to supplement maize which is the staple food for many communities.

- Smallholder farmers should supplement their pigs, especially the sows, with protein rich feeds.
- Smallholder farmers should improve on the sow reproductive performance and reduce grower pigs mortality.
- Sarcoptic mange and gastro-intestinal worms could be controlled cost-effectively, using amitraz/levamisole drugs combination.
- Formation of pig farmers' cooperative societies would allow the smallholder farmers to bargain for better feed and pig prices. In addition, through such organisations, farmers may communally own genetically improved breeding boars that would also ensure timely service.
- Further research to determine the causal associations between the identified risk factors and the outcomes is recommended.
- Although reduced morbidity as a result of using cost-effective drugs against sarcoptic mange and gastro-intestinal worms might result in increased gross revenue for the smallholder farmers it may still be necessary to determine the benefits in terms of weight gain inorder to determine the net profitability.

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LIST OF APPENDICES

Appendix 1.1.

PIG HEALTH AND PRODUCTIVITY STUDY

FARM SURVEY QUESTIONNAIRE-CROSS-SECTIONAL STUDY

1 Date (day/month/year):________________

2. Investigator Administering Survey:_______

3.(a) Owner/Farm name:____________________
(b) Farm numerical number:________________

4. For how long have you been keeping pigs?
(1) <1 year
(2) > 1 year and < 5 years
(3) > 5 years.

5 What breeds of pigs do you keep?
(1) Landrace
(2) Large white
(3) Crossbreeds
(4) Others (specify):___________

6 What is the size of your herd?

		Number
(1)	Sows	_______
(2)	Gilts	_______
(3)	Boars	_______
(4)	Weaners	_______
(5)	Piglets	_______
(6)	Growing-Finishing	_______

7 What are your reasons for keeping pigs?
(1) Source of income
(2) Domestic consumption
(3) Others (specify):

8. Do you consider pig keeping a profitable farm enterprise?
(0) No
(1) Yes

9. What is the type of your operation?
   (1) Farrow-to-finish
   (2) Farrow-to-weaner
   (3) Feeder operation
   (4) Others (specify):_________

10. If you keep other livestock, what do these include?

		NUMBER
(1)	Dairy cattle	_________
(2)	Beef cattle	_________
(3)	Sheep	_________
(4)	Goats	_________
(5)	Chicken	_________
(6)	Other (specify):	_________

11. What other farm enterprises do you engage in?
   (1) Grow cash crops
   (2) Grow subsistence crops
   (3) Others (specify):________

12. If you grow cash crops on your farm, what are they?
   (1) Coffee
   (2) Tea
   (3) Horticultural products
   (4) Other (specify):_________

13. What is the acrerage of your farm?______________(acres)

14. What proportion of your land does your livestock occupy?__________%

15. What proportion of your land does the crops occupy?______________%

16 What proportion of your land does the pigs occupy?_______________%

17. Who manages the farm?
   (1) Owner
   (2) Owner's wife
   (3) Owner's children
   (4) Manager

18. Is the owner employed or has any other business?
   (1) Farming only
   (2) Full-time employment
   (3) Full-time business
   (4) Part-time employement

19. Does the farm use advice on pig husbandry from other sources?
(0) No
(1) Yes

20. If yes, circle the ones you use:
(1) Neighbour
(2) Other farmers
(3) Livestock extensionist
(4) Animal health assistant
(5) Veterinarian
(6) Company representative (Livestock)
(7) Farmers training centres
(8) Others (specify)

21. Do family members assist in the activities of pig production?
(0) No
(1) Yes

22. Do you employ non-family members to assist with the pig production?
(0) No
(1) Yes

23. If yes, are you able to hire as many workers as you want?
(0) No
(1) Yes

24. For how long has the worker(s) been in the farm?
(1) < 1 year
(2) > 1 year < 5 years
(3) > 5 years

25. Is housing/shelter available to the pigs?
(0) No
(1) Yes

26. If yes, what is the type of housing for the pigs?
(1) Completely closed
(2) Completely closed with open yard
(3) Open with only roof available
(4) Others (specify):____________

27. What is the nature of floor?
(1) Dirt
(2) Concrete
(3) Concrete/slatted
(4) Wood

(5) Wood/slatted
(6) Others. (specify):______________

28. What is the nature of bedding in the farrowing/rearing area?
(1) None
(2) Saw-dust
(3) Wood-shavings
(4) Dry grass
(5) Others. (specify):_____________

29. How are the pregnant sows housed?
(1) In groups
(2) Individually

30. If housed individually, what is the type of facility?
(1) Pen with open yard
(2) Pen with no open yard
(3) Crate
(4) Tethered

31. How many days before farrowing are the sows placed in the farrowing area?______

32. What is the size of the farrowing/rearing area?

		Size(sq.m)
(1)	Farrowing pen	_________
(2)	Farrowing crate	_________
(3)	Tethering area	_________

33. Does the farrowing/rearing area have a dunging area?
(0) No
(1) Yes

34. Does the farrowing/rearing area have guard rails?
(0) No
(1) Yes
(2) Other means of piglet protection.(specify):

35. Does the farrowing/rearing area have a creep area?
(0) No
(1) Yes
(2) Others (Specify):_____________

36. How are the weaners kept?
(1) In mixed litters
(2) Not mixed but grouped according to littters

37. How many growing- finishing pigs are kept per pen?__________

38. What is the average size of these pens?________________(sq.m)

39. Where are the boars housed?
(0) No boars present
(1) Adjacent to newly weaned sows
(2) Adjacent to pupertal gilts
(3) Others (specify):____________

40. How do you remove the pig waste/manure?
(1) Carted
(2) Sludge

41. What do you do with the manure from the pigs?
(1) Use it as fertilizer on crops.
(2) Use it for biogas production
(3) Sell
(4) Other uses (specify):______________

42. What type of feed do you give to the pigs?
(1) Commercial feeds
(2) Swill
(3) Self formulated feed
(4) Others (specify):______________

43. Do you provide piglets with creep feed?
(0) No
(1) Yes

44. If so, when is it provided?
(1) < 14 days
(2) > 14 days

45. Do you use feed additives in pig feed?
(0) No
(1) Yes

46. If yes, what are the feed additives used?
(1) Antimicrobials
(2) Anthelmintics
(3) Vitamins/minerals
(4) Others (specify):____________

47. What is the method of feeding dry sows?
(1) ad Libitum

(2) Restricted

48. What is the method of feeding pregnant sows?
    (1) ad Libitum
    (2) Restricted

49. What is the method of feeding lactating sows?
    (1) ad Libitum
    (2) According to litter size

50. What is the method of feeding gilts?
    (1) ad Libitum
    (2) Restricted

51. What is the method of feeding weaners?
    (1) ad Libitum
    (2) Restricted

52. What is the method of feeding growing-finishing pigs?
    (1) ad Libitum
    (2) Restricted

53. What is the source of water provided to the pigs?
    (1) Communal piped
    (2) Private well
    (3) Stream/river
    (4) Collected rain water
    (5) Others specify (specify):____________

54. How is the water provided?
    (1) Troughs
    (2) Buckets
    (3) Others specify:___________

55. How often are the troughs or buckets cleaned?
    (1) Rearly cleaned
    (2) Once per day
    (3) Others (specify):__________

56. If water is provided manually in buckets or troughs, how often is it offered?
    (1) ad Libitum (kept full)
    (2) once per day
    (3) Twice per day
    (4) Three times per day
    (5) Others. (specify):___________

57. What mating method do you use?
   (1) Hand mating
   (2) Pen mating

58. If hand mating, what signs do you look for before presenting your female pig for service?
   (1) Enlarged and reddened vulva
   (2) Restlessness
   (3) Repetative grunt
   (4) Seeking after the boar when brought around
   (5) Exhibit a standing response to a back pressure
   (6) Mount other animals
   (7) Varginal discharge
   (8) Others.(specify):______________

59. And how many times are the sows/gilts observed for heat?
   (1) Once a day
   (2) Twice a day
   (3) More than twice a day

60. If the sow/gilt is hand mated, how many times is it mated?
   (1) Once
   (2) More than once

61. If more than once, when is it done
   (1) Day heat observed
   (2) 1st and 2nd day heat observed
   (3) 1st, 2nd and 3rd day heat observed

62. If more than once do you use the same or different boar?
   (1) Same
   (2) different

63. Do you keep your own boar(s) or do you hire when needed?
   (1) Keep own
   (2) Hire all the time
   (3) Hire in specific circumstances (specify):__________

64. How many times is the boar used per week?
   (0) Unknown
   (1) One sow/week
   (2) More than one sow/week

65. Are the gilts exposed to boars to enhance oestrus?
   (0) No
   (1) Yes

66. How do you tell that your gilts/sows are pregnant?
   (1) Failure to return to oestrus
   (2) Physical look
   (3) Consult a veterinarian

67. Are the sows/gilts observed when farrowing?
   (0) No
   (1) Yes

68. Do you keep written records for the pig sub-sector?
   (0) No
   (1) Yes

69. If yes, what records?
   (1) Service
   (2) Farrowing
   (3) Litter
   (4) Feed
   (5) Sale
   (6) Disease
   (7) Others (specify):___________

70. If no, what is the most important reason for not keeping records?
   (1) Can't write
   (2) No time
   (3) No knowledge on the use of records
   (4) Others (Specify):___________

71. If no, would you be willing to start keeping records?
   (0) No
   (1) Yes

72. Do you use any form of identification on your pigs?
   (0) No
   (1) Yes

73. If yes, what do you use?
   (1) Names
   (2) ear tags
   (3) Tatoos
   (4) Others(specify):_____________

74. Do you give the piglets iron injection?
   (0) No
   (1) Yes

75. If yes, at what age?
(1) One week
(2) Two weeks
(3) Three weeks
(4) Others.(specify):__________

76. Do you treat the pigs against worms?
(0) No
(1) Yes

77. If yes, how often?
(1) Every three months
(2) Others.(specify):_________

78. Do you control ectoparasites?
(0) No
(1) Yes

79. Do you vaccinate your pigs against any disease?
(0) No
(1) Yes

80. If yes, what diseases do you vaccinate for?
(1) Brucellosis
(2) Colibacillosis
(3) Parvovirus
(4) Foot and mouth
(5) Leptospirosis
(6) Others (specify):____________

81. At what age are the piglets weaned?
(1) Four weeks
(2) Six weeks
(3) Eight weeks
(4) Other specify:

82. Do you withhold water/feed in sows after weaning?
(0) No
(1) Yes

83. If yes, for how long?
(1) 24 hours
(2) 24-48 hours
(3) > 48 hours

84. Do you castrate the male piglets?
 (0) No
 (1) Yes

85. If yes, at what age?
 (1) < 3 weeks
 (2) > 3 weeks
 (3) Others (specify):__________

86. Do you provide any heating to the piglets?
 (0) No
 (1) Yes

87. If yes what is the source of the heat ?
 (1) Kerosine lamps
 (2) Electric bulbs
 (3) Jiko
 (4) Others (Specify):__________

88. How is the ventilation facility?
 (0) None
 (1) Natural ventilation.
 (2) Others (Specify):__________

89. Do you clean the pig houses?
 (0) No
 (1) Yes

90. Do you disinfect the pig houses?
 (0) No
 (1) Yes

91. If yes, when do you disinfect the pig houses?
 (1) Between batches of pigs
 (2) Others (specify):__________

92. Which particular areas do you disinfect?
 (1) All areas
 (2) Farrowing area
 (3) Nursery area
 (4) Others (specify):__________

93. What is your strategy for replacing sows?
 (1) Selection of gilts with desirable traits
 (2) Others (specify):__________

94. When selling growing-finishing pigs for slaughter, what do you consinder?
(1) Live body weight
(2) Age

95. If by live body weight, at what weight do you sell?__________kg

96. If by age, at what age do you sell?________(Days)

97. What are your reasons for selling boars?
(1) Old age
(2) Low fertility
(3) Lameness
(4) Others.(specify):__________

98. When selling sows to slaughter houses what are your reasons?
(1) Too old
(2) Produces few piglets
(3) Lack of milk
(4) eats piglets
(5) Crushes piglets
(6) Does not conceive
(8) Lameness.
(7) Others(specify):_______________

99. Do you have market problems for your pigs?
(0) No
(1) Yes

100. What is your main market for your growing-finishing pigs?
(1) Farmers choice
(2) Local butchers
(3) Others (specify):__________

101. Is credit availability a constraint on the use of purchased inputs?
(0) No
(1) Yes

102. Do you receive any form of credit?
(0) No
(1) Yes

103. If yes, who gives you credit?
(1) Agricultural Finance Corporation
(2) African Development Bank
(3) Other banks
(4) Local Cooperative
(5) Others (Specify):____________

Appendix 1.2.

PIG HEALTH AND PRODUCTIVITY STUDY

CONSTRAINT IDENTIFICATION QUESTIONNAIRE-CROSS-SECTIONAL STUDY

1. Date:___/______/_____

2. Investigator:___________

3. Farm numerical Number:___________

4. Location:______________

5.Rank the following production constraints in order of importance 1-7, (7= most important)

Pig production constraint	Rank
Feed	
Marketing	
Disease	
Water	
Labour	
Credit	
Breeding	

6. What are the four most prevalent diseases that affect your pigs (In order of priority)?

Disease 1	Disease 2	Disease 3	Disease 4

Appendix 1.3

PIG HEALTH AND PRODUCTIVITY STUDY
SOW-LITTER RECORD CARD-LONGITUDINAL STUDY

Farm numerical number:______________
Sow ID:_____________
Parity:______________
Farrowing Date:________
Alive_________
Dead_________
Mummified_____
Date weaned:_________
Number
Age

Piglet Morbidity

Cause	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Diarrhoea								
Pneumonia								
Pruritis								
Illthrift								
Others								

Piglet mortality

Cause	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Overlay								
Unviable								
Starvation								
Scours								
Pneumonia								
Salvage								
Others								

Feeds and feeding

	Feed type	Amount/day
Sow		
Piglet		

Actions/events:Deworming, castration, treatment, others

Appendix 1.4

PIG HEALTH AND PRODUCTIVITY STUDY

DRY-SOW RECORD CARD-LONGITUDINAL STUDY

Farm Numerical number:__________________

Sow ID	Gilt ID	Date weaned	Service date	Date farrowed	Boar used/Comments

Feeds and feeding

Feed type	Date introduced	Amount/day

Actions/events: Death, Metritis, Culled, Abortion, Treated, Lameness, Others

Appendix 1.5

PIG HEALTH AND PRODUCTIVITY STUDY

GROWER PIG RECORD CARD-LONGITUDINAL STUDY

Farm numerical number:___________

Date weaned:___________________

Number/pen:___________________

Size of the pen:_________________

Trough space: (1) Adequate (2) Inadequate

Grower pig morbidity:

Date	Disease/condition	Number

Grower pig mortality:

Date	Disease/condition	Number

Feeds and feeding

Feed tvpe	Date introduced	Amount/dav

Weight 1: ____________________________________

Weight 2:_____________________________________

Appendix 1.6

PIG HEALTH AND PRODUCTIVITY STUDY

CODES FOR THE HERD-LEVEL FACTORS -LONGITUDINAL STUDY

Farm numerical Number.________________

1. Farmer controlled mange at least once to the pigs
   (0) No
   (1) Yes

2. Chemical used to control for mange
   (1) Acaricide
   (2) Ivermectin
   (3) Used engine oil
   (4) Not applicable

3. Farmer controlled for worms at least once to the pigs
   (0) No
   (1) Yes

4. Hygiene status of the pig pens
   (1) Poor
   (2) fair
   (3) Good

5. Housing design
   (1) Open
   (2) Semiclosed

6. Farmer owned boar
   (0) No
   (1) Yes

7. Anemia prophylaxis practised
   (0) No
   (1) Yes

8. Person who frequently attended to the pigs
   (1) Family
   (2) Hired labour

9. Feed fed to the dry sow
   (1) Commercial pig feed
   (2) Swill

(3) Low protein commercial feed
(4) Not applicable

10. Feed fed to lactating sow
(1) Commercial pig feed
(2) Swill
(3) Low protein commercial feed
(4) Not applicabl

11. Protein supplement for the sow (Fish meal or plant proteins)
(0) No
(1) yes
(2) Not applicable

12.Feed fed to the grower pigs
(1) Commercial pig feed
(2) Swill
(3) Low protein commercial feed
(4) Not applicable

13. Protein supplement for the grower pigs(Fishmeal or plant protein)
(0) No
(1) Yes
(2) Not applicable

14. Size of the farrowing pen.
(0) Inadequate
(1) Adequate
(2) Not applicable

15. Pig protection device
(0) absent
(1) Present
(2) Not applicable.

Appendix 1.7

PIG HEALTH AND PRODUCTIVITY STUDY

DATA COLLECTION CARD-INTERVENTION STUDY

1. Intervention Group: ______________________

2. Farm number: ______________________

3. Date of Visit: ______________________

4. Sow ID: ______________________

5. Grower pigs ID: ______________________

6. Date weaned: ______________________

7. Number weaned: ______________________

8. Have you treated the pigs for mange in the last one month? No (0) (1) Yes

9. Have you dewormed the pigs in the last one month? No (0) (1) Yes

10. Feed Provided: ______________________

12. Drugs given (i)____________ Cost per unit_______ Total cost____________

(ii) ____________ Cost per unit ________ Total cost ___________

13. Labour: ______________________

Family: __________________

Hired: __________________

14. Professional fee: ______________

Appendix 2.1 Descriptive statistics for pig helminths of different age categories of pigs in 62 smallholder herds Kikuyu Division, Kiambu District, (January 1999- December 1999).

	Mean	Median	Range	SD	Percentile 25	Percentile 75	Prevalence
Piglets (n=83)							
Strogyles	188	0	0-3000	522.1	0	0	22.9%
Strogyloids	67.5	0	0-2400	304.1	0	0	14.5%
Ascarids	19.3	0	0-1300	144.4	0	0	3.6%
Trichuris	2.4	0	0-100	15.4	0	0	2.4%
EPG	277	0	0-5400	790.1	0	100	27.7%
Weaners (n=54)							
Strogyles	111.11	0	0-1600	266.8	0	100	31.5%
Strogyloids	0.0370	0	0-2	0.3	0	0	1.9%)
Ascarids	235	0	0-3100	568.7	0	100	27.8%
Trichuris	48.1	0	0-1300	213.4	0	0	11.1%
Epg	394.4	100	0-3200	577.7	0	450	55.6%
Grower-finisher (n=204)							
Strogyles	218.6	0	0-5400	617.9	0	175	41.7%
Strogyloids	5.4	0	0-500	45.7	0	0	2%
Ascarids	114	0	0-5800	534.2	0	0	13.2%
Trichuris	6.8	0	0-300	36.5	0	0	4.4%
Epg	343	54.5	0-6200	821.5	0	300	50.5%
Adults (n=257)							
Strogyles	157.6	0	0-5000	521.5	0	100	34.6%
Strogyloids	0.8	0	0-100	8.8	0	0	0.8%
Ascarids	54.5	0	0-6000	429.2	0	0	5.8%
Trichuris	47.5	0	0-7000	483.9	0	0	2.7%
Epg	260.3	0	0-8600	895.9	0	100	40.5%
Farm total (n=598)							
Strogyles	178.4	0	0-5400	539.8	0	100	35.1%
Strogyloids	11.5	0	0-2400	118.1	0	0	3.2%
Ascarids	86.5	0	0-6000	459.3	0	0	10%
Trichuris	27.4	0	0-7000	324.6	0	0	4%
Epg	303	0	0-8600	837.6	0	200	43.5%

Appendix 2.2. Descriptive statistics for sarcoptic mange in pigs of different age categories in 40 smallholder herds in Kikuyu Division, Kiambu District (January 1999- December 1999)

Age category	Number	Physical signs	Clinical forms		Prevalence (%)	
			Hypersensitive	Chronic	Physical signs	Mite detection
Piglet	117	42	42	-	35.9	10.3
Weaners	113	64	51	13	56.6	34.5
Grower	154	105	95	10	68.2	19.5
Adult	92	62	46	16	68.5	8.7
Total	476	273	234	39	57.3	18.9